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A Framework for Controlling & Managing Traffic with Modern Technology

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Abstract

Thousands of people die on roads every day. Despite advances in technology, controlling vehicular traffic remains a challenge. Modern technologies can be very helpful in controlling and managing traffic. In particular, the Internet of Things (IoT) and Machine Learning (ML) have created a new level of automation of services and applications, which have given rise to smart cities, smart health, smart business, and smart transportation. In this thesis, we shall provide a framework for better and comprehensive control and management of road traffic with the help of modern technology. The proposed system has four layers, namely Application Service Layer, Cloud Computing Layer, Fog Computing Layer, and Sensing and Objects Layer. We shall provide details of these layers and associated levels.

The First level of the proposed solution addresses the issue of traffic congestion at intersections, with a proposal of a dynamic smart traffic light with the help of Image processing algorithms. The second level will deal with the surveillance of selected streets to provide information about possible hazards. The third level deals with data mining and machine learning algorithms to add information to the knowledgebase to enable better planning. The fourth level proposes several applications to assist general services like school buses, ambulance, parking, places of interest, pollution, emergency cases, etc.

Congestion often occurs during peak hours. One of the causes of increased volume of traffic in town centres and business districts is a lack of suitable carparks. In this thesis, we also provide a framework for smart parking which can be extremely helpful in preventing frantic searches for parking, which are a cause of congestion. Road users often use various services like toll tax, parking-fee services, etc. These often require users to furnish their data to the service provider, who could potentially breach their privacy. We shall discuss ways to preserve the location and ID of the users. We shall also provide a framework for assisting with emergencies like accidents. Several measures proposed in this thesis may also be used in other situations

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CHAPTER I - Introduction

About three thousand and seven hundred people die on roads every day. According to World Health Organisation (2021), these deaths can be attributed to ignorance, poor management, inadequate use of technology, lack of infrastructure, speeding, alcohol, distraction and so on. The majority of road deaths involve pedestrians, cyclists, and motorcyclists. Moreover, road injuries are the leading cause of death for children and young adults. Most of the road related deaths occur in poor and developing countries.

According to the US Department of Transportation (2021), traffic congestion has three key sources. The first one is related to traffic-influencing events, such as incidents, working zones, and bad weather conditions. The second one is related to traffic demand, which means fluctuations in normal traffic and special events. The last source is the transportation infrastructure, which represents the traffic control devices and physical bottlenecks. These bottlenecks are responsible for 40% of the overall traffic congestion, followed by traffic incidents, such as vehicles accidents with 25%, bad weather conditions with 15%, work zones with 10%, and poor traffic light timing and special events with 5% each.

There is hardly a country with a sizable population which does not encounter traffic congestion, at least at peak hours or due to some irregular road activity like funerals, political rallies, religious processions, protests, sports, musical and social events. Too many vehicles on roads coupled with poor infrastructure results in congestion. In many cases, in order to overcome lost time in congestion, drivers end up speeding. Indeed, as outlined above, there are many other reasons for speeding including habit, delayed start of journey, thrill of fast driving, road rage, intentional and un-intentional speeding, emotional issues, and so on.

Figure 1.1 (Ghosh, 2019)

Traffic Congestion in Mumbai (India)

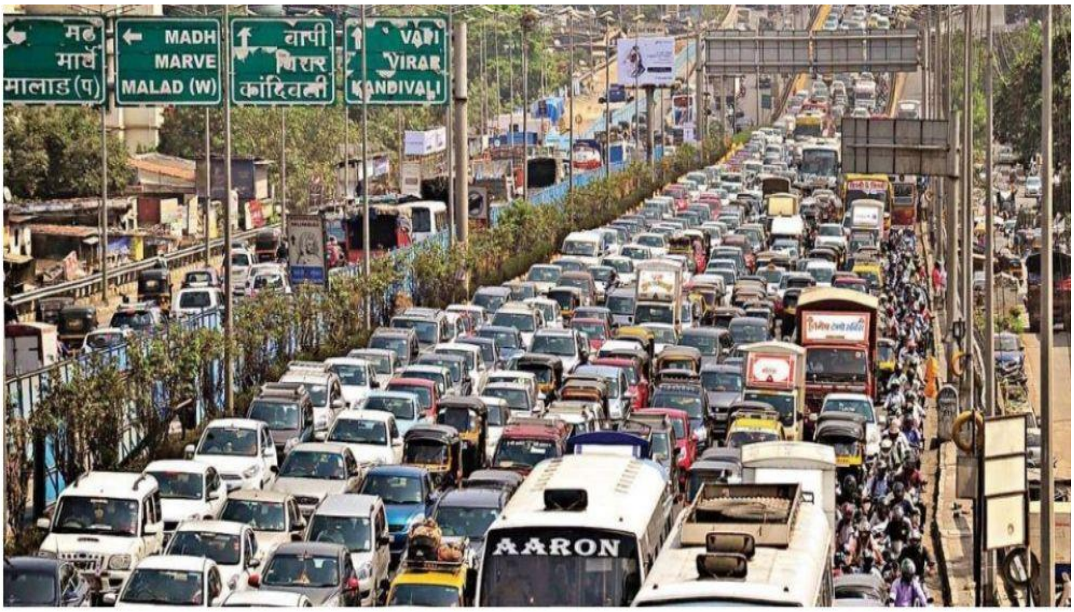


Figure 1.2 (Ranjan, 2017)

Traffic Congestion in New Delhi (India)

It is well known (World Health Organisation, 2021) that speeding is a major cause of road crashes resulting in many deaths especially of young people every day. Many countries are now using speed and traffic light cameras linked to hefty fines for infringements. Despite the presence of these cameras, the problem of speeding

Figure 1.3 (No Author [traffic deadlock], 2018)

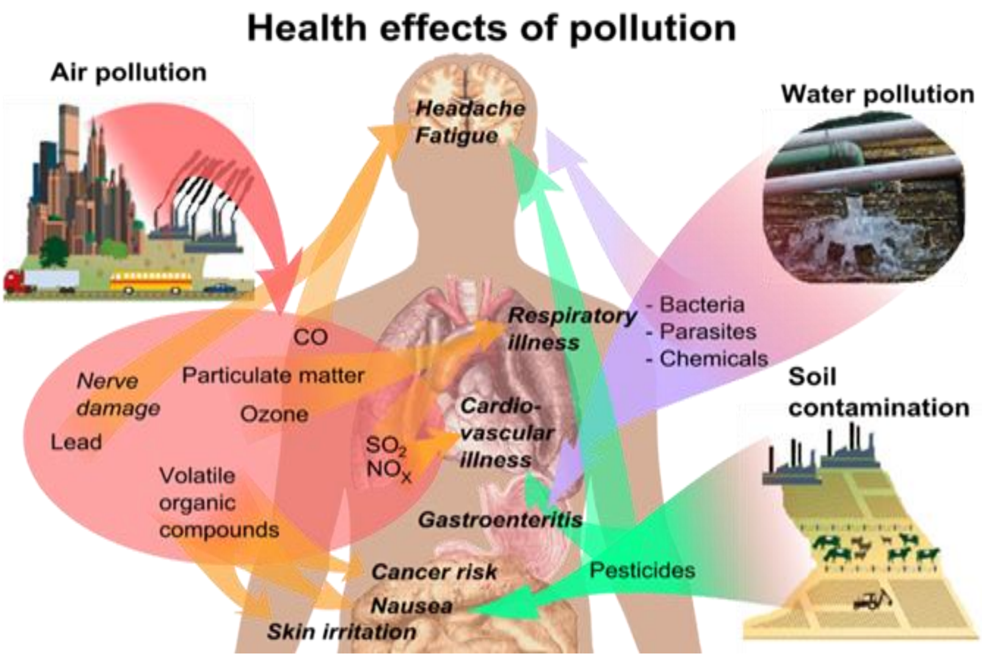
Traffic Deadlock

still persists. In fact, there are Computer Apps, including Google maps, which can detect mobile and fixed cameras, which some drivers use to avoid detection when breaking speed limit rules. Figures 1.1 and 1.2 show two instances of traffic congestion. One of the major causes of congestion resulting in considerable loss of time is poor management of traffic on intersections, such as what’s depicted in Figure 1.3.

Air pollution is mainly caused by emission from traffic fuel. Extended delays in traffic movement increases fuel emissions. In some cases, like in Mumbai and New Delhi in India, a 20- minute journey could take up to five hours due to traffic congestion. In such cases the fuel emission is twenty-fold. Several studies (Bertazzon et. al, 2020; Matz, et. al, 2019; Naqvi et al., 2021; Suhaimi et. al, 2020; Xiang, et. al, 2020; Yamin, 2020; Zakaria et. al, 2018; Zhang et. al, 2013) have discussed effects of fuel related pollution on health. Impact of pollution on health issues, as shown in Figure 1.4, can be highly toxic and injurious to vital organs like the lungs and heart.

Figure 1.4 (Häggström, 2014)

Impact of air pollution on human organs



Poor management of traffic has a severe impact on many facets of our lives including the economic growth, accidents resulting in loss of lives, injuries, and pollution by way of an intolerable spike in greenhouse emissions, loss of precious time, and health hazards due to many factors of fossil fuel-based traffic. These problems can be contained, if not eradicated, by means of effective and efficient traffic management with the help of modern technologies like Artificial intelligence, sensor networks, RFID, IoT, Digital streets, fog, and Clouds. These and other technologies can effectively reduce and manage congestions, which is a root cause of many problems associated with traffic.

In order to address the problem of congestion, many countries have tried different methods and traffic-control mechanisms. Some of them are technology based whereas others are infrastructure based.

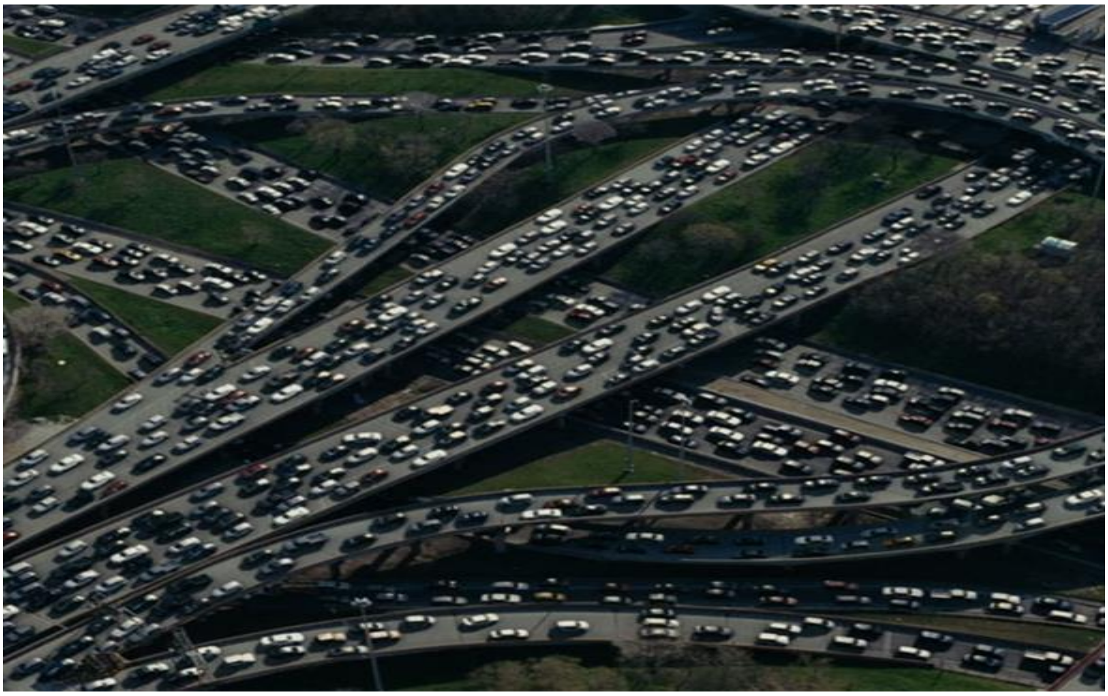
1.1 Traffic Management

Here we summarize several ways to manage traffic to contain the problem of congestion.

1.1.1 Use of Traffic lights at Intersections

Almost all countries use a set of traffic lights with different colours (green, red, amber) to manage and regulate the traffic on certain intersections. Most of these traffic lights,

Figure 1.5 (Akinshete, 2020)
Multi-level Roads and Bridges



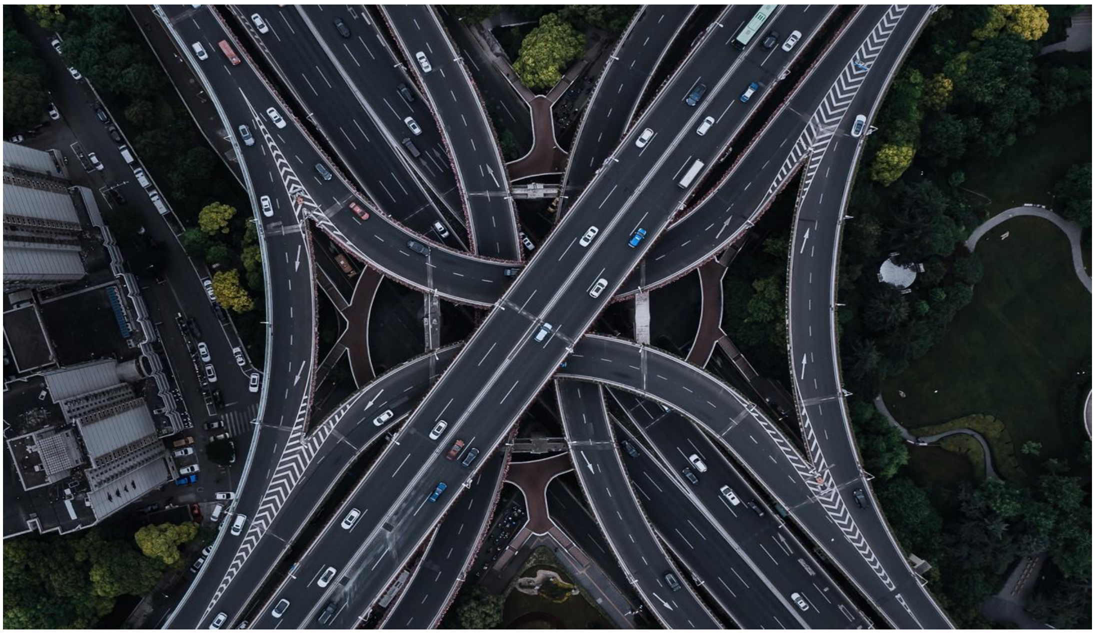
especially in the developing and poor countries, use a fixed routine of giving turns to different roads meeting the intersection by assigning an interval of time (usually ranging from 15 seconds to 120 seconds). This system is very inefficient as some vehicles on busy roads do not get their turn for several periods, resulting in long delays, sometimes 15-20 minutes long. Sometimes, this system gives way to a road which may even not have any traffic.

Some countries use sensors under the surface of roads to detect the presence of vehicles on a road section near an intersection. By doing so, traffic lights are programmed in such a way that if on certain road there is no vehicle until the cut-off time, the road will not get a clearance signal. In order to further better manage the traffic lights, some intersections give priority to the traffic on certain roads, especially in peak hours, by giving two turns in one cycle for traffic to clear.

1.1.2 Bridges and Multi-level Intersection

Current methods which are being used to regulate traffic at intersections by means of traffic lights have proven to be inefficient in case of heavy traffic. In order to address this problem, some countries have built multilevel intersections on some roads such

Figure 1.6 (Jaime_Silver00, 2019)
Multi-level Roads and Bridges



as shown in Figures 1.5 and 1.6. These structures are very costly to build and maintain. Due to complexity in levels and layers, sometimes GPS will be unable to guide to the desired route to follow. If a driver is confused for some reason, it would cost them considerable time to come back to the same spot.

Figure 1.7 (Newman, 2020)
Road and Light Rail together

1.1.3 Roads over Roads

In some cities (for example, Bangkok, Manila, Jakarta), there are multi-level roads (usually two levels of road) for several kilometres. The advantage of the multi-level road system is that the upper road can be made a kind of freeway or expressway without any stoppages and traffic lights. Indeed, this system is very helpful to reduce congestion, but it may not be feasible to build everywhere due to lack of space. Indeed, it is very costly to build and maintain multi-level roads. The other disadvantage is that the lower road still has intersections prone to congestion. This practice was very popular in the late part of last century but is not as popular now.

1.1.4 Roads and Light Rail Tracks Together

Light rail network using the normal traffic roads complicates issues. As shown in Figure 1.7, Part of the rail network invariably uses some sections of roads including busy intersections. Managing such intersections with traffic lights becomes increasingly difficult. This slows the traffic resulting in extended delays.

1.2 Objectives and Contributions of this Study

The main objective of the proposed work is formulated as follows:

The aim of this study is to propose a comprehensive and integrated solution to all major problems associated with traffic. The proposed solution is provided in the form of a framework dealing with the issues of congestion, street management, smart and innovative parking, privacy and security of road users, collection and usage of historical data for better management of traffic, and other related issues. A number of algorithms are provided for the implementation of various solutions in the proposed framework. In order to achieve the objectives of this research, many technologies need to be integrated, including Artificial Intelligence, Machine Learning, Internet of Things, Sensor Networks, Cloud and Fog computing, Digital Street, Radio Frequency, Big Data Analytics, High Resolution Cameras, and Real Image Processing and Simulations.

Since the beginning of the 21st century, especially in the last decade, there have been tremendous developments in technology, which have remarkably improved the quality of our lives. Now we have smart tools available, which are proving to be very helpful and useful in managing various aspects of our lives. Likewise, use of adequate and appropriate technology and tools can manage road traffic issues and drastically lower the probability of road accidents.

Traffic management systems are composed of a set of applications and management tools to improve the overall traffic efficiency and safety of transportation systems. There is no comprehensive framework with an integrated system to manage all the issues that we have mentioned. This is the hypothesis of this study. This research proposes a comprehensive framework for Smart Traffic Management System (STMS). The STMS framework, proposes several solutions to manage traffic and control congestions. These solutions, if implemented simultaneously, can resolve most of the traffic issues. The STMS has four main layers. Each layer includes new technologies which provide for some important functions. These functions will create new smart services and applications. In this manner, more advantages will be achieved for the end-users, government, city, society, and environment. Moreover, the STMS will also provide a new active solution to tackle the issues of security and privacy of data of the users of the systems. In addition, we provide a new method of protecting privacy road users as well as in other scenarios.

Now we provide an itemised summary of the research presented in this thesis. This includes description, design, and implementation aspects of different levels and constituents of the STMS.

A. A framework for comprehensive solutions for traffic issues

The STMS framework’s aim is to provide solutions to many issues related to traffic, such as congestion, safety, security, privacy, awareness, guidance, and other related issues. Our solutions will be divided to multi-levels integrated with each other to provide a comprehensive solution. One of the central components of the proposed framework is to provide mechanisms, models and schemes to address the issue of congestion, which is the root for other traffic related problems.

B. Algorithm for smart traffic light

A major component of STMS is built on a Smart Traffic Light (STL) system, which uses Image Processing, Wireless Sensor Networks (WSNs) and IoT, and RFID. We provide algorithms for Image Processing, which are used for regulating traffic lights.

C. Algorithm to detect the information from tweets

An important part of the STMS is text mining for tweet analysis. For this, we provide algorithms to extract relevant information from tweets.

D. Mobile application to track the status of main streets

The STMS framework is supported by several APIs to update the status of streets in several respects like pollution, accidents, road closures, environmental hazards, and other issues. We shall provide details of these APIs.

E. Advantages from the Historical Data

Data collected from different operations of systems forms a knowledge base. In our case, data which is generated by managing and serving streets, is very useful for future improvements. It involves creating useful historical data and applying Machine Learning (ML) and Data Mining (DM) algorithms to extract useful information from the historical data (accidents and traffic data by the time) for decision support.

The STMS framework has a component of Machine Learning (ML) and Data Mining (DM). The first step to realise these is to create historical data about roads, accidents and other events, which requires database skills and Machine Learning. The historical database would very soon contain huge data, requiring data mining skills.

F. Other Applications for mitigating congestion

Assistant applications are proposed for smart transportation, including smart parking, Pollution Reading and Updates, Places of Interest (POIs), Public Transportation, Marketing, and Safety. As can be seen, the STMS framework contains several assistant applications. These include Smart Parking, Pollution status, Public

Transportation, and so on. We provide details of these and other assistant tools. In particular, we provide a framework for Smart parking using an API to update the status of parking in different locations.

G. Privacy and Security of Road Users

We propose a new approach (with multi-methods) to address privacy and security issues in the Transportation domain. As part of the STMS, we provide a framework to protect privacy and security of the road user data. This framework takes most of the well-known privacy methods into consideration. We also present a new method to safeguard the privacy of road users.

H. Technologies used in Framework

The STMS uses many modern technologies and tools including IoT, Wireless Sensor Networks, Digital Street, RFID, Cloud and Fog computing, Image Processing, High Resolution Digital Cameras, Tweet Analysis, as well as the latest approaches to tackle the problems of safety, security and privacy of road users. These technologies and tools combine to provide novel solutions to manage and solve traffic related problems, create an awareness, and provide guidance to road users.

We shall also demonstrate the effectiveness of the proposed system by applying it to crowded streets. The above solutions will be provided as part of a comprehensive framework. In this thesis, we shall also discuss security, privacy and trust aspects associated with road users and transport users. Further details of these solutions are provided in chapter three.

Detailed discussion of the STMS, which embodies a comprehensive solution to the problems of traffic related issues, will be included in chapter 3. In chapter 4, we shall introduce and discuss the concept of Smart Traffic Lights. Our discussion will also include algorithms of the proposed Smart Traffic Lights. Simulations and applications of the Model will be presented in Chapter 10. In chapter 5, we shall discuss Street Status, and provide ways to monitor the status of streets at critical points which are not facilitated by traffic lights. In Chapter 6, we shall analyse historical traffic data with Machine Learning, which would empower us not to repeat the mistakes of the past. In chapter 7, we shall provide several assistant applications to help travel various clusters of the society smoothly and help reduce the traffic congestion. In chapter 8, we shall propose a web-based Smart Parking System, which can be very useful in reducing traffic congestion in and around town centres in peak hours. A framework to protect the privacy of users will be provided in chapter 9. In chapter 10, we shall provide technical details of our proposed methods in earlier chapters. In chapter 11, we shall provide an extensive summary of the research in this thesis. In the next chapter we shall discuss Literature Review.

Before discussing various solutions to congestion and other traffic issues, it should be born in mind that we do not claim to solve all the problems associated with traffic. Our effort is to reduce the problems and to ease congestion, and hence minimise road accidents, thus saving many precious lives. Apart from providing piecemeal solutions to all separate issues the main challenge of the work is to integrate them in a single comprehensive solution which can be applied in practice.

I. Author's Publications

The author has published the following research articles directly associated with the research in this thesis:

1. Alharbi, A.S., Halikias, G., Yamin, M. et al. Web-based Framework for Smart Parking System, Int. j. inf. Tecnol. (2021). DOI: https://doi.org/10.1007/s41870-021-00725-8 (Indexed in Scopus)
2. A. Alharbi, M. Yamin and G. Halikias, "Smart Technologies for Comprehensive Traffic Control and Management," 2021 8th International Conference on Computing for Sustainable Global Development (INDIACom), 2021, pp. 357-362, doi: 10.1109/INDIACom51348.2021.00062. Web-based Framework for Smart Parking System (Indexed in Scopus and SCI)
3. A. S. Alharbi, G. Halikias, A. A. Abi Sen and M. Yamin, "A New Framework to Protect Privacy of Location from Malicious Applications," 2021 8th International

Conference on Computing for Sustainable Global Development (INDIACom), 2021, pp. 390-394, doi: 10.1109/INDIACom51348.2021.00068. (Indexed in Scopus and SCI)

4. A. S. Alharbi, G. Halikias, A. A. Abi Sen and M. Yamin. A Framework for Dynamic Smart Traffic Light Management System. Int. j. inf. Tecnol. (Accepted for publication) (Indexed in Scopus)

The author has also published another thirteen research articles, some of which are associated with some aspects of the research in this thesis. A list of these articles is provided in Appendix A.

CHAPTER II - Literature Review

In this chapter we shall review research related to traffic issues and provide a summary of the background concepts used in the following chapters. As outlined in the previous chapter, we shall use several modern technologies to support our proposed solution to manage traffic and congestion. In this chapter, we describe some of these technologies. Here we shall provide a detailed discussion of road traffic issues, Machine learning, Image processing, deep learning, security, privacy and other issues associated with traffic control in the literature. We shall then discuss a number of topics associated with recent advances including Internet of Things, Cloud and Fog computing, Sensor networks, 5G, RFID, Text Mining, and Security. We shall discuss various aspects of Security in detail.

2.1 General Traffic Management Issues

Here we shall record main points of earlier research in the area of traffic control and management.

2.1.1 An Overview of Traffic Issues around the Globe

Traffic congestion has become one of the most prevalent challenges facing city municipalities, especially during the last decade. Traffic congestion is a significant problem across the world because it makes life uncomfortable for people living and working in urban centres, whether in developed, developing or under-developed countries. According to Bashingi et al., (2020), traffic congestion occurs as a result of demand and supply imbalances in the transport sector. An increase in the number of vehicles on the road slows down the flow of traffic and vice versa, which ultimately leads to unmanageable traffic congestion. This imbalance arises from various causes such as increased urbanization, rapid population growth, poor planning at early stages of urban development and diminishing financing for transport infrastructure, among others.

Traffic congestion leads to a series of issues including greenhouse gas emission, extra travel time for both passengers and drivers, monetary losses, increased vehicle crash rates, slower speeds, higher fuel consumption rates and so on (Kurniawan et al., 2018). As a result, governments across the world allocate massive budgets to solve the problem by improving road infrastructure or using Transport System Management (TSM) techniques and strategies. However, these traditional approaches are quite expensive and unsustainable; and so, governments must find more affordable and sustainable ways to solve the problem.

2.2 Earlier Research and Solutions

Rising traffic congestion is an inevitable condition in large and developing metropolitan areas across the world from New York, Los Angeles to Tokyo, and from Sao Paulo to Cairo, among others. Peak-hour congestion is particularly an immanent result of the way conventional societies operate. People across the world inevitably overburden existing roads and transport systems every day in pursuit of their goals. Nonetheless, everyone dislikes traffic congestion, but it keeps deteriorating despite numerous attempted remedies. Commuters are frequently frustrated by failed attempts by policymakers in reverting problems associated with traffic congestion, which has posed a substantial public policy challenge. Different authors agree that governments may never be able to successfully eliminate traffic congestion, but cities and states can implement certain strategies to curb the challenge.

2.2.1 Traffic Issues

Many researchers have studied and proposed solutions to the problems associated with traffic. Marie et al., (2020) state that the real-time Traffic Management System using Radio Frequency Identification (RFID) and sensor networks has been proposed. The proposed system discusses measures about managing traffic accidents, emergencies, infringements, and other associated issues. Citing a survey, the paper asserts that India is losing hundreds of billions of dollars every year because of traffic congestion. The paper also recognizes fuel wastage, air pollution (due to congested traffic is multiple times higher which leads to carbon-dioxide emissions) as serious issues facing the country. The research acknowledges that congestion is responsible for an increased number of road accidents. Furthermore, major accidents in the urban area are due to red signal violators. Qi et al., (2018) have proposed an intelligent traffic control system based on real time traffic statistics. According to Bratuand & Cretu, (2017), research focuses on a system for managing emergency situations, which provides a way of giving emergency access to ambulance and other essential service vehicles by stopping other vehicles. Meghana et al., (2017) state that a traffic management system based on RFID has been proposed which finds vehicular density and proposes dynamic signal times at the peak of congestion and alternative routes to solve the problems of congestion. Sankhe et al., (2014) use image processing for several traffic associated applications. Applications of Artificial Intelligence in transport are discussed by Abduljabbar et al. (2019). An overview of traffic issues is presented by Souza et al., (2017). In a PhD thesis submitted to the Liverpool University, Raphael (2018), has carried out an in-depth study mainly on a traffic control system which does not rely on vehicle agents.

A former brooking senior fellow and financial expert, Anthony Downs, maintains that traffic congestion is not essentially an independent problem. Instead, traffic congestion is a solution to the basic mobility challenge, which is that an unprecedented number of people want to move into the town centres at the same time (Souza et al., 2017). This problem arises as a result of school and the economic system, which necessitate that people work, go to school and run businesses within a certain timeframe to maximize interaction. Such a basic requirement cannot be altered without immobilizing the economy and society as a whole. The same challenge exists in every fundamental metropolitan area across the world. For instance, most people in the United States seeking to move during rush hours use private vehicles for two reasons (Meghana et al., 2017). First, private automotive vehicles are faster, more comfortable, flexible and convenient and because most American citizens live in low-density areas that public transport vehicles cannot serve effectively. Similarly, more people around the world shift from inflexible, faster and cheaper modes of transport to private vehicles as household income increases.

2.2.2 Traffic and Congestion Solutions

Marie et al., (2020) propose four ways in which metropolitan areas can cope with the mobility challenge that causes traffic and congestion. These remedies include charging peak-hour tolls, expanding road capacity, expanding public transit capacity and living with congestion. Unfortunately, the first three solutions are politically impractical, and physically or economically impossible (Marie et al., 2020, Qi et al., 2018, and Bratuand & Cretu, 2017). For instance, charging peak-hours tolls would reduce congestion in major roads during peak hours and allow the remaining vehicles to move at higher speeds, hence allowing more people to travel per lane per hour, which is better than the current heavily congested conditions. Although transport economists have been in favour of this strategy, most American citizens reject it for two key reasons. First, they believe that the tolls would favour wealthy drivers at the expense of poor ones, causing resentment from the larger percentage of the citizens. Secondly, citizens think of tolls as an additional tax, requiring them to pay for something they have already paid for by other means such as fuel taxes. Besides, some researchers (Souza et al., 2017 and Raphael, 2018) maintain that road-pricing techniques are not feasible because surveys from countries that have adopted them including England, Singapore and Norway show that they only affect traffic congestion in crowded downtowns, which do not match the kind of congestion experienced in major arteries experienced around the world.

Expanding road capacity is another approach to manage traffic congestion in large cities. However, this solution is impractical and extremely expensive because governments would have to expand all central commuting roads by demolishing numerous buildings, cutting down trees and transforming most metropolitan regions into an enormous concrete slab. Those roads would then be underutilized during off-peak hours. Therefore, several researchers such as Bratuand & Cretu, (2017) and

Sankhe et al., (2014) agree that it is impossible to completely eliminate peak-hour traffic congestion, especially by expanding road capacity.

Expanding public transport capacity is another strategy that would minimize traffic congestion by ensuring that most people use public transportation rather than private means to reduce the number of vehicles on the road during peak hours. However, a study by Bashingi et al., (2020) indicates that this approach is almost impossible because only 5% of the total commuters in the United States used public transport means in 2010. In fact, outside New York City, only 3% use public means while 93% use private vehicles. Kurniawan et al., (2018) show that even if America tripled its existing transit capacity and utilized it fully, morning peak hours would rise 12%, which would significantly minimize morning trips via private means by only 8%. These findings show that there would be progress, but it would not be enough to completely end traffic congestion. Besides, tripling public transport capacity would be extremely costly. Kurniawan et al., (2018) claim that living with congestion is the most feasible solution to accommodate excess road demands during peak hours. This suggestion means that traffic congestion is certainly an essential mechanism for metropolitan areas across the world because it helps them cope with excess demand for road spaces during peak hours during the morning and evening.

2.2.3 Traffic Congestion: Mother of the Problems

In the previous section, we provided an overview of the problems of congestion and its effects on human life. According to Agyapong & Ojo, (2018), "*congestion refers to any inevitable outcomes of insufficient transport facilities such as parking areas, road capacity, road and traffic signals and efficient traffic management*". Furthermore, the authors argue that the problem is compounded because of the usage of the urban roads by both freight and passengers' transports. Hossain et al. (2019) have discussed the reasons for and impact of traffic congestion. Yu et al. (2019) attribute the increase in traffic to the expansion of the middle class, especially in developing countries. It is well known that in the middle class in developing countries, especially India and China, has expanded many-fold, contributing to congestion in many of their cities.

2.3 Modern Technologies for Traffic Management

Research on traffic issues is varied and scattered. As can be seen by the above literature review of the current research in the area of traffic management, many aspects associated with congestion, emergencies, infringements etc. are discussed and several technologies are utilized to find the solution. However, a comprehensive solution to all the problems is not discussed

A distinct feature of the present research is the aim to integrate many different ideas and solutions within a single framework to achieve more effective traffic management by making use of many technologies including Sensors, RFID, Image Processing, Remote Image Processing, Analysis Historical-Data, and the Location Based Services (LBS). We also analyse tweets of users by Text-Mining Algorithms to ensure that our system is realistic and comprehensive. The information we collect and use makes our system more acceptable in managing real-world traffic issues and to incorporate applications towards an overall improvement. In this research, we also propose some supportive mobile applications, like smart parking, School and Employee Buses, to make the proposed framework more beneficial. Next, we provide details of technologies and tools used in this thesis.

2.3.1 Internet of Things (IoT)

Internet of Things (IoT) (Lin et al., 2017, Atzori et al., 2010, and Abdulrahman et al., 2012) now links millions of objects (Whitmore et al., 2015). These things are spread in every walk of our life and provide valuable solutions to our day-to-day activities (Rabby et al., 2019, and Khanna & Kaur, 2020). The IoT applications and Machine Learning techniques and tools are known to be very effective to manage better road conditions, enabling smooth movement of traffic to reduce road fatalities.

Figure 2.1

Some IoT Objects and Fields

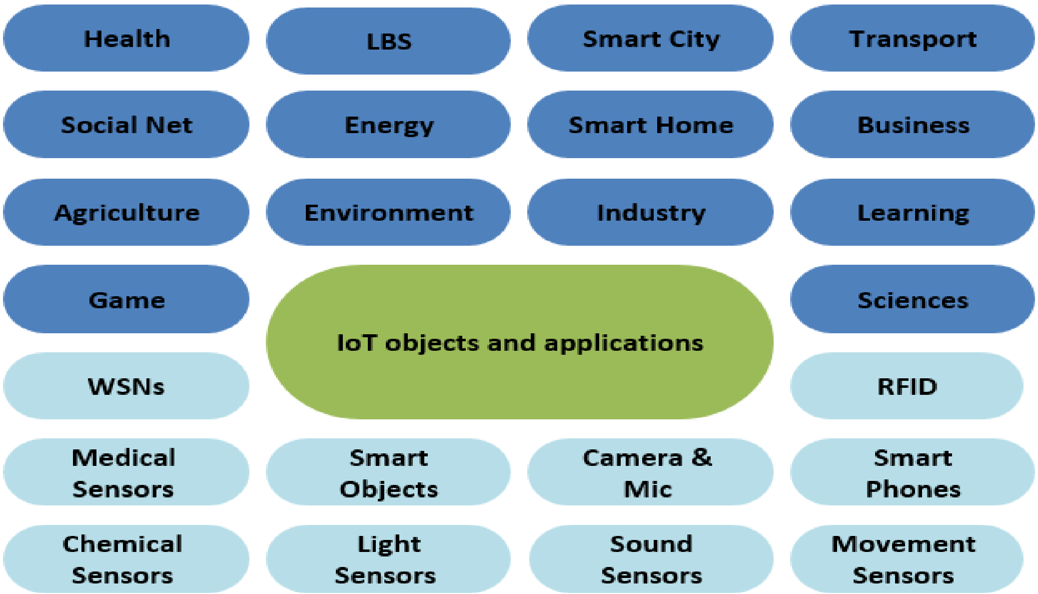


Figure 2.2 (a) (Abi Sen et al., 2018)

IoT Applications

IoT now uses the latest technologies in conjunction with billions of smart devices, objects applications and platforms (Huang et al., 2018). Some of the smart devices and technologies include Wireless Sensor Networks (SWSNs), light, sound sensors and medical sensors, RFID, Smart phones, Digital Streets, Location Based Services (LBS), and Cloud and Fog computing, some of which are shown in Figure 2.2 (a).

IoT was introduced in 1999. Since then, IoT applications have been growing exponentially. Applications of Internet of Things can be found in almost every academic, scientific, business, economic, social and industrial field affecting and improving all facets of life (Whitmore et. al., 2015) IoT has many applications in traffic management and transportation (Rabby et al., 2019, Khanna & Kaur, 2020, and Huang et al., 2018). This research has several applications of IoT which will be described in later chapters.

2.3.2 Cloud and Fog Computing

Fog is a model for computing, introduced by CISCO in 2012 to reduce or eliminate some limitations of Cloud computing. Fog can be defined as an extension of Cloud to the edge of a network with smaller memory and processing power - it can be any device with an ability to do some computing and storage. Therefore, unlike Clouds, Fog is close to the end user and supports distributed computing model instead of only the central one. More information about Fog can be found from (Xu et al. 2014, Ngu et al., 2016, Lee & Lee, 2015, Lopes & Gondim, 2020, Mutlag et al., 2020, Mahmud et al., 2018, Song et al., 2017, Kumar et al., 2019, Mohammad et al., 2020 and Naha et al., 2018). Here we summarise properties of the Fog which differ from Cloud.

a) Fog can be any technological device which has the ability to compute and cache data in addition to network. However, Cloud is a set of servers.
b) Fog supports applications that are response time sensitive and require low latency, high processing speed, and lessen the number of traffic links, whereas Clouds generally have a much bigger latency.
c) Fog node is near the end user which makes it suitable for filtering and processing data before sending it to the Cloud. This means that the overhead on the Cloud decreases along with the traffic on the network links. Hence, it is very useful for big data applications. For example, Fog can process images and detect their features, which are then sent to the Cloud in place of images.
d) Fog can also apply various policies on data also before sending it to the Cloud which increases security, especially for IoT objects not having enough memory and processing power to perform the same tasks.

e) Fog supports smart traffic mobility apps and manages crowd better than clouds.

f) Fog increases the availability service compared to Cloud, which makes it more beneficial in traffic and congestion applications.

g) Fog nodes can be spread out to cover any area fully, such as an intersection or a section of road or a village, so it supports distributed computing as opposed to central computing, which cloud does.

h) With Fog node there is a limitation in resources unlike Cloud, so Fog computing cannot replace Cloud, but it can integrate with it.

i) Fog supports awareness location which is not achieved with Cloud.

j) Users can have full control on Fog, unlike clouds which provide three control levels (SaaS, Paas, and IaaS)

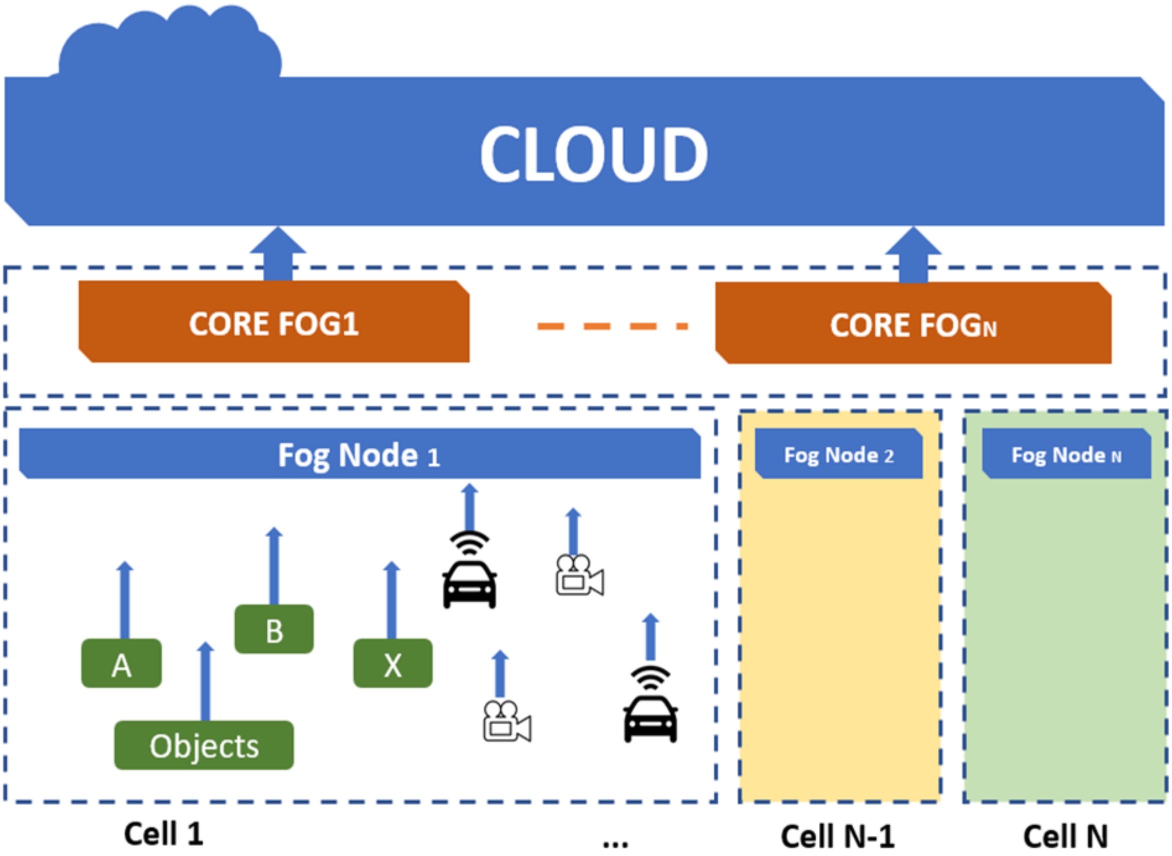
Table 2.1 summarises all these and other characteristics of Clouds and Fog computing (Yamin and Abi Sen, 2020). For a hierarchical or Fog architecture, involving the user, object, Fog nodes, core Fogs, and Cloud, see Figure 2.2 (b) and (c).

Figure 2.2(b)

Cloud and Fog

Davis (2020) claims that the number of devices connected to the internet could amount to fifty billion by the end of 2020. One of the issues with cloud computing is the speed or response. With the forecasted increase in the number of devices, cloud computing cannot provide a fast response to the vastly increasing number of smart applications, including traffic related ones, especially the traffic light priority processing. For more details on time sensitive applications, refer to Venkatesh & Eastaff (2018) and Zhou et al., (2017).

Figure 2.2(c)
Cloud and Fog



High demand for time sensitive applications led to the emergence of mobile clouds or multiple clouds and fog computing in 2012 (Abi Sen et al., 2018). Fog computing has features which are not available in cloud computing and can be considered as an alternative to cloud computing, providing a faster response. Most of the advantages of fog computing arise from the fact that it works from positions close to the applications. Typically, fog nodes are widely distributed at the end of the network and IoT devices (perception layer) which are closer to the user (Yang et al., 2017). This setup manages a cluster or region with tools to provide responsiveness, especially in emergencies, as well as initial processing of data before sending it to the cloud for permanent storage. Fog nodes can store data for small periods of up to two hours, which is usually enough for nodes to collect and summarize the data (Dabbagh & Rayes, 2019). The next step for the fog nodes is to send the data directly to the cloud instead of hundreds of connections from numerous devices every few seconds. Batch transmitter also has a big role in reducing the load and improving the performance and privacy dramatically within applications that use this technology (Khalilov & Levi, 2018).

Fog nodes make a hierarchical structure which is used for sharing information by means of what is known as the core fog, headed by the cloud, a distributed structure instead of a centralized one (Ziegeldorf et al., 2014). The main differences between fog and cloud structure are summarized in Table 2.1. For more information on these aspects, refer to Kumar et al., (2019) and Abi Sen & Yamin (2020). From Table 2.1, it is evident that fog computing cannot be a substitute to cloud computing, but with their integration, a higher level of services and applications and features can be provided.

2.3.3 Radio Frequency Identification (RFID) and Wireless Sensor Networks (WSNs)

Radio Frequency Identification (RFID) technology made headlines in 2002 (Boss, 2003). Since then, the use of RFID is steadily increasing. The technology is very efficient for the purpose of tracking. RFID tags can track movements of people, vehicles and goods. RFID tags can also contain some data. RFID and Wireless Sensor network (WSN), when combined, bring state of art solutions for tracking people and objects. The location of a RIFD tag can be accessed by Wireless Sensor Networks (WSNs), 4G/5G Cellular Network or GPS. A WSN consists of many sensors, which, in addition to detecting RFID tags, can be used to detect, sense and monitor many physical states and events such as light, heat, pressure, pollution, wind, turbulence etc. As the sensors of a WSN are wireless, it is very easy to install them anywhere to have better usage and larger scalability.

Table 2.2

RFID and Wireless Sensor Network

Main goal	Monitor and sense environment	Detection location and Identity
Tasks	Collect, Process, Transfer, and Store	Usually reflects RF signal transmitted from Reader for identification of location of the attached object
Element	Sink aggregates the information from sensor nodes. Sensor node with sensing, Computing, and communicating elements	Tag (Passive/Active) stores the unique serial number, and it provides memory for some additional info. Passive tag is used only for reading info by a Reader. Active tag supports two ways communications with higher signal strength and can store some information, but it is costly. Reader can read or write data on Tag and pass it to the host. Capable to send messages to an individual tag or broadcast to all tags within range. Host Computer analyses data
Range	Can't support long range of communication, so it uses multi-hub to reach the Sink Node and increase the range	Usually small Range of communication, where Passive Tag (2-3 meter), Active Tag (100-200) meter, but it is costly according to its abilities.
Application	Applications in many fields including Safety and Wellbeing, Healthcare, Smart-Grid, Environment	The main applications are Tracing, Security & Access Control, Healthcare, Crowding, Clothes stores, etc.
Protocol of connection	Wireless connections: Wi-Fi 802.11WLAN but is High on power, Bluetooth 802.15.1 WPAN, ZIGBEE 802.15.4 Low Power WPAN	RFID Protocols (Air-Interface)(IOS-x), LF, UHF, NFC, etc.
Communication and Connection	Multi-hop to increase strength of signal, and WSNs can link to each other (Ad-hoc)	Single-hub and there isn't communication between RFIDs
Mobility	Usually Static	Usually Mobile
Programmability	Supported	No Support
Deployment	Random or Fixed	Attached to or embedded in objects
Power and energy	Battery for sensors, and power supply for Sink Node.	No need of battery for Passive Tag, but powered- battery is needed for Active Tag, and power supply for Reader.
Usability	Car, phone, clothes, electronic devices, etc.	Card, bracelet, phone, car, etc.
Limitation	Range, Architecture, Massively heterogeneous, Real-Time Apps, Privacy & Security, etc.	Power, Communications, Cost of Active Type, Security & Privacy, etc.

Table 2.3

Characteristics of Clouds and Fogs

Factor	Fog	Cloud
Nodes Number	Large number of nodes, capable of cooperating in different forms (Cluster, P2P, and Master-Slave)	One or more servers
Storage Type	Caching data for a few hours	Permanent storage of data
Cooperation	Mostly cooperative (hierarchically), but, the fog can work independently	Mostly independent, but it can cooperate with another cloud
Connection	Wireless connection	Internet connection
Location	At the edge of the network (local) closed to the user.	Far from users
Distribution	Dense and distributed	Central
Application type	Supports new types of applications which need high speed, and response time (RT) interactive	Applications need to power in computing and analysing on big data
Real Time	Strongly Supported	Weak supported
Working as broker	Can play this role between users and SP	It is the main party
Mobility	Strong Supported	Weak supported
Accountability	Weak, but increases the privacy of user by hiding their IDs	Strong, but creates more threat to privacy

Using a WSN for accessing signals from RFID tags is very effective and provides very accurate longitudinal and latitudinal coordinates. Wireless sensor networks can be costly and require generous space for their installation (Fu et al., 2017). For making the network efficient, repeaters may be required. Table 2.2 (Yamin et al., 2018) provides a summary of applications of RFID and WSN.

Depending on the location and geography, a Sensor Network may require many repeaters to ensure access in all areas of RFID tags. RFID and WSN are central to this study and many applications designed are dependent on these technologies. RFID and WSN have been used in traffic management research (Das et al., 2018, and Nagpurkar & Jaiswal, 2015). GPS can be an alternative to sensor network in many (but not all) applications. It is well known that GPS does not work in heavily congested and fortified areas and tunnels. In such situations, WSN must be deployed.

2.4 Traffic Management with Technology

Traffic has increased many-fold in the 21st century, especially in the developing countries with a rise of their middle class. The number of cars produced in the world in 2000 was about 41 million, whereas this figure in 2020 has gone up to 92 million, with a total of about 1.4 billion cars on the road today. With the increase in the number of vehicles, congestion problems have also increased. Many people have contributed solutions to the traffic issues with modern technologies. Here we provide a summary of some of those solutions.

Jebamalar et al., (2019), while commenting on new technologies and the increasing population which has caused a spike in the number of vehicles, have suggested using data mining for classifying the road to six categories according to rate of density, the six categories being Free, Low, Mid, High, very High, and abnormal depending on the speed of vehicles and average waiting time, and then notifying the end-user to select the right path and predicting any expected congestion. The paper discusses how traffic congestion can be predicted using data mining classifiers with big data analytics and compares different classifiers and their accuracy. An overview of the applications of AI in transport system is provided (Abduljabbar et al., 2019). Basavaraju et al., (2014) have dealt with the dangerous problem of congestion all over the world and suggested some solutions by using WSNs and RFID on the road to create a smart/dynamic traffic light system. Although this solution could be costly, it compares favourably with other techniques such as image processing which can be accurate and effective for traffic lights or random movement of vehicles. Moreover, using Fog computing can reduce costs. Parekh et al., (2019) have proposed a system for monitoring and managing traffic by IoT and sharing data by drivers, so the system can rely on this data to support decisions in traffic light control. Tandon et al., (2019) discussed the problem of ignoring traffic regulations which results in the loss of many precious lives which necessitates the use of new technologies like sensors, alarm, push-to-talk, smart vehicle, and smart traffic lights to enhance the level of safety.

Hussain et al., (2019) have provided an overview for an Intelligent Transport System (ITS) which integrates with IoT tools. They showed that the cloud computing will not be effective in dealing with the sensed big data and instead suggested using fog to solve this issue. They also presented a new parking system. Hussain et al., (2018) discussed the challenges of using Fog and the opportunities it offers. Ma et al., (2019) argue that Smart systems requires a new level of security and privacy for private data of users, especially in a world which is full of electronic attacks. Alexander et al., (2019) and ITS, (2019) stressed that many cities have started depending on Integrated Transport Systems to improve the transportation policy and increase efficiency and performance. However, using sensors has opened the door to new gaps and new threats. Masinde et al., (2019) claim that there is a noticeable increase in LBS Applications, especially in smart cities with IoT and a new framework is proposed by merging many IoT services in the transport sector to monitor public transport. According to Muthuramalingam et al., (2019), IoT connects the physical things to Internet to build smart systems like ITS, where the communication among the vehicles created a new age of services in the land, sea, air and rail sectors like tracking luggage. John et al., (2019) state that the importance of an existing real connection between smart vehicles for more sophisticated and safe transportation system is emphasised, but there are some challenges that need to be addressed related to infrastructure and security & privacy information.

Ang et al., (2019) proposes a new term, the Internet of Vehicles (IoV), where vehicles will be sensing points, resulting in more services, safety, and efficiency for the transport system. Moreover, vehicles can be used as sensors for environment conditions, meeting the needs of a smart city for wider data uses. The paper also reviewed the challenges and future trends of IoV. In the research of Lam et al., (2016), scheduling algorithms are proposed as a means of selecting optimal paths for Autonomous Vehicles (AV). An overview of AV's is presented in Tokody et al., (2017) research. Costa et al., (2020) proposed a solution dependent on trains and metro to reduce traffic and a smart control system with new algorithms to select the best paths in real-time. Shen et al., (2018) propose an inelegant transport system (ITS) to manage metro-related issues and provide information on the paths and timetables, in addition to a smart system for payment. Costa et al., (2020) propose an algorithm for to estimate the speed of vehicles with the help of images taken from the video, using an image scale factor. More methods for dealing with video can be found in the study by Luvizon et al., (2017). Other techniques depend on image processing (deep leaning) for remote sensing images, which is discussed by Wang et al., (2020). An overview for image processing algorithms and traffic issues is presented in the work of Sankhe et al., (2014).

Qu et al., (2019) have studied the speed, acceleration and direction of traffic flow depending on deep learning and processing for collecting data, where the result will be used to update the pattern of the traffic flow by a central controller. Arifin et al., (2019) have provided information about the new technologies which have been used in traffic management systems of the developed countries, which can help us to find a smart central controller operating in real-time to deal with emergency cases like pausing the traffic along specific routes to give priority to another vehicle, for example, an ambulance. It should be noted that this can be achieved only by depending on RFIDs in vehicles and traffic-light control. In other words, all vehicles are required to use RFID otherwise the system will not work. More details about sensors and RFID's are presented by Guerrero-Ibanez et al., (2018). Celesti et al., (2019) claim that Smart Traffic Light systems can enhance the level of safety, by issuing slow-down commands for incoming vehicles, which could otherwise cause an accident. The importance of collecting data about traffic and mining it to provide useful knowledge about traffic lights switching is discussed by Guo et al., (2019). In the study of

Rathore et al., (2017) Transport systems in cities using big-data is discussed. Traffic data can be exploited to address congestion issues which cause pollution. The new electric vehicles, in addition to the idea of vehicle sharing, can relax this issue in the future. Babar et. al., (2019) discuss the challenges and motivations of using Machine Learning algorithms with big-data in the transport field. Using Hadoo and Map-Reduce can be a good solution for data management. The results can be useful in many applications such as parking, RT monitoring, vehicle sharing, auto-vehicle location, etc. Darwish & Abu Bakar, (2018) have proposed using Fog computing to address these challenges. Pelletier et al., (2011) focus on the importance of moving to public or mass transportation which is considered more sustainable. To push toward these tools, we proposed smart vehicles to automate the function of ticketing systems and facilitate multiple trips. Ratrout et al., (2018) consider the effects of public transportation for students. Employing buses to transport them will reduce traffic during peak hours and in addition will enhance students' safety. Moreover, the proposed system depends on GPS to enable parents to monitor their children transportation on buses. Faheem et al., (2013) mentioned the advantages of smart-transport systems as enhancing the safety, reducing pollution and integrating with the smart-city to provide more adaptive services for end-users regarding cost, safety and efficiency. These objectives can be achieved by many applications and methods, like using autonomous vehicles, connected vehicles, smart traffic lights, auto detection for accidents, smart parking, avoiding stopping in the wrong places, etc. More details about smart parking applications are presented in by Al-Turjman & Malekloo (2019).

In practical terms, one of the most important factors to enable a city to be smart is the transport system. However, this requires an integrated and comprehensive framework. Moreover, preserving privacy is a vital issue in smart systems which must be addressed because it is the most threatening aspect facing the future of IoT and its applications (Mehmood et al., 2017). Classification of attackers on privacy and their skills are explained by Shin et al., (2012). In the research of Wernke et al., (2014) and Abi Sen et al., (2018), a survey for the methods and techniques of preserving privacy are introduced.

CHAPTER III - A Framework for Smart Traffic Management

As discussed earlier, the aim of this research is to provide a comprehensive and long-term solution for the traffic problems. In this chapter we provide an update on the current research. In particular, we propose a framework for Smart Traffic Management System (STMS) to manage and control the traffic issues including congestion in a systematic and comprehensive manner. The proposed STMS is designed to suggest a comprehensive solution for most critical and inter-related issues of modern traffic management. The current and future research will relate to this framework.

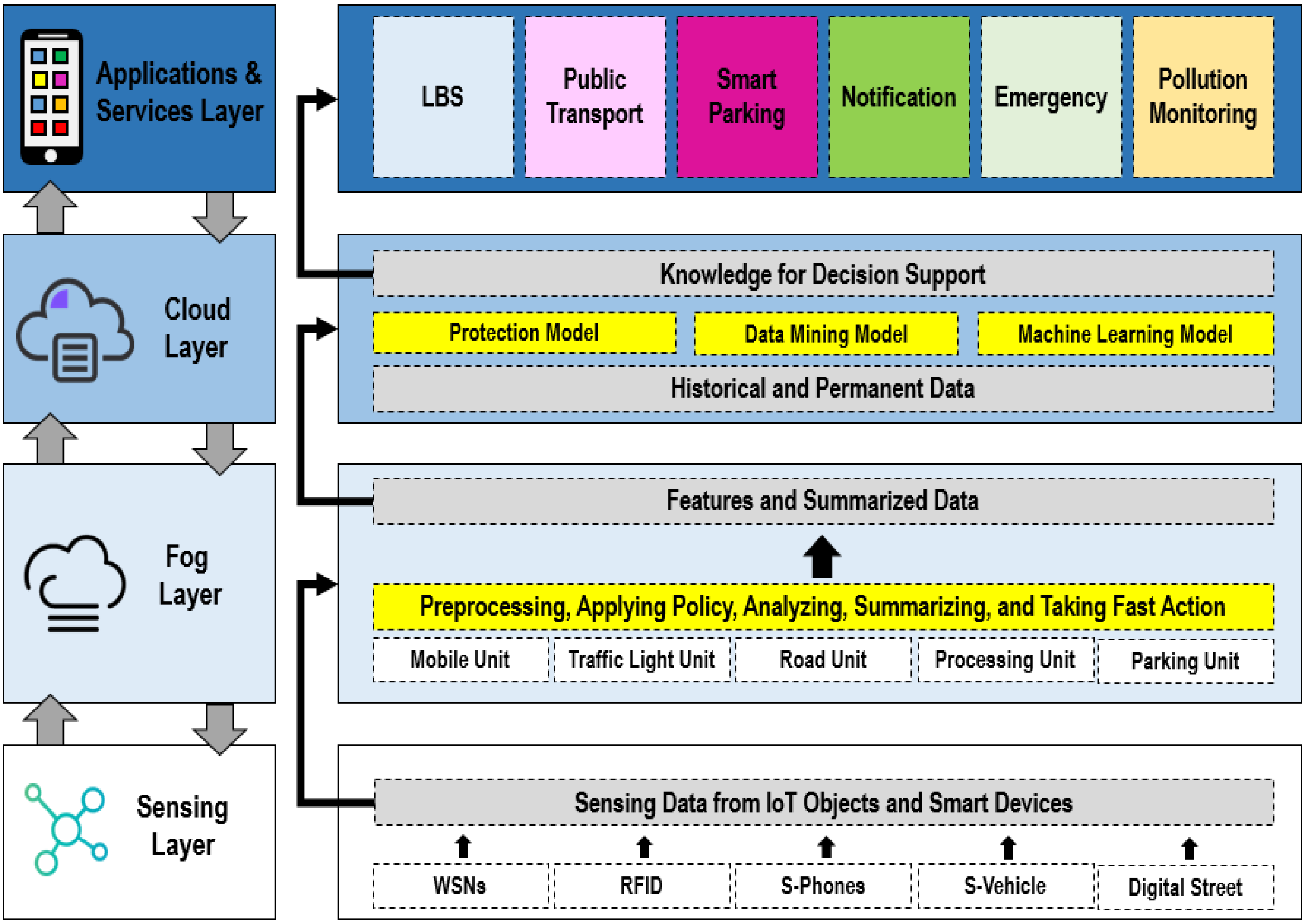
Technical architecture of the STMS is shown in Figure 3.1. It has four layers, which combine several technologies to provide a comprehensive solution to the problems of congestion, safety, security, awareness, and guidance. Each layer outlines a number of services, which are dependent on technologies included in the layer. One of the most important components of the proposed framework is a model of Smart Traffic Lights (STL), which uses different technologies and tools like high resolution cameras, Image processing, IoT, Sensor Networks, Cloud and Fog Computing, Smart Street, Location based Services (LBS), GPS, RFID, and so on.

3.1 Architecture of Proposed Framework

Here we describe the layers of the STMS, the role of technologies in each layer, and the support they provide to different applications in the proposed framework shown in Figure 3.1.

Figure 3.1

Architecture of STMS framework



3.1.1 Sensing and Object Layers

Sensing layer is at the bottom of the STMS architecture, as shown in Figure 3.1. This is the most critical layer of the STMS as it provides basis for the other layers and hence the applications. As can be seen, it has Wireless Sensor Networks (WSNs), Radio Frequency Identification (RFID), Smart Phones (S-Phones), Smart Vehicles (S-Vehicles) and Digital Street. Each of these technologies and tools perform specific tasks. When working in tandem, these technologies support other tasks in order to provide innovative and state-of-art solutions to solve and mitigate many traffic problems.

3.1.2 Smart Traffic Light

An extensive discussion of the 3.1.2 Smart Traffic Light (STL) will take place in chapter 4, which would include different methods to accurately assess the congestion levels with the help of three different ways, including Machine Learning.

3.1.3 Fog Computing Layer

As discussed in the Literature Review, Fog computing is critical in providing fast processing. Fog computing in the STL will provide a facility and environment for all the calculations required by the tools and technologies at the Sensing layer. Fog also provides temporary storage for the applications data.

3.1.4 Cloud Computing Layer

As discussed earlier, Cloud and Fog computing play a critical role in wireless applications. As discussed in Chapter 2, there are particular roles for each of the two technologies. The role of Clouds in the STL is to extend the functionality of the fog.

3.1.5 Applications and Services Layer

At this layer, all applications needed by the STL are provided. The groundwork for these applications starts at the Sensing layer and finishes at the Cloud computing layer, making them available for using at this layer. A brief description of some of these services follows.

3.1.6 Location Based Services

Location based Services (LBS) is an environment to provide many services to different kinds of users. Many IoT and Digital Street Applications take place with the LBS. In the LBS, there are privacy issues, especially the need for protecting Identity, and location privacy from the SP themselves. As will be seen later, the STL uses LBS for some applications.

3.1.7 Public Transport

It is very important to manage Public Transport by controlling traffic congestion. Unlike private traffic, public transport is relatively easier to manage because of the predictability factor operations. In particular, because of school/college and office transportation needs, the public transport is quite heavy in peak times, which are prone to congestions in many cities.

3.1.8 Smart Parking

Finding parking at peak hours, especially for latecomers, can be a daunting task. This forces many vehicles to roam around in the quest of finding parking. This contributes to congestion and adds to the complexities of managing traffic. The STL provides a smart parking framework coupled with an app to scan the parking facilities for possible vacancies. Further discussion of Smart Parking will be provided in chapter 8.

3.1.9 Notifications

The aim of notifications is to keep commuters informed of road conditions and closures and suggest alternative ways to avoid roads with congestion and other problems. The notifications are app-based and are sent with alerts to the mobile devices of the registered road users. Naturally, the notifications can only be sent to those who provide their details and grant access and download the STP Notifications App. This gives rise to the issue of data privacy and protection, which will be discussed in detail in chapter 6.

3.1.9.1 Emergency

Emergency services are warranted in case of sudden problems like accidents, road closure, flooding, fire, and other disasters. Emergency services can be sought by dialling an emergency number, sending message and location by mobile apps on smart phones, tweet analysis, and so on. Emergency services may include onsite treatment of the injured or their transportation by road or air ambulances. In some cases, services of drones may also be needed. Police Investigation and wreckage removal may also be applicable in some cases.

3.1.9.2 Pollution Monitoring

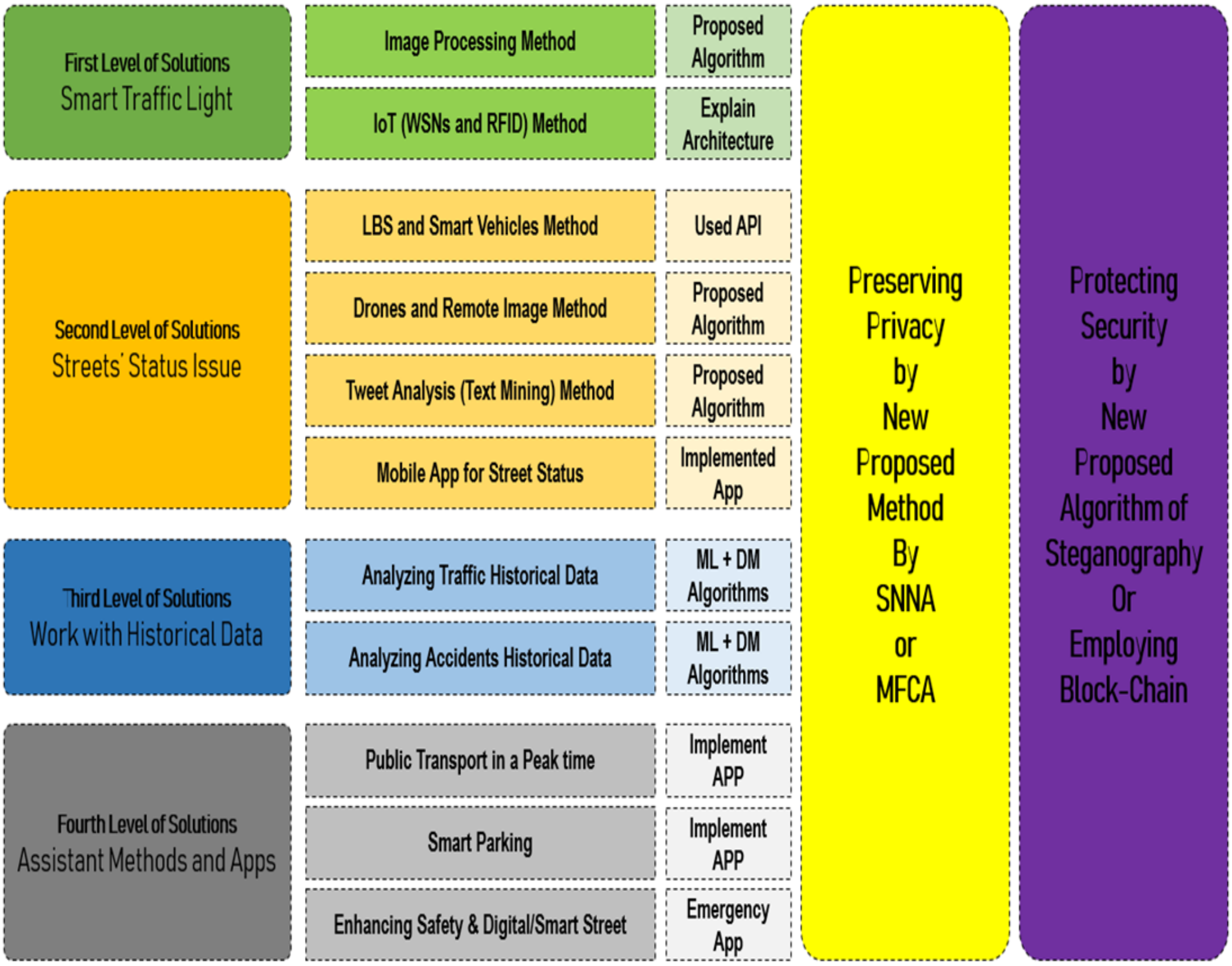
It is very important for the road managers to monitor pollution levels and provide reporting to the greater benefit of public health. Exposure to pollution can be lethal for the people with an asthmatic condition. Pollution readings of different roads and areas should be made available by the mobile applications so that people can take alternative routes and postpone their trip to protect their health.

3.2 Levels of Solutions in Smart Traffic Framework

As shown in Figure 3.2, there can be different levels of solutions by using different technologies. The first and foremost level of solutions is by means of smart traffic lights.

Figure 3.2

Levels in Smart Traffic Framework



3.2.1 Relationship between Levels with Layers?

There is no direct relationship between the Levels and Layers (Figure 3.1 and 3.2). The layers represent the deployment or system architecture for the proposed framework. The levels show the logical list of tasks or functions which need to be followed to achieve the main goals for managing traffic involving intersections, streets, and cities, some assistant applications to provide indirect solutions. In this way, each proposed solution can be achieved by navigating through layers. For example, STL solution depends on the first layer for collecting data about traffic, second layer for processing data in Fog without delay, while the third Layer will store all the temporal and spatial information for future analysis.

3.2.2 Level 1: Smart Traffic Lights for Managing Intersection

The smart traffic lights will operate based on the level of congestion on each street approaching the intersection where the lights are installed. There are two ways of assessing the level of congestion on roads. The first way is by processing images taken by high resolution long-range digital camera. The other method is to use RFID and sensors to count the number of vehicles entering the traffic light zone. A detailed discussion of Smart Traffic Lights will be provided in chapter 4.

3.2.3 Level 2: Managing Traffic on Main Streets

The second level of solution is integration of methods for relaxing the congestion issue proactively by monitoring the status of main streets and notifying the users to avoid coming to these streets. The methods of monitoring status are:

a) Location Based Services (LBS) and Smart Vehicle Method

b) Drones and Remote Image Method

c) Tweet Analysis (Text Mining) Method

d) Mobile Apps for Street Status

Details of these methods for assessing street status will be included in the chapter 5.

3.2.4 Level 3: Historical Data

The third level of solution is by analysing historical data to update the policies used for different roads and traffic lights. By analysing historical data, various statistics for different roads can be re-assessed periodically. Also, by analysing road accident data, the extent of the levels of dangerous driving on different roads can be assessed and preventive measures can be taken. We will use cloud not only for historical Data, but also as computation resources for the methods of Level 2. Details of these will be discussed in chapter 6.

3.2.5 Level 4: Assistant Methods and Apps

The fourth level of traffic solutions is proposed by means of Assistant Methods. Apps Assistant methods are the ones which the management would have in place such as providing emergency services in case of emergency, crises or a disaster-like accidents, floods, fires, cyclones, and earthquakes. Various kinds of Computer Apps can also be provided to guide and update the public with all necessary information about-roads. In this chapter, we shall address this topic in three sections. The first section will deal with the Public Transport at peak hours, second section will deal with Smart Parking, and in the third we shall discuss safety issues by means of digital streets. Details of various assistant methods will be provided in chapter 7.

3.2.6 Additional Level: Preservation of Users' Privacy and Security of Data

A very important aspect which is often neglected when solving traffic problems is the privacy of users' personal data. With the proliferation of technology and the search of innovative solution, users of the applications invariably must share their privacy information (ID, location, etc.) with the service providers. All service providers cannot be trusted to protect the users' privacy. On the contrary, some of the service providers can be unscrupulous and may use the privacy information for their personal gain. In chapter 9, we shall discuss these issues in detail and provide a method to protect the privacy of the users.

Security is an equally important issue to deal with when providing or accessing traffic data. There are several methods for data protection security, details of which will be discussed in a future study. Data security methods can be advanced by using

Steganography or Blockchain technologies. In future studies, we shall provide a framework for security and privacy of road users.

A detailed discussion of manipulation and technological treatment of various proposal in this thesis will be provided in chapter 10. In chapter 11, we shall present a summary and conclusions.

CHAPTER IV - Smart Traffic Lights

Before discussing various solutions to congestion and other traffic issues, it is worth mentioning that it is unrealistic to assume that all problems of traffic can be solved easily, and we do not claim to solve them completely in this thesis. Our effort is to reduce the problems to ease the congestion, and hence to minimise road accidents, thus saving many precious lives. Apart from providing piecemeal solutions to all separate issues, the main challenge of the work is to integrate them in a single comprehensive solution which can be applied in practice.

Some of the common causes of congestions are inadequate roads, indiscipline, and poor management of traffic at intersections. Controlling and managing traffic at busy intersections is an important issue to the whole world. To regulate smooth traffic movement, busy intersections require development, installation, maintenance and management of Traffic Lights. Traffic congestion at intersections is one of the problems which can be fully or partly solved by applying available technology and tools in deploying Traffic Lights. Given the need of millions of intersections in individual countries, considerable investment is required but that would be outweighed by the benefits, including possible reduction in road related deaths and injuries. Alternative solutions, namely construction of bridges, tunnels, and multilayer roads, are even more costly than the cost of technology to manage the intersections. In this Chapter, we shall provide a framework of smart traffic lights. Simulations and applications of the Model will be presented in Chapter 5

4.1 Efficient Traffic Lights

One of the main contributions of this thesis is to provide an adaptive method to control and manage Traffic Lights at busy intersections. The proposed adaptive method would determine the priority periodically at a set interval of time, usually 10 seconds, which could be adjusted according to the ground realities (15 or 20 seconds). Accordingly, the method will reset traffic clearance priority to the street having the greatest number of vehicles. At the same time, the method will not neglect the streets with lean traffic beyond a maximum time limit depending on the road (normally three or four minutes). One of the proposed methods to calculate vehicles on each road will be assisted by long-range digital cameras fitted on the intersections. The photo frames taken by these cameras will be processed by Image Processing with Machine Learning algorithms. Roads having larger traffic volumes will be given longer clearance time, which can be extended by further evaluation dynamically. A Traffic Light with the above-mentioned characteristics and facilities is called Smart Traffic Light (STL).

The method of detecting and counting the number of vehicles or assessing the extent of congestion on each street at any given time by image processing is quite practical as it only requires large resolution cameras, like in Figure 4.1, and backend processing using Fog computing. One of most important and major components of STMS Smart Traffic Light (STL) system, which uses Image Processing, Wireless Sensor Networks (WSNs), IoT, and RFID.

Fig 4.1 (Rainville, n.d.)

Multi-purpose cameras for intersections

Fig. 4.2 (Ju, 2019)

Cameras for vehicle count

We would provide algorithms for Image Processing with Machine Learning and demonstrate their relevance and usefulness for regulating traffic lights. The algorithms would include code for assessing the extent of congestion in a multi-road scenario, with at least three road converging to an intersection. When coding, we would take different scenarios into consideration. We shall also provide simulations, statistics, and data analysis by using Image Processing Toolkit in MATLAB.

As mentioned earlier, the STL relies on processing the number of vehicles or the extent of crowd on each street. There are several ways to achieve the objective, practicality and efficiency of which would depend on several factors, usually the location, available space, street, and budget. In particular, vehicle counting can be done by-Wireless Sensor Networks (WSNs) and RFID sensors. Generally, wireless sensor networks are efficient but require significant infrastructure and maintenance. In chapter 5, we shall provide full details of the proposed STL, including algorithms for counting vehicles by image processing, and simulations on picture-frames of vehicles on the intersections taken by the high-resolution cameras. We shall also describe the methods for determination of the extent of congestion by sensors, as well as with the help of RFID and sensor networks.

Figure 4.2 (Teledine Flir, 2020)

Camera for People Safety in Digital Street

Most countries manage their road interactions by means of traffic lights which are programmed to provide each side of roads with a fixed amount of time. These signals work statically, usually on the assumption of a fixed traffic rate in all directions of the intersection. This causes traffic to build-up on busier roads at the cost of empty roads. This causes health hazards in the form of inhaling polluted air, especially to people having breathing issues. Agonizing waiting times, sometimes creating anxiety, delay in meeting deadlines, and wastage of fossil fuel are some other problems caused by delays in traffic movement (Figures 1.1 and 1.2).

Most of the congestion is a result of the static nature of traffic lights at intersections. For example, on a four-section intersection, like in Figures 4.2 and 4.3, clearance of traffic may be set to a static cycle of 60, 60, 30, 30 seconds. If any street does not require its allotted time to clear out the traffic, then, it would be a waste of time which may cause huge traffic build-up on the other streets, causing congestion, as shown in Figures 1.1 and 1.2. Some countries, including many European countries, Australia, Canada, the USA, South Korea, Hong Kong, Malaysia and Singapore are using some form of advanced traffic management of intersections with the help of sensors under the road surface. These detect the arrival or presence of vehicles, and hence are very helpful to efficiently manage the intersections during low traffic volume, when some roads do not receive any vehicles for several minutes. If there are no vehicles on a particular side of the road, clearance is facilitated by turning the signal to green. However, this mechanism is of no benefit in the case of heavy traffic on each side of the road, typically during the peak hours.

Figure 4.3
Static Traffic Lights

Yet another method used in some countries is to provide double priority to certain sections of roads at peak times. For example, a road leading to a town centre or office park at peak hours is provided double priority as a result of prior observations and study of traffic volumes at particular intersections. This certainly helps to ease the traffic, but at the cost of delays to the traffic clearance on the other roads. A downside of this system is that the double priority would be in play even if it was not required or became obsolete due to some special circumstances at a particular day or time. There are some other ways to regulate traffic at intersections which we have discussed in preceding chapters, but none of them can be classified as intelligent or smart, which is the topic we shall discuss in the next section.

4.2 Smart Traffic Light (STL)

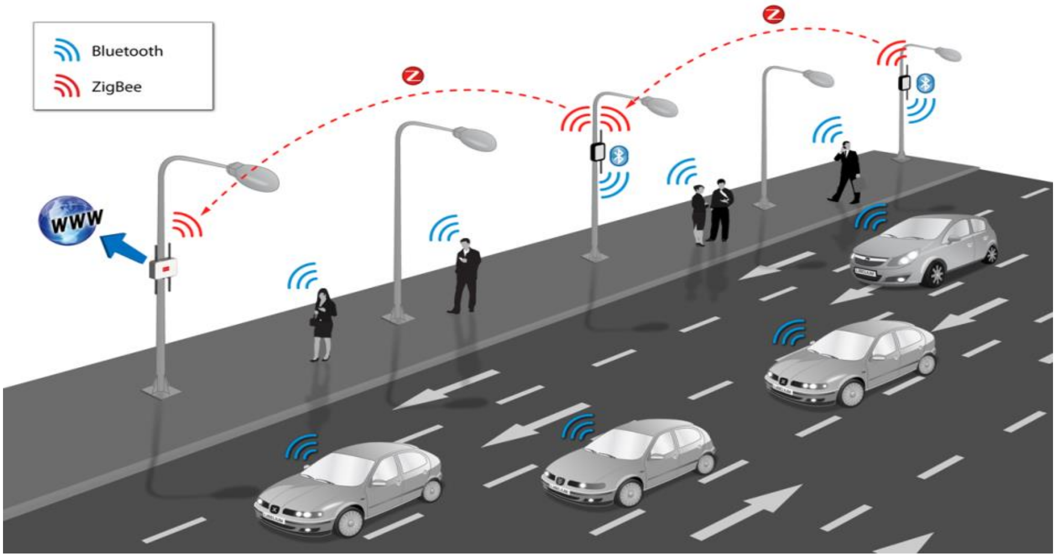
One of the main contributions of this thesis is to propose an adaptive method to control and manage Traffic Lights at busy intersections, which is described next. Proposed adaptive method would determine the priority periodically at a set interval of time, usually 10 (sometimes 15 or 20 seconds). Accordingly, the method will reset traffic clearance priority to the street having the greatest number of vehicles. The method will not neglect the streets with lean traffic beyond a maximum time limit, normally three to five minutes depending on the road. The number of vehicles will be counted by processing the images taken by long-range digital cameras fitted on the intersections. A Traffic Light with the above-mentioned characteristics and facilities is called Smart Traffic Light (STL). Proposed STL will provide an optimum solution, although we do not claim that it would solve all the congestion problems completely.

4.2.1 Details of STL Operation

As mentioned earlier, the STL relies on processing the number of vehicles or the extent of crowd on each street. This can be done by using a number of technologies including Image Processing (IP), Wireless Sensor Networks (WSNs) and RFID sensors, as depicted in Figure 4.4, depending on the assessment of the location, space, street, cost etc. Generally, wireless sensor networks are efficient but require significant infrastructure and maintenance. As for using RFID, it would be very difficult to force every vehicle to use RFID chips when using roads, and so feasibility would be an issue in using this method.

Figure 4.3

Sensors for reading location and other data from RFID in smart vehicles



The method of detecting and counting the number of vehicles or assessing the extent of crowd on each street at any given time, based on image processing is quite practical as it only requires large resolution cameras (like in Figure 4.2) and backend processing using Fog computing. In this chapter, we shall discuss this method in detail. For transforming a busy intersection to the STL, each side of the roads approaching the intersection will be fitted with long range, day-night, high resolution, and weather-proof cameras. These cameras would be set to take photos of the vehicles on each side of the road facing the intersection, periodically at the same time. Interval or period of time may differ for different intersections depending on the volume of the traffic, normally in the range of 10 to 20 seconds. On a four-way intersection, four images would be taken, and then processed to determine the number of vehicles waiting for clearance on each way. Based on this information, clearance would be signalled by a green light to the most crowded way. The system should not neglect any street after the expiry of the maximum limit of waiting (e.g., 120 or 180 seconds), and grant them clearance after a lapse of maximum time irrespective of the number of vehicles on that side. The STL would provide a perfectly coordinated and smooth traffic movement through intersections, which in turn would reduce traffic congestion, and related problems.

4.2.2 Issue of Delays

There is no significant delay in communication because we depend on fog computing and wireless connection, in addition to our algorithm, to count vehicles. This is simple and takes about than 200ms for 1 image so the four images will be less than 1sec. As our system depends on the ratio of traffic and not the specific number of vehicles, therefore the noise can only affect the number of vehicles but will not affect the ratio. In addition, we use range for a threshold (min and max), not a specific value. So, if any unexpected failure occurs, the dynamic feature will stop and the traffic light will continue as a static traffic light until the issue is resolved. To capture traffic on a long stretch of the road, it is advisable to install one camera in the centre of the intersections which can rotate 360 degree, or 4 fixed cameras as shown in Figure 4.1.

There are several possible scenarios, but we shall discuss only two of them which we deem to be important and applicable for most situations that arise in practice.

4.2.3 How would STL Process Extra-long Queues?

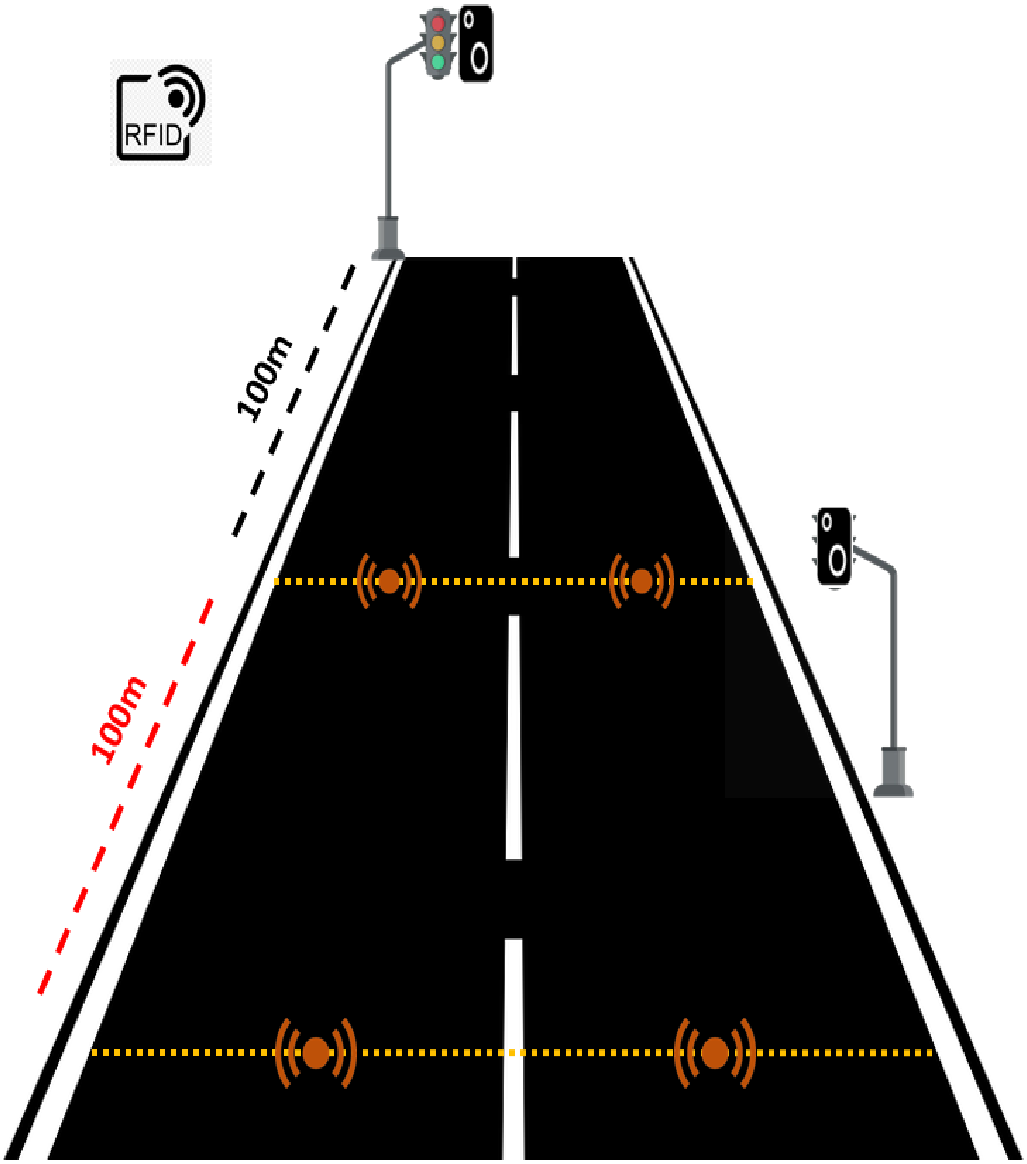
A modern traffic camera would have a limit of capturing traffic within a certain range, say 100 meters. If traffic accumulation on any side exceeds 100 m, then the following measures can be taken:

- Allow maximum set time for clearance of this road
- Use multiple cameras to assess the level of congestion of the road as shown in Figure 4.3 or Figure 4.4

- Use sensor RFID readers or wireless sensor networks well before and synchronize them to the traffic light to assess the congestion level as shown in 5.3 or Figure 4.4.

Figure 4.4

Multiple camera and multiple sensors



- Generates tweets to advise commuters to use alternate routes.
- If the problem persists in a way that certain roads regularly collect too much traffic for a considerable period of time, then the management should consider

different ways of improving infrastructure, either by widening the road to increase the number of lanes or build an overpass to allow rapid clearance.

- It should be born in mind that traffic problems cannot be solved completely in all cases and circumstances.

4.2.4 Long-term Benefits of STL

All results of operations of LTS would be stored in the central database for the purpose of analysing the behaviour of each street to readjust time limits and determine the peak-time of traffic in each street at different times with an interval of 15 minutes on each day of the year. Data collected from road traffic and STLM would likely be accurately analysed by means of Big Data Analytics and other scientific methods to improve the plans, methods, and organization of the traffic system. We shall show that the proposed method outperforms the existing system in terms of average waiting time. This method will be cost effective and time saving. We shall demonstrate this experimentally by simulating both the existing and proposed systems.

Figure 4.5
Case of normal traffic hour

4.2.5 How to Measure Benefits of STL?

We shall simulate traffic management by STL and analyse the operational results. From the simulations of traffic control with and without STL we will determine the rate of vehicle clearance, time saved, and control of wastage of time. This will indicate the value gained by using STL. Practical application of STL requires installation of cameras with processors to measure the rate of crowding in every street and determine optimal lights switching. This will benefit people by avoiding crowding and delays, thus reducing tension and anxiety caused by waiting for a long time.

To sum up our discussion, the STMS will provide a new automated system to toggle between the Traffic Lights in proportion to the degree of crowding in the street. The STMS will gather data from different streets, study them and suggest changes for future improvements.

4.3 Mathematical Simulation of Problems of Current Static Traffic Light System and Solutions by STL

By means of examples, we shall provide shortcomings of Static Traffic Lights Signals using simple mathematical calculations. In all traffic systems, engineers estimate the degree of traffic flow by waiting time for each street. As a result, they provide the suitable timing for the signal to turn green.

4.3.1 Case of Lean Traffic

To provide an example, as shown in Figure 4.5, let us suppose that there are three sides at an intersection, and average flow in each street is about the same. Accordingly, each side would be provided by the same duration for clearance of traffic. Let (**Street1, Street2, Street3**) represent the number of vehicles arriving at a given interval of time. Suppose 2 vehicles during 15 sec and 3 vehicles exit each at a rate of 6 sec per vehicle during the green light at each street, and that each Traffic Light is open for 30 seconds.

In the normal case:

1. Total time for a complete cycle of each street = 30 + 30 + 30 = 90 seconds
2. Average number of vehicles that arrive in a cycle = (90/15) *2= 12
3. Number of vehicles that will exit during 30 sec of opening = (30/6) *3 = 15 Vehicles

There will not be traffic congestion in this case as the clearance of vehicles exceeds the number of arrivals (note all streets have the same flow rating in this case).

4.3.2 Case of Heavy Traffic

In the following discussion, we have used time periods from common sense, which in reality can be changed depending on the ground realities. During the rush hour or peak period, as shown in Figure 4.6, let us suppose that Street1 has heavy traffic. Let us suppose that the flow of Street1 increases to 2 vehicles in 10 sec instead of 15 sec. Then, the number of vehicles is (90/10) * 2, which is equal to 18. In this case the number of vehicle arrivals exceeds the number of vehicle clearance by 3 (18-15 =3 vehicles). Thus, after each complete cycle, three additional vehicles will be waiting at the Traffic Light, which would gradually build up (3, 6, 9, 12, etc.), meaning the congestion will continue building despite having a traffic light system. This is exactly the problem of static traffic light signals which causes traffic congestion.

4.3.3 Proposed Solution by STL (Our Second Scenario)

In times of high volume of traffic arrivals, the system will check the number of vehicles on each street. Let us first look at a different scenario of traffic management with and without STL.

Figure 4.6
Case of rush-hour traffic

CASE 1: Without STL

Street1

The number of vehicles that arrived is (30+30+15)/10) *2 = (75/10) *2=7.5*2=15, while the number of cleared vehicles is 15/6= 2.5 * 3 = 7. The difference between them is 15-7 = 8 >0. Therefore, 8 vehicles will still be waiting because there is a peak-time, which creates a traffic congestion problem.

Street2

The second street has now indicated the red light for 15 sec, therefore,
(15/15)*2 =1 * 2 = 2 >0. Hence, 2 vehicles will be waiting.

Street3

Red light has started from 15 +30 = 45. But as (45/15) *2=3 *2 =6 >0. Hence, 6 vehicles will be waiting

CASE 2: Without STL

Let us first look at different scenarios with STL.

If the number of vehicles in **Street1** is the bigger then others (as is the case under consideration), the system would add extra time of 12 sec to the green signal in Street1. In this case, the complete cycle for **Street 2** or **Street3** will become as follows.

Street2 or **Street3**

90 + 12 = 102 ➔ 102/15 ~=7 ➔ 14 vehicles ➔ 14 -15 = -1 < 0

Thus, we have no traffic congestion problem in this case.

Street1

102/10 ~= 10, which is equal to 20 vehicles, making the Total Green time equal to

42/6=7➔21➔20-21= -1 < 0.

Therefore, the problem is solved, as the balance returns for all streets.

4.3.4 Methods for Counting Vehicles

In this chapter we shall provide algorithms for counting vehicles, which is the backbone of the Smart Traffic Light Management (STL).

We know that traffic lights are part and parcel of our daily life. Despite other options being available, traffic light signals cannot be eliminated because they are easy to install, do not require extra space, and is an economical way of controlling traffic. For these reasons, their use is justified, and so they are a common solution in most countries.

Current practices for smart management of traffic lights predominantly use sensor devices under the road surface to detect the presence of vehicles. In this way, the street which had no vehicle at a cut-off point of time is not given a green signal. It is very logical not to give way to the traffic on a particular street if no vehicle was sensed before the cut-off period. However, this method is not helpful in managing traffic at peak traffic times because it is highly unlikely that any street would be empty for a period of 90 seconds, which could be the minimum time for a complete cycle of traffic lights changing. Instead, streets should be checked for the volume of the traffic on each of them.

A smart way of managing traffic clearance on intersections with the help of traffic lights is to give way to the street with the heavier traffic. This can be done by counting vehicles on each street of an intersection and then automate the traffic according to the count of the number of vehicles on different streets. Let us demonstrate this-with an example. Suppose a Traffic Light is managing the traffic on four streets A, B, C, and D. Let us say that at a given time T_1 the number of vehicles N_A on street A is 36. Similarly let us suppose that $N_{\mathbf{B}}$, = 18, N_C, = 14, and N_D = 7. Accordingly, the street traffic on street A should be cleared first, during which time the count of vehicles is updated. If the updated number of vehicles at time T_2 was $N_{\mathbf{B}}$ = 28, N_C = 34, and N_D = 17, then the traffic of road on C should be cleared. This process should continue in this way. The only thing that needs to be taken care of is not to neglect a low traffic street beyond a set time (no more than the time equal to two misses).

There are several possible scenarios, but we shall discuss only two of them which we deem to be important and applicable for most situations that arise in practice.

4.4 Algorithms to Count Number of Vehicles

The algorithms are coded with a representation of multiple roads with two or more possible ways of traveling on those roads. The algorithms are developed in different scenarios, which are described as follows.

4.4.1 Main Scenario for Managing Traffic Lights

1. Set the maximum time limit, ***Max_Time***, for any street to be facing red signal on the traffic lights. This could be set to 120 or 180 seconds, depending on the circumstances.
2. Take a new image for each street at the intersection in each specific period (say 10, in a real life scenario, this could be dependent on the circumstances).

3. Processing these images by Proposed-Image-Processing-Function to find the number of vehicles in each street (Function: ***Get_Objects_Num***).
4. Compare the number of vehicles on each street to determine the street with the maximum number of vehicles. Let us designate "**A**" to the street which has the maximum number of vehicles.
5. Check if there is any street which has been facing a red signal for the duration of ***Max_Time***.
6. If there is one, illuminate it to green for a limited period (10 seconds, same as the interval for taking new road images) before changing the signal of **A** to green
7. Go to step 4 and repeat steps 5 and 6.

4.4.2 Second Scenario (Additional Requirements)

1. Take a new image for each street at the intersection, after an interval of time (say 10 seconds).
2. Process these images by Proposed-Image-Processing-Function to find the number of vehicles in each street (***Get_Objects_Num*** Function).
3. Compare the result for each street to find the street "A" which has max number of vehicles.
4. If the street with the green light is "A" then
5. Does street A have green signal?
6. If yes, then
7. Is there a street B which has red light for more than ***Max_Time***?
8. If yes, then illuminate the signal of B to green for 10 seconds
9. If there no street with ***Max_Time*** of red signal
10. Illuminate signal for "**A**" to green light for 10 seconds

11. Repeat all steps

4.4.3 Algorithm 1

Input: Query Q // Query of Counting Number of Vehicles on street **A**

Output: Results R[ ] // Number of Vehicles on street **A**

Initialisation: Max_Time = 180; Time_A // Time allowed for green signal for A

Start

1: Step 1: Take new images of all streets

2: Step 2: For each street

Get_Objects_Num // count the number of vehicles on each street

3: Step 3:

IF a red signal is attained Max_Time for Street **S** THEN

    Change the signal to green for **S**

ELSE

    IF Street **A** has the Max_Num of vehicles THEN

        If A has the green signal, THEN

            Extend the time of green signal by 10 sec to A

        ELSE

            IF Change the signal to green for **A** for Time_A

                    // for the duration of Time_A for Street A

            END

        END

    END

END

4: Step 4: Go to Step 1

STOP

4.4.4 Counting Vehicle Function

Let us denote the function used for counting the vehicles as Get_Vehicles_Num. We use image processing to evaluate this function. To be specific, we use Get_Vehicles_Num(t) at a given time, where the format of t can be as complex as desired. For example, t may in the form of a function with four arguments (i.e., date, hour, minutes, seconds). Figure 4.7 shows the steps for the processing number of vehicles on a street.

4.5 Economic Feasibility of the Proposed STL

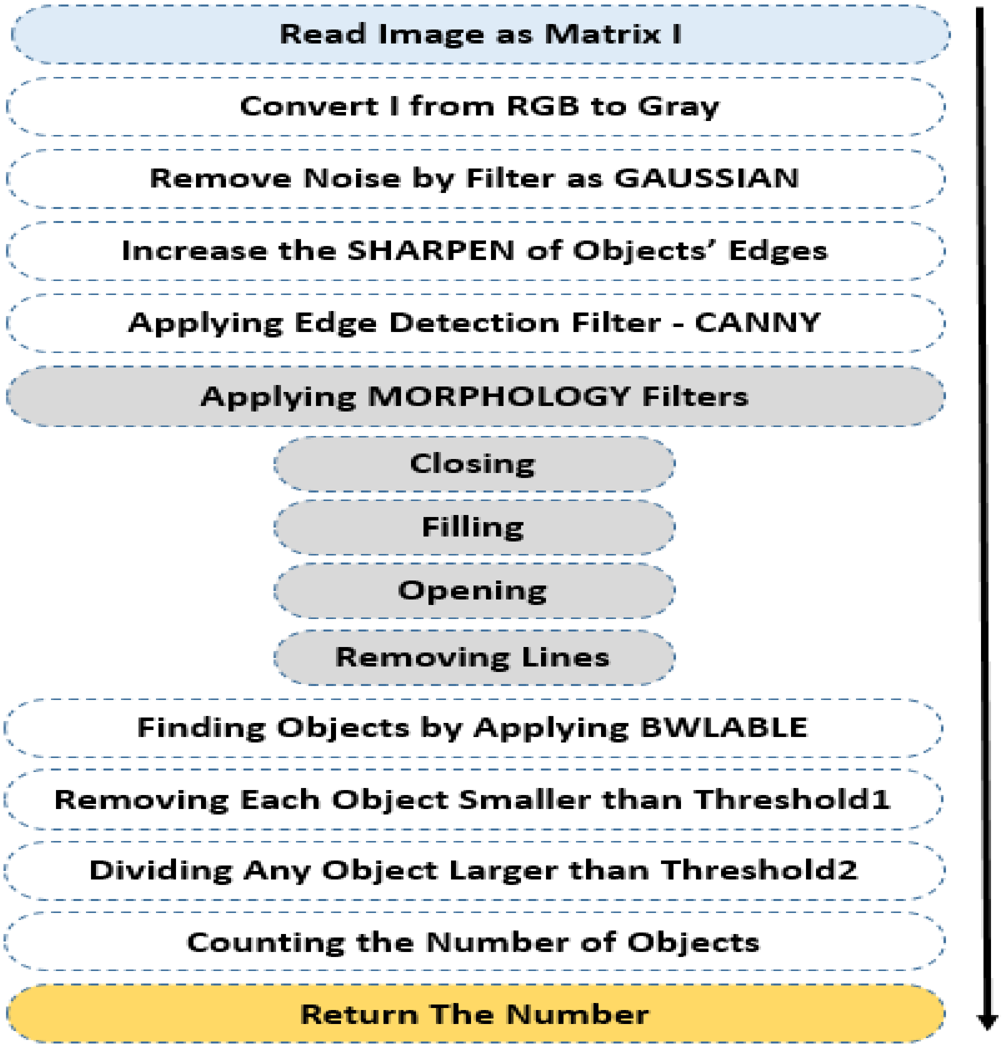
Economic feasibility is a process of gathering information about the project and analysing it to determine the possibility of its implementation, reduce the risks and increase profitability. Therefore, one must know the extent of their success or failure after making an assessment according to the needs of the local market. In our case, there are two kinds of analyses.

4.5.1 Analyses in Two Cases

Here we provide analysis in two cases.

Figure 4.7

Algorithm for counting vehicles: **Get_Vehicles_Num**



4.5.1.1 Case I: Strategic Analysis

In this case, we provide a strategic analysis of reality. The strategic analysis is evolved on the criterion of the market study and basis for acceptance of a technology, idea or product depends on the amount of local and foreign competition. But the traffic related issues are global, as people in all countries suffer from traffic mismanagement or lack of infrastructure or management. Therefore, the solutions proposed in this thesis would be acceptable if they provide the desired solution, which is significantly minimizing traffic congestion.

In terms of competition there are applications that allow communication and exchange of tasks. All other roads need high-cost price or may not be effective because most of them need to be a very big achievement for a time, which differs when it comes to the principle at work algorithm. From a cost perspective, cost is not significant since with our algorithm we need to install only one camera at an intersection within a day or two. From a strategic perspective, this idea can be accepted easily and quickly without problems or barriers.

4.5.1.2 Case II: Financial Analysis

The second case is financial analysis which is about how much the project costs compared to the revenue it generates. The costing provided here is only a rough estimate, which would vary in different regions. However, we estimate that the cost in this case would be low because this system just needs a computer for an administrative employee, Swish Devices, Cables for connection, and the main fingerprint devices with application.

The actual cost for a STL project should not exceed $7000 for one intersection. This includes the cost of camera (PTZ) with high resolution which is around $5000 in addition to implementing the program on the controller with timer, costing around $1000, and the cost of labour and equipment which we estimate to be around $1000. Thus, this is a low-cost solution compared to the alternative idea involving significant infrastructure like a bridge for an overpass/underpass, or a multilevel road, which could cost millions of dollars. Further, expanding the work in a large area will cost much less per unit due to economies of scale. On the benefits side we should include average speed increase and many other benefits related to overall improvements in traffic.

Finally, the project will achieve its goal if it relies on probabilistic methods. They involve appreciation of the success of the project and its ability to continue before the real implementation, which involves referring to previous information.

4.5.2 SWOT Analysis

SWOT analysis is a structured planning matrix used to assess the strengths, weaknesses, opportunities, and threats in a business venture or project (Gürel, 2017). SWOT analysis can be conducted for a person, place, industry, or product. It always involved identifying and describing their objectives as well as identifying internal and external forces that may inhibit or facilitate the achievement of these objectives (Gürel, 2017). The goal of this SWOT analysis is to identify the strengths, weaknesses, opportunities, and threats that may impact the framework established to mitigate transport congestion using various modern technologies including Machine Learning, Internet of Things (IoT), Artificial Intelligence, Wireless Networks, cloud and fog computing, RFID, Sensor Networks and Twitter Analysis.

4.5.2.1 Strengths

These are the characteristics of a project or business venture that gives it an advantage over others. Using this framework presents the following strengths:

1. Integrating modern technologies such as IoT, Big Data, RFID, and Machine learning among others, facilitates increased security and the utilization of resources, leads to sustainable business, and reduced costs, which makes it suitable for any special agency or country. The framework presents these benefits while at the same time providing improved input by increasing privacy and security for road users.

2. The framework leads to significant benefits for both the people and governments in countries it is implemented in because it does not only lead to reduced traffic congestion, but it also fosters economic productivity by reducing time taken on the roads and minimizing traffic-generated accidents.

3. The idea will lead to efficient transportation systems across the world, which will achieve significant benefits and economic opportunities such as reduced transportation costs, improved market accessibility, employment, and additional investments. Transportation is one of the most significant economic activity in logistics because transport cost represents the biggest share in the structure of any country's infrastructure. Therefore, using such a framework that leverages numerous modern technologies will positively impact business in the transport sector leading to a competitive advantage over countries that will not implement it.

4. Using this framework will lead to data standardization, which will in turn lead to improved information exchange and communication between stakeholders. The technologies used will reduce paperwork and provide a standardized communication system that will not only foster effective transport operations involving numerous stakeholders, but also lead to improved integration, coordination and performance.

5. It is easy to implement most ideas provided by the framework such as Smart Traffic Light (STL), deploying drones to take street images, and analyse, update and store street status.

6. Using Machine Learning in this framework makes it easy to manage independent data sources. The framework leads to the generation of extensive data from different independent sources along the transportation path. For instance, data must be collected at every level of the STSM framework including data relating to smart traffic light, and street status. As such, it becomes difficult to process all the incoming data as well as providing proper real time information to effectively support ongoing transport operations. Besides, the framework employs numerous objects of Internet of Things and smart devices in the first two phases, which means that after a period of time a huge amount of data would be accumulated in the cloud. Using Machine

Learning algorithms makes it easier to classify and collect data on traffic congestion according to specific criteria (time, days, road ID, city, locality, area, region, and level of congestion in addition to the reasons of congestion). Consequently, the STMS will enable decision-makers to develop appropriate strategies to mitigate congestion and other problems.

4.5.2.2 Weaknesses

These are characteristics that place the project or the business at a disadvantage against others.

1. High costs associated with Big Data storage and manipulation. Advanced data-processing tools and techniques are required to effectively analyse and utilize data collected at different phases of congestion management. The STMS framework uses Machine Learning, which is expensive.

2. The first phase of the framework, Smart Traffic Light (STL), may be difficult to use in some weather conditions, which may limit the accuracy of the images captured. This inaccuracy may result in errors when calculating the number of vehicles in traffic. However, there are modern methods which can be used in such circumstances to reduce this effect. The idea eases the traffic problem significantly and improves the performance of traffic, but it does not solve the problem completely. Besides, it presents a challenge, such as a high cost of replacing sensors, high maintenance cost and vandalism. Therefore, these challenges cause delays, but on average, they are less severe than the disadvantages of the current system.

4.5.2.3 Opportunities

Opportunities are elements that the project could exploit to its advantage. The following is a list of opportunities offered by the implementation of this framework.

1. The emergence of new and advanced technology including Artificial Intelligence, Machine Learning and Internet of Things presents an opportunity to ease traffic congestion, street management, enhance privacy and ensure security of road users.

2. Integrating modern technology in the framework such as video cameras, Machine Learning algorithms, and electronic road signs presents an opportunity to completely manage and end traffic congestion. This is because research indicates that modern technology is a more effective approach towards managing traffic congestion than constructing more roads.

3. Besides, the emergence of modern technology presents an opportunity for on-road communications to dramatically change how vehicles operate by providing competencies and information for improved, real-time traffic management. The integration of these technologies as recommended by the current framework will transform transportation into a dynamic, interconnected component by creating the city-as-a-system. More importantly, the opportunity they provide to ease movement will have a positive impact on quality of life and economic productivity for everyone involved including local and international businesses.

4. Modern technology integrated in the framework will improve transportation mobility and safety by integrating advanced, wireless communication technologies into vehicles and transport infrastructure. The framework suggests implementing an Intelligence Transport System, which will foster effective information processing and sharing to prevent vehicle collision and

eliminate traffic congestion and all its related environmental impacts. Therefore, the idea also promotes sustainability.

4.5.2.4 Threats

These are elements in the environment that could cause problems for the business or project.

1. Opposition from some beneficiaries of the old system, such as government officials, who refuse to effect change.

2. Network attacks on Intelligence Transport System created by integrating different technologies to manage traffic congestion pose the greatest threat to growing smart transportation systems. Malware is particularly commonly used by cybercriminals to paralyze both private and public sectors including government institutions, logistics sectors and associated infrastructures that depend on communication and connectivity. Therefore, this poses a great threat to the management of traffic using modern technologies.

CHAPTER V - Streets Status Manipulation

Apart from assessing and managing traffic at the intersections, we also need to assess the status of all roads at vulnerable points or sections. For a successful management and regulation of traffic, the status of all the cities of a country should be analysed round the clock, made available through different channels, including social media and updated regularly.

Tracking the status of vulnerable parts of streets and roads is a highly neglected aspect in current traffic management globally, which often results in terrible incidents and accidents. Figure 5.1 shows a massive deadly pile-up of 133 vehicles on an icy highway in Fort Worth, Texas on 11th February 2021, in which 6 people were killed and another 6 were injured (Washington Post, 12th February 2021). Another disaster is shown in Figure 5.2, which occurred on March 12, 2008, which is regarded as the worst ever vehicle pile-up in world history, in which 227 cars and 12 buses collided into one large mess of mangled, burning metal on the Abu Dhabi-Dubai highway (Khaleej Times, 12th March 2008). The crash was blamed on reckless driving in heavy fog, which could have been avoided by status tracking, and creating a detour and warnings to the incoming traffic.

These two disasters could have been avoided if the road status was scanned, especially in extreme heat or cold situations, and proper warning and awareness of the potential hazards on the roads were issued and communicated promptly about the status of the road conditions. Timely information can efficiently be gathered by continuous monitoring of road conditions on venerable points. We strongly advocate monitoring the status of roads and streets at vulnerable sections. The STMS framework is supported by several APIs to update the status of streets in several respects like pollution, accidents, road closures, environmental hazards, and other issues. Details of these APIs are provided below.

Figure 5.1 (Jenkins, 2021)

A pile-up of 133 vehicles on an icy road in Texas on 11th February 2021

Figure 5.2 (Wrecked Exotics, 2008)

A pile-up of 239 in UAE on 12 March 2008

There are several ways to assess and determine the status of streets. In this chapter, the following ways of determining the status will be discussed.

A. LBS Provider: Commercial SBS provider APIs like Google maps colours and other features can be integrated with our system.

B. Drones: If required and feasible, drones can be deployed to take images of streets, to analyse, update and store street status. Captured images can be processed by image processing algorithms discussed earlier.

C. Tweet Analysis. We can use text mining to analyse tweets and gain relevant information about status and events of streets. This is a faster way to get news around.

D. Mobile App: For several reasons, we need to have our own APIs to update street status and events associated with traffic movement.

Next, these methods are discussed in detail.

5.1 Location Based Services APIs

Our framework can be integrated to use Location Based Services (LBS) like Google Maps to update the status of different streets. Several home-grown APIs can be used in conjunction with commercially available solutions.

5.2 Drones and Remote Image Method

In this method, drones (Figure 5.3) can be deployed to take random screenshots and movement clips of traffic on selected streets. These picture frames can be processed by image processing to determine the status and subsequently make it available to road users. Also, image processing can be used for assessing the traffic conditions and congestion at desirable points or sections of some roads. It is worth mentioning that Saudi Arabia has started to use drones for surveillance and monitoring roads during Hajj to avoid help reduce congestion and help manage accidents and violations.

Figure 5.3

Drones in use for Traffic Management

5.1 Tweet Analysis (Text Mining) Method

Tweet Analysis is an important component in our Proposed Architecture for Smart Traffic Light (STL). By analysing tweets, we can provide street by street status of the city roads, not covered by STL (Figure 5.4). Next, we look at all the details of this method.

In our proposed model STMS, especially in level two, we seek to deal with an overall status of traffic in the main streets and city, not focusing only on the cross-sections and traffic lights as shown in level one. Firstly, we propose a mobile application to enable users themselves to report the status of streets and alert other abnormal events like accidents, a storm, rain, high winds, snow, fire, and damage from events like a tsunami or an earthquake.

Figure 5.4 (Iscan, 2019)

Status of free moving segments of street

Recently, the IoT objects, GPS services, Smart Devices, and Social Media have become important resource for data and information (Atzori et al., 2010). In the present context, we focus on social media and specifically twitter to provide up-to-date road status and conditions. Twitter is now considered as the most appropriate social medium to provide short and concise messages on current news and events in real time. However, there are two challenges for dealing with the kind of data associated with traffic and roads, namely variety and size. There are privacy issues associated with this kind of data, which we shall discuss in Chapter VIII. To overcome the challenge of the size, we need cloud resources, while for the variety challenge, we propose a classification algorithm, based on text mining and natural language processing (NLP).

The main goal of the proposed classification algorithm is, in phase 1, to classify tweets and auto-detect those that are related to ~~the~~ transportation or traffic issues in a specific city, street or district. Then, in phase two, the algorithm is designed to detect the abnormal events and report them.

5.2.1 Phase One

In this phase we determine the relevance of tweets related to road congestion, safety, security, hazards, pollution etc.

1. Collect the tweets from twitter by using Twitter-API. This provides 100 tweets in each request, so it needs time to collect a big number of tweets to deal with them. There is another option to work on an existing Filter the previous collection to save what is only related to Saudi Arabia and is written in English (in Future extensions we will deal with Arabic tweets with suitable modifications)
2. Remove the repeated tweets to reduce the total volume.
3. Pre-Process each tweet in the collection. This step has many sub steps, which are:
    1. Clean the text from the special characters, punctuation marks, other languages characters, numbers, etc. and replace them with a blank space.
    2. Tokenize the tweet to list of tokens at every blank space.
    3. Remove stop words which do not affect the classifying result because they do not have bias to specific class (like the, a, an, in, on, they, I, have, will, etc..) where in each language there is list of these words, and the developer can edit this list. In our algorithm we depend on the list of the NLTK library.
    4. Normalize when dealing with Arabic language text when there are many similar characters for the same work as using "ى" or "ا" and "ة" or "ه" etc.

4. Stemmer which returns the word to the root by removing some characters from the prefix of term or suffix. We use Porter Algorithm for this step which is considered the best for English.

The importance of this step is that it reduces the size of index and number of different words or terms by more than 60% compared to the original text. However, there is a disadvantage with stemmer step, where some results of words will not be in the dictionary. So, another solution, as discussed below, can rely on a specific dictionary for stemming, although this usually needs need more time in the processing level.

There are a number of methods of selection and reduction, and the features which would be inputs for the model of ML. So there is a method which uses all available features, however other methods remove some of these features which can adversely affect accuracy of the model. To arrive a t a conclusion, many of experiments have to be used, out of the results, most accurate is selected. Here we use these methods:

a) The first scenario depends on machine learning and finds the features of each tweet by calculating the TF-IDF factor for each term (IDF refers to the number of all tweets that contain term T dividing on the total number of tweets). Then, any method or algorithm of machine learning (ML) can be used, (Liner Regression, Logistic Regression, Support Vector Machine, Decision Tree, etc.). The most appropriate method can be selected as the one that provides the best accuracy on the training and testing groups. The process cannot be automated in its entirety. Some work still needs to be manual, where the user must classify the training set of tweets to enable the selected model to learn from them.
b) The second scenario relies on DMOS dictionary which classifies millions of web pages by thousands of special editors contributed by many classes. We use this dictionary to count the number of words related to transport and if the number is greater than the threshold value the tweet will be classified in this class.
c) The third method is applied before the stemmer to find the position of speech (POS) for each term in the tweet. In this case we can focus only on the names and resources and then then we can measure the percentage of similarity with the

transportation root in WORDNET Tree in NLTK. If the calculating value is greater than the threshold then the tweet will be in this class.

Normally, we opt for the second method because it does not need any interference by a human; it is easier and faster and provides good accuracy.

5.2.2 Phase Two of Proposed Algorithm

In this phase, we classify categories into problems and try to mitigate them and assist the road users with this information

We propose an algorithm to detect abnormal events. In this phase we will deal only with the tweets that have been classified in the transport class.

1. We create a list of terms for different kinds of events. Our list of terms is related to congestion or stopping traffic in a street or similar area which contains terms like "Accident", "Police checkpoint", "Traffic Stop", "Congestion", "Fire", "Heavy Rain", and "fixing works".
2. Check if the number of tweets that have one of the previous terms is greater than a threshold value, which means that there is an issue in this area or street. The system will then notify the drivers in other areas to avoid heading towards that congested area. This will certainly reduce the size of the problem and prevent it from further deteriorating, while at the same time helping to deal with the problem as quickly as possible.

Here, we can also use Machine Learning (ML) models to learn about the tweets that have abnormal issues as well as those that have the IDF feature.

5.2.3 Testing the Proposed Algorithm

We will use a statistical method depending on Precision, Recall, Accuracy, and F-Score metrics taking into consideration the use of (+) for right classification and (-) for error. We shall return to these issues later.

Precision metric refers to the number of true positives, that is, the number of items correctly labelled as belonging to the positive class, divided by the total number of elements belonging to the positive class. Essentially, it is the sum of true positives and false positives. Recall is a metric used to quantify the number of correct positive predictions made from all positive predictions that could have been made. Recall defers from precision because it provides an indication of missed positive predictions. Accuracy metric is the measure of correct predictions of the classifier compared to the overall data points. Basically, it is the ratio of the units of correct predictions and total number of predictions made by the classifiers. The F-score metric combines the model’s precision and recall, which is then defined as the consonant mean of the model's precision and recall.

5.2.4 Final Visualization

We must provide the result as a chart for the decision maker or observer of the street status to make the right decision in RT.

5.2.4.1 Note

For tweet location, some tweets have accurate location (latitude and longitude), however, if the end user has disabled GPS, then we will use the name of place or street that is mentioned in the tweet by using a bi-gram tool and searching for “Street, Area, District, and City” terms.

5.2.4.2 Note

This algorithm will be with our Street Status App in addition to the reports of LBS API like Google Maps to enhance the accuracy of the decision. Moreover, in some cases, we can use drones to get a remote image of the hot area to obtain more accurate information.

5.2.5 Main Algorithm Pseudo Code – Tweets Analysis

```
Tweets = Get_Tweets();
//Preprocessing Phase
Terms = [] ; // initial list for terms after preprocessing phase
Foreach Tweet in Tweets Do:
        //Cleaning
        Tweet1= Tweet.Replace("Special Character" , "  ");
        // repeat this line according to the Characters
        //Tokenizing
        Tweet_Words= Tweet1.Split("  ");
        //convert tweet to vector of words according to the Space char
        //Remove Stop Words
        StopWordList= NLTK.Get_Stopwor(Lang=En);
        //Prepare the list of English stop words based NLTK
        StopWordList.add (I can add any term as stop word to the previous list); // Optional
        Foreach word in Tweet_Words Do:
                If StopWordList.Contain (word) Then
                        Tweet_Words.Remove(Word Index) // Remove
                Else
                //Stemmer
                        Term = NLTK.PorterStemmer( Tweet_Words(Word Index) );
                        Terms.Add (Term);  // create vector of terms after preprocessing
phase
        End Foreach
        // First Classification Phase, There are three options here
        Class = ML_Method(Terms);
        Class = DMOZ_Method(Terms);
        Class = WORDNET_Method(Terms);
        If Class = "Traffic" Then
                //Start Second Classification Phase
                Keywords = Get_Initial_Keywords_Of_Traffic();
                //Expert will initial this list according to Traffic tweets same Stemmer on it
                Count =0;
                Foreach term in Terms Do:
                        If Keywords.Contain(term) Then //matching
                        Count++;
                End Foreach
                Percentage_of_Matching = Count / Terms.Length();
                If Percentage_of_Matching > Threshold Then
                Add This Tweet to Sub_Class_of_Traffic (Class1++)
                // example Class1 for Accident
End Foreach
If Class1.Count > Threshed2 Then
        Send_Alert ()
```

5.2.6 Machine Learning Method (Tweet Terms)

```
//Training Phase
url = "Tweets_DataSet.txt"
Inputs = ['Feature1', Feature2', 'Class']
// Class Traffic or Not
// Feature1 is IDF, Feature2 is Tweet Length
dataset = pd.read_csv(url, names=Inputs) // Read
print(dataset.describe()) // Print Some Info about Data
array = dataset.values // Get All Data As Table
//Split the Data to Features and Class
X = array[:,0:2] # All rows of cols (start from 0 to 2-1)
Y = array[:,2] # All rows of the col 3
// Split Data 80% for Training and 20% for Testing
x_train, x_test, y_train, y_test = model_selection.train_test_split(X, Y,
test_size=0.2)
// Select the Best ML Model / Algorithm
// K Nearest Neighbors, VSM, Random Forest, LG Regression etc.
model = KNeighborsClassifier()
model = SVM()
model = RandomForestClassifier(n_estimators=5)
model = LogisticRegression()

// Apply Training
model.fit(x_train,y_train)
predictions = model.predict(x_test)

// Apply Testing
print('KNN',accuracy_score(y_test, predictions))
// Select the Model of the Best Accuracy
// Call The Model for any new tweet after calculate Feature 1 and Feature 2
Res=model.predict([[F1,F2]]);
        Return Res[0]// End Result
```

Remark:-For Calculating Feature 1, we used the product IDF*TF, where TF(t) is the Number of times term t appears in a doc divided by the total number of terms in the doc, and IDF(t) is the (natural) logarithm of the ratio of the total number of docs over the number of docs containing term t.

5.2.6.1 Note

All the information will be stored with temporal and special databases and use it in the third level of our solution (ML on the stored permanent data for last month or year) to-detect new knowledge and make recommendations to enhance the quality of the transportation system.

5.2.7 DMOZ Method (Tweet Terms)

```
Foreach Term in Terms Do:
        Count = 0;
        Classes = DMOZ_Search (Term); // Get the Top Five Classes For Selected
Term
        If Classes.Contain("Traffic") Then
                Count ++;
End Foreach
Return Count/Terms.Length
```

5.2.8 WORDNET Method (Tweet Terms)

```
Foreach Term in Terms Do:
        Count = 0;
        // Calculate the Similarity according to distance from the matching father in
the WorldNet Dictionary Tree
        Sim = WN_Get_Similarity (Term, "Traffic");
        If Sim > Threshold Then
                Count ++;
End Foreach
Return Count/Terms.Length
```

CHAPTER VI - Analysing Traffic Data with Machine Learning

At the first and second levels of the STMS which deal with smart traffic light and Street status, many technologies and applications are used to contribute to the objective of reducing congestion and managing roads efficiently. In particular, we employ many objects of Internet of Things and smart devices. This means that after a period of time a huge amount of data would be accumulated in the cloud. This data will prove to be very useful and critical for improvements and efficient management of roads. From this (historical) data, we can get valuable information and knowledge, which can have a significant impact on improving the level of services and supporting the choices of the traffic decision makers. This data should be classified as Big Data, and appropriate Big Data analytics should be employed to process it. Here we propose a processing mechanism, in addition to applying many existing data science mechanisms and models, such as machine learning and data mining. Since we are extensively using machine learning techniques in STL and other solutions, it is natural and efficient to use it for analytical purposes as when feasible and advantageous.

6.1 Main Objectives of using Machine Learning for Data Analytics

Our main objectives in this chapter are as follows:

A. Apply Machine Learning algorithms in order to classify and collect data on traffic congestion according to specific criteria (time, days, road ID, city, locality, area, region, and level of congestion in addition to the reasons of congestion). In this way, the STMS would enable the decision-makers to develop appropriate strategies to mitigate congestion and other problems.

B. Apply Machine Learning algorithms in order to classify and predict the rate of congestion at a given place and area in future dates and take steps to resolve the imminent congestion and ensuing issues.
C. Apply Data Mining algorithms to gain valuable information about accidents, detect relations between the most common causes of accidents and discover new knowledge about these accidents. The information which will be collected may include the main cause of accident, correlation with gender, nationality, car type/model, road condition, level of crowding/congestion, age, and day and time of accident with accident rate.

The above information will be helpful in modelling and simulation work to determine the effectiveness or impact of certain policies in dealing with congestions or accidents.

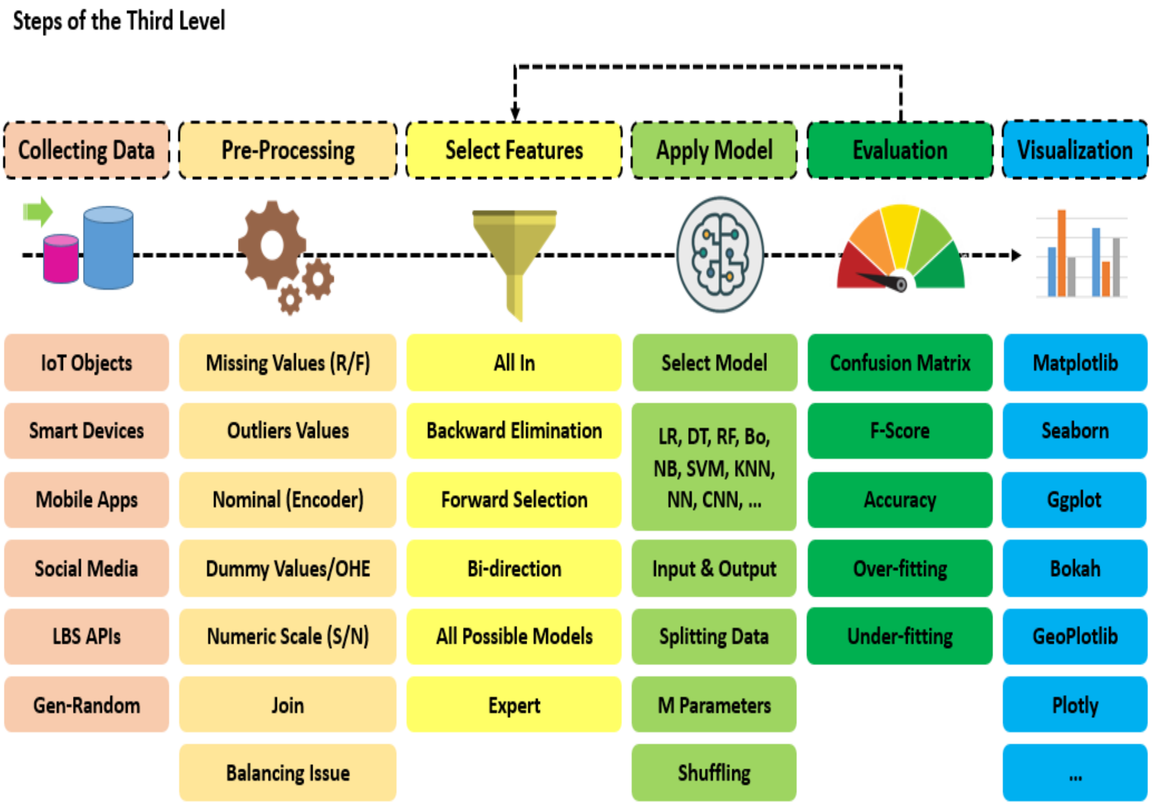
6.2 A Model for Data Mining

To achieve the goal of getting valuable information from the historical data, we proposed the following model which has a set of main steps and a number of subsidiary steps:

6.2.1 First Step in Data Collection

Our first data set will be formed from the data obtained from the applications and tools used in the first and second levels of the proposed STMS, the majority of which measure the level of congestion at specific times and places. The second dataset will be formed from the accident data already collected in a database registered with government agencies. The traffic management will work on this data to improve road conditions to prevent further accidents on the same locations. The details of the data to be collected are as follows.

Figure 6.1
Steps for Data Collection in Third Level



a) The data which arrive in the STMS cloud from the WSNs, is initially collected within the cache in the fog node and then sent periodically to the cloud to be stored in the database permanently. The data format will be as shown in the following table:

Street ID	Longitude	Latitude	Vehicles Number	Time	Date	Crowd Rate

It should be noted that the congestion rate will be divided into four main categories, namely normal, medium traffic, heavy traffic, closed.

b) The data which is collected from smart traffic lights (if the cameras are used on behalf of the wireless network sensors) will be in the same format as described above.

c) Data which is obtained from the proposed mobile applications for finding out the street status will be in the following format.

Street Name	Longitude	Latitude	Time	Date	Reason

The causes of congestion will be divided into several categories like schools, personnel, checkpoints, weather conditions, excavations and maintenance, and accidents.

d) The data which is provided by the LBS APIs such as Google Maps, would be read periodically by a special application and will be organized as follows.

Street ID	Longitude	Latitude	Time	Date	Crowd Rate

Also, the congestion rate would be divided into four main categories according to colour being natural green, medium orange, intense red, or dark red.

e) Finally, the data coming from the analysis of the tweets will be organized as follows

Street Name	Longitude	Latitude	Time	Date	Reason

Note: This data is important because it relates to our idea suggested in our STMS framework.

We will merge all this data into one database to enhance its reliability and make it ready to integrate. This data would reduce the volume of information depending on the mapping in location, time and date. This data will be organised as follows:

Street Name	Street ID	Longitude	Latitude	Time	Date	Day	Name	Crowd Rate	Reason

Note: The accident data would look like:

City	Street	Lon	Lat	Time	Date	Day	Accident Kind	Reason	Vehicle 1 Type	Vehicle 1 Model	Vehicle 2 Type	Vehicle 2 Model	Gender 1	Gender 2	National 1	National 2

6.2.2 Second Step for Data Processing and Cleansing

This step contains several sub-steps, namely:

a) Processing empty values, usually by either deleting the entire record or by replacing the empty value with the mean or median of other records' values to make the data complete.

b) Outliers are treated in the same, i.e., they are deleted or replaced by the mean or median value of the other records to isolate their negative impact on the accuracy of the results and learning.

c) Converting nominal or categorical data into numbers to enable the machine to deal with it automatically. For example, the level of crowding will be expressed by numerical values from 1 to 4, with number 4 being the highest crowded. Usually Scaling is done after this process so that the value of each column is recorded between 0 and 1 and also, like the previous case, the column is divided into four columns (normal, medium, heavy, closed) so that the values in each column are either 0 or 1.

d) Usually, One Hot Encoder algorithm is used to handle cases requiring the deletion of data or the introduction of dummy values in the database. For example, after coding the column for the congestion rate, one of the previous four columns can be deleted because it is possible to deduce its value from the remaining information, for example, if the medium, heavy, and closed values are equal to 0, this means that the normal is 1 and there is no need to store this in the database.

e) Processing digital data to lie in the field [-1,1]. Here we can use one of two methods: Normalization or Standardization, defined as follows:

   1. N = [X – Min (x)]/[Max(x) – Min(x)]

   2. S = [X – Mean(x)]/Std(x)

f) Merging or deleting similar data to prevent duplication if they almost coincide.

g) Ensure that data is balanced so that the value of each class of the output variable classes (crowding rate here) is close to the number of other class records as far as possible. Some records may need to be duplicated in small categories or some records deleted in large categories.

6.2.3 Third Step - Feature Selection

Here, we can use several standard methods to determine which features are most influential or most important. There are a number of methods of selection and reduction, and the features which would be inputs for the model of ML. So there is a method which uses all the available features, however other methods remove some of these features which can adversely affect accuracy of the model. To arrive at a conclusion, many experiments have to be used and out of the results, the most accurate is selected. The following procedure can be followed:

a) Choose all features.

b) Use the Backward Elimination technique.

c) Use the Forward Selection technique.

d) Use both the previous two techniques together.

e) Use all possible situations (this is the best choice but requires a lot of resources and time).

f) Hire an expert to determine which features are most influential.

6.2.4 Fourth Step – Selection of Machine Learning Model

Here we use most popular machine learning algorithms which are widely reported in the literature. This step is known as the Algorithm step. We provide two examples.

Example 1: For Classification we can use Linear Regression, Logistic Regression, Decision Tree, Random Forest, Boost, Naïve Bayes, Support Vector Machine, K-Nearest Neighbour, Neural Network, and Deep Learning algorithms.

Example 2: For Clustering, we can use K-Means, Principal Component Analysis, and Singular Value Decomposition algorithms.

Note for Example 2. It should be noted that the purpose of the model is to determine the number K of clusters. We have noted earlier that in our research we have only mentioned the importance of using the ML models like clustering algorithms. We have provided a summary of how to collect data in the future from our framework in a cloud layer (minimum number will be 2) and the expert can try and check the results where clustering is unsupervised models.

6.2.5 Fifth Step - Evaluation

Here, we rely on famous metrics such as Confusion Matrix, F-Score, Accuracy, Performance, Precession, and Recall, for comparison and evaluation [18].

a) Also, at this step, and after testing the results on new data, we would discover whether or not the best model suffers from over-fitting. In other words, was the model over-trained on the data and thus provided good results on the training data, but the results changed significantly when applied to new real data.

b) In the case of all the models, did the analysis result in low levels of accuracy, poor training low performance and under scoring? In this case, the trained data must either be reviewed or increased, or the features chosen be reconsidered.

6.2.6 Sixth Step - Visualization

The results will be displayed graphically and with several charts depending on several offices, as shown in the figure 6.1.

CHAPTER VII - Assistant Applications and Services

Traffic problems cannot be solved by fixing one issue. Our aim in this study has been to suggest solutions to all individual issues and link them together in the STMS framework to provide a comprehensive solution to the problems associated with traffic. As is evident, the STMS paves the way for many adaptive and smart services in addition to many smart applications which also can help directly and indirectly in addressing almost all issues of traffic and providing smart transportation. Let us describe some of the services and applications which are part of the solution.

7.1 Safety Mechanisms

Here we provide some helpful safety mechanisms which can be used in case of need.

7.1.1 Places of Interest

Often people need to know some places of interest. Different countries and regions have different facilities and how they can be accessed not only depends on the geographic situation but also other aspects like culture. Another issue is that of the privacy of the user in the process of accessing particular information from an LBS server. For example, Google maps neither provides all of the services in a particular region, nor can be trusted to protect the privacy of the user. A service provider may also not take sensitivity, culture and religion of a particular region into consideration. Lastly, a particular service provider may not be permitted to operate in a particular region due to political, cultural or social differences. So, additional APIs are needed to link to the special services available in a particular region.

With a home-grown system, which has in-built privacy and security controls, a user can search for any of Place of Interest (PoI), without worrying about their privacy. This can be achieved by means of system provided API. Information about markets and their goods and offers in the vicinity of the street can also be linked to this API. So, if the user needs anything, they can access the place of interest. Petrol stations, shopping malls, restaurants, and tyre services are some of the common needs of road users. Special offer notifications may be regulated through the API.

7.1.2 Additional Safety for Road Users

On some roads, inside as well as outside metropolitan areas, some occasional hazards can be seen. For example, roads being crossed by camels in the middle east, abundant kangaroos crossing Australian roads, cows roaming through Indian city roads, the presence of other domestic and wild animals on roads, forest fires along the road, flooding, and uprooted trees on the side of the road are some other examples of traffic hazards. Often, traffic management is slow in identifying these kinds of issues, let alone fixing the problems. These hazards not only slow down traffic, but also contribute to some serious accidents resulting in deaths, injuries and loss of property. These incidents are also the cause of road closures prompting serious congestion. The traffic management should install cameras at vulnerable sections of some roads and highways, which are prone to hazards, to monitor the conditions. In this case too, like in the Smart Traffic Light, image processing and fog nodes can be used for surveillance of the road condition.

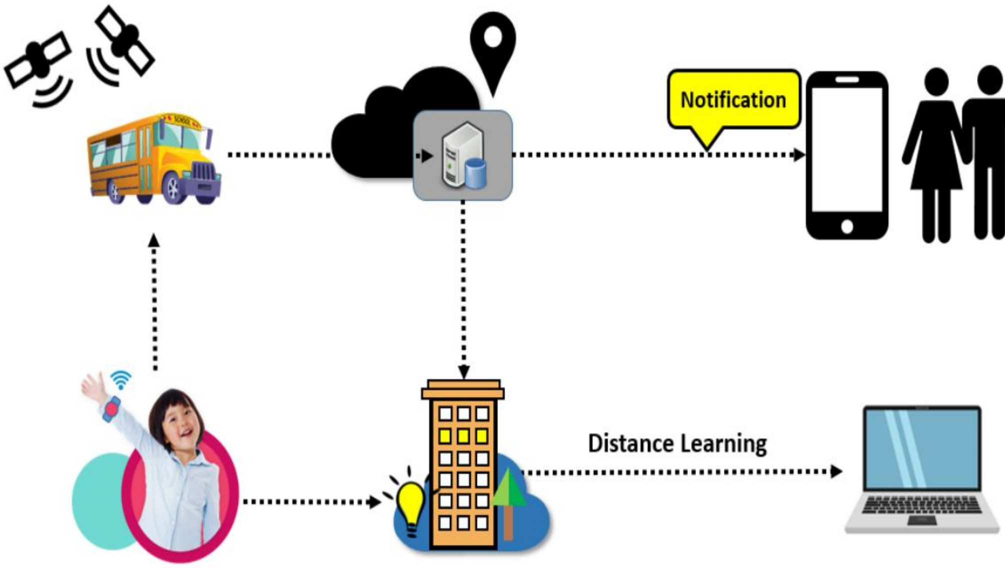
7.1.3 Public Transportation

Problematically, congestion is more severe in peak hours when school children, college students, trade individuals and market worker’s commute. Different countries have different ways to deal with peak time congestion. Some of them allocate more clearance time for the traffic heading towards educational institutes, business parks and other places of work. Others provide dedicated lanes for buses and cars carrying more than two or three persons. But these solutions are not enough to solve the problem of peak time traffic. These classes of commuters should be encouraged to use public transport. This method will help to relax traffic issues in peak time, especially if it is used by schools and students, or by companies and employees.

One of the reasons for the lack of popularity of public transport, in many countries, is the non-availability of instant, accurate and credible information about public transport. As part of STMS, IoT with Fog nodes can be used to provide more features to encourage peak-time travellers to use public transportation. For example, parents can track the school bus or normal bus of its movement so to be there right on time and avoid unnecessary waiting, sometime in unfavourable weather (rain, snow, humidity and heat). More information on this aspect can be found in Bahbouh et al., (2019) as shown in Fig 7.1. Similarly, employees can track their bus or metro train to save wait time, and effort. Moreover, school management and business owners can also track their students or employees. This system can also be used as an attendance system, removing the need for a head count.

Figure 7.1

Monitoring School Bus Movement



7.1.4 Smart Parking (Online Parking)

One of the contributory factors for the congestion in and around city areas is the mismanagement of parking. Most countries do not provide abundant parking facilities. Often, the available parking spaces are less than the demand for parking. One difficult problem is to correctly estimate how many parking slots would be sufficient. Many cities provide multi-level carparks in congested areas such as city centres. Instead of vehicles, in this section, we shall deal with cars as Smart Parking is usually meant for cars, although it may also allow two wheelers. Smart Parking is also referred to as a Smart Carpark.

A usual tendency of vehicle drivers is to find a parking slot close to their place of their interest. This can create significant congestion. As a result, vehicles roam from one carpark to another and sometime end up doing this exercise for half an hour or so. In all the developed countries of the world there is great attention to the problem of traffic and organizing the streets and reducing traffic as much as possible. All the developed countries have a focus on saving time because it means more comfort and welfare for citizens. Many researchers have contributed new ideas in the field of traffic development, such as the study of the streets, crowding, building bridges and tunnels.

As commented earlier, congestion and other issues can be solved satisfactorily only by providing a compressive solution to the traffic problems. One of the contributory factors of congestion in and around town centres is poor and inadequate parking. Once the adequate and well managed facilities are provided, the vehicles roaming in and around these areas would disappear. This would reduce the congestion, which would also save some precious time, fuel and reduce fuel emission reducing the impact on pollution.

Smart Parking provides a web-based application for booking a parking space for a vehicle (usually a car), prior to coming to the carpark. In this way, only the cars with prior booking would be allowed to enter the carpark. In other words, vehicle drivers or owners must make online booking to access the carpark. Parking charge for the duration of the parking must be paid at the time of the online booking. While the car was in the carpark, the duration may be extended online by advanced payment, subject to the availability of the space. Time management for claiming the space and cancellations can also be regulated. This type of carpark will stop people trying to find a parking space in different car parks. In the next chapter (VIII), we shall provide full details of the Smart Parking System.

Chapter VIII - Web-based Smart Parking System

Smart cities are providing many innovative applications for citizens. As a result, millions of smart services and applications have changed many of our lifestyles for the better in various fields such as transportation, health, education, services, business, and others. However, users want more of these services that make their lives easier and more sophisticated. Here we introduce Web-based Framework for Smart Parking System, and simply call it Smart Parking System (SMP), which could also be termed as online parking. The SMP is one of the most highly desirable solutions to reduce the congestion in and around town centres. Using IoT technologies and artificial intelligence algorithms, and other related tools and technologies, we present a Web-based Framework for Smart Parking System. As the parking in some streets and vital places in cities is an important factor in traffic congestion, the proposed framework would go a long way to reduce the congestion in city centres, especially in peak hours. The framework also demonstrates the usage of an intelligent system to solve this problem by enabling an automatic pre-reservation process, for vacant positions in the parking place, by users before reaching the venue. This can be readjusted by a process based on automatic detection of the composite plate using a proposed web application based on the OCR algorithm. The application has been implemented to confirm the ease of applying this system in some streets of the Kingdom of Saudi Arabia to reduce traffic congestion and improve the level of transport sector services as well as the level of safety of citizens.

8.1 Efficiency & Effectiveness of Smart Parking System

The Internet of things plays a big role in enhancing smart city services and making them smarter and more available (Agrahari & Singh, 2020). The most recent of these services are those related to traffic problems, organizing streets, and reducing congestion (Lanza et al., 2016). Numerous developed countries are interested in saving time and reducing pollution because it corresponds to more comfort, well-being, and health for citizens (Farid et al., 2021). Therefore, there have been many contributions and ideas in the field of traffic development, such as studying streets, crowding, building bridges, tunnels, and others (Elkin & Vyatkin, 2020, Lalitha & Pounambal, 2020). One effective way to improve traffic is to pay attention to the parking and organize its functionality (Karami & Kashef, 2020).

One of the factors that contributes to congestion in and around the city is parking mismanagement. Many countries do not provide a lot of parking facilities. Usually, the number of car parking is not enough, and knowing the appropriate number of car parks required is a challenge (Shen et al., 2020). Many cities provide multi-level parking in important places (Yee & Kasim, 2020).

Finding rush hour parking, especially for late arrivals, can be a daunting task. This forces many vehicles to drive around in search of a parking space. This contributes to increased congestion and more traffic management complexities. Some statistics indicate that 37% of drivers spend more than 10 minutes searching for parking spaces in city centres during peak times. Moreover, 34% would resort to parking in illegal places, exposing themselves to violations and causing more complications and traffic problems (Lin et al., 2017, Geng & Cassandras, 2012).

Despite allocating 31% of the central places for parking in some cities, many drivers reconsider their trips due to this problem. Smart car parking may be an effective solution to this problem, which can provide many advantages, the most important of which according to (Geng & Cassandras, 2012, Hassoune et al., 2016, Al-Turjman & Malekloo, 2019) are:

- Saving time and effort
- Reducing traffic congestion
- Reducing environmental pollution
- Reducing fuel consumption costs
- Reducing the problems of parking in illegal places
- Providing additional economic and investment income
- Supporting the general trend towards mass transit

- Providing special places for people with special needs and supporting them.

8.2 A Historical Perspective of Smart Parking System

Usually, the development of smart parking systems requires the integration of several basic components, which are: the infrastructure, the software system, data sensors for vacant positions, and finally, studying of parking and driver behaviour. In addition, it requires the availability of many tasks, the most important of which are: directing drivers to vacant positions, organizing parking, the reservation process, dynamic pricing and the payment process, reporting, forecasting, and others (Lin et al., 2017, Polycarpou et al., 2013).

All the above indicates that managing smart parking is not an easy thing, and therefore we find many different solutions that were previously presented in this area. Lin et al., (2017) presented a classification of solutions in the field of parking during the period of 2000 to 2016, in addition to presenting a general definition of the main tasks of developing smart car parks. Generally, these solutions can be classified into main categories according to the technology used, such as RFID, WSNs, GPS, Smart Phone Apps, and each category contains many different methods as well (Yamin et al., 2018).

Khanna & Anand (2016) have suggested relying on IoT by employing network sensors to read vacant positions and alert nearby vehicles via the Android app. Others use roadside sensors or lighting sensors to facilitate detection of parking conditions and thus increase revenues for those associated with specific wages. Research in Perković et al., (2020) has used a different type of sensor that detects large metal objects with the suggestion of using batteries that last for long periods to save energy consumption in smart car parks. Traffic management, suggested in Pala & Inanc (2007) and Lee et al., (2016), have relied on RFID to calculate the arrival and departure time quickly, but this is intended for specific people and vehicles equipped with an RFID-TAG so that the gate can open automatically for them.

Kianpisheh et al., (2012) used ultrasonic network sensors to track vacant places as well and display them to drivers within the system. It also presented the idea to use cameras for the same purpose of tracking vacant places. Thangam et al., (2018) went further and used the camera to recognize faces, thus allocating parking spaces to specific people only, not to the public. Traffic management, discussed in Polycarpou et al., (2013)., have relied on a software part only through a smartphone application based on the Crowd-Sensing concept so that the drivers themselves cooperate in the exchange of information about the state of the parking. To facilitate the previous process, Lu et al., (2009) proposed relying on Connected Vehicles equipped with a GPS tracker.

Some other researches were concerned with issues of providing special places for people with needs, such as in (Lanza et al., 2016), and others were concerned with the issue of calculating parking time and the payment process as in the research of Vakula & Kolli (2017), who employed a QR code on automatic gates in order to calculate entry and exit times without the need for physical materials, as in Wang & He (2011), which is based on the Park-Meter to calculate the parking time of the vehicles. Also, Kuran et al., (2015) suggested utilizing parking as charging stations for electric vehicles at the same time.

We note from the foregoing the great diversity of proposed solutions. To excel on these solutions, we propose a hybrid model based on the integration of several ideas, where cameras can be used to identify the vehicle through an automatic detection algorithm for the plate number, in addition to a software system to track the number of available parking spaces by managing the parking positions when a vehicle enters or exits. Finally, the system provides an application to pre-book parking by completing the payment process electronically while determining the exact location of the parking through the GPS service. All the above will provide more services and features for the proposed idea to prove its distinction from the previous ideas. The proposed system will be explained in detail in the next section.

8.3 Working of Smart Parking System

Here we discuss how we can automate the car parking system. In the proposed framework, we shall demonstrate that the proposed system is immensely helpful in addressing and resolving traffic issues directly or indirectly. The SPS provides a smart parking framework coupled with an app to scan the parking facilities for the possible vacancies.

Smart Parking provides a web-based application for booking a vehicle (usually a car) parking space prior to coming to the carpark. In this, only a car which has had a prior booking from a chosen starting time will be allowed to enter the carpark, within up to half an hour of the starting time. In other words, vehicle drivers or owners can make online bookings any time prior to arriving at the carpark and can be allowed to enter the parking complex up to half an hour before the starting entry time. The driver will depend on the **map** in the system to select a suitable parking space, while the driver can also use the map to reach their allocated parking spot or to find their car when leaving. The parking charge for the duration of the parking must be paid at the time of the online booking. While the car is in the parking complex, the duration may be extended online by making an advanced payment, subject to the availability of the space.

Smart Carpark consists of auto gates for vehicles to facilitate entry to the carpark, as shown in Figures 8.1 and 8.2. The main gate is an auto gate which has a camera to capture the image of the registration number plate located in the front of the vehicle. The number plate captured by the camera is instantly processed, usually by the image processing of the STMS to determine the booking details. Once the booking and currency are confirmed, the system allocates a parking slot to the vehicle, and assigns a gate number to enter from. Then the auto gate opens and directs the vehicle to the assigned gate to facilitate the vehicle to reach its parking slot, whose opening is

Figure 8.1

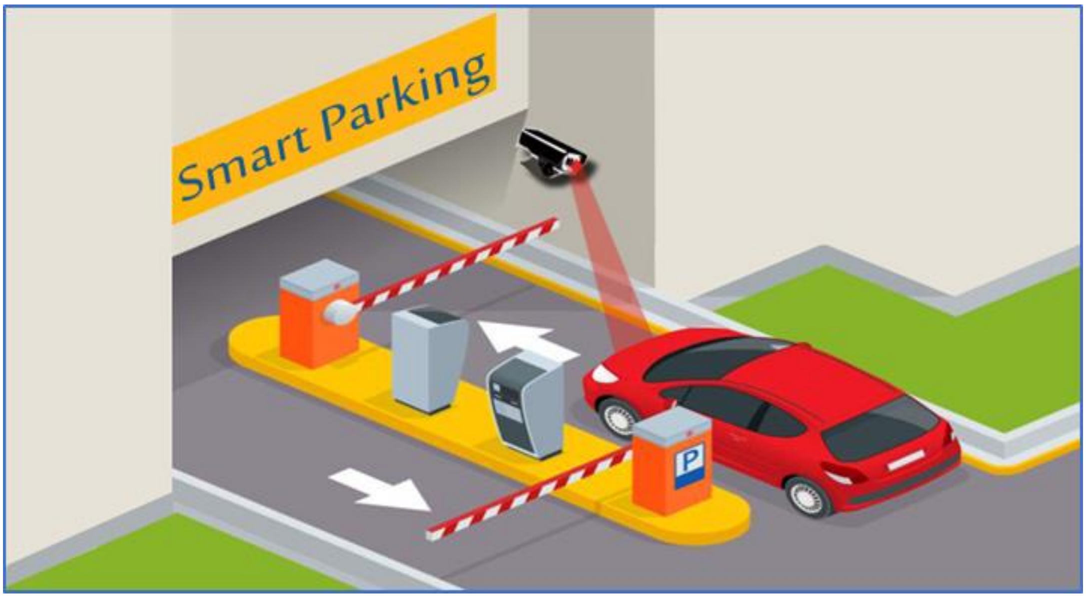
External Entry Gate for Car Park

controlled by the main entry gate as shown in Figure 8.1. The system will record the vehicle registration number, arrival time, and date for record purpose in the database. If for some reason the vehicle registration plate is not read, the driver can enter the number at the booth available for this purpose at the gate. When a car wants to exit the carpark, the previous steps of scanning and marking the registration number are repeated. If a vehicle overstays without an approved extension of the time, they must pay a small fine in addition to the charge for the extended time. The payment must be made online. Cancellations may be allowed before one hour without any charge, and with a charge within one hour of the arrival time. Allocation of parking space is allocated at the time of the actual entry of the vehicle to the Smart Parking to allow maximum usage of the car park

Some mechanisms are indicative and may be set according to the desired outcome depending on the location, crowd intensity, etc. In some cases, the management may decide to provide a human being to oversee the operations of the Smart carpark to ensure its smooth functioning. If, in case a person has difficulty in paying overstay charges, this person can provide alternative payment methods. There can also be more than one main entry gates depending on the size and location of the carpark.

Figure 8.2

Hardware Tools in the Smart Parking System



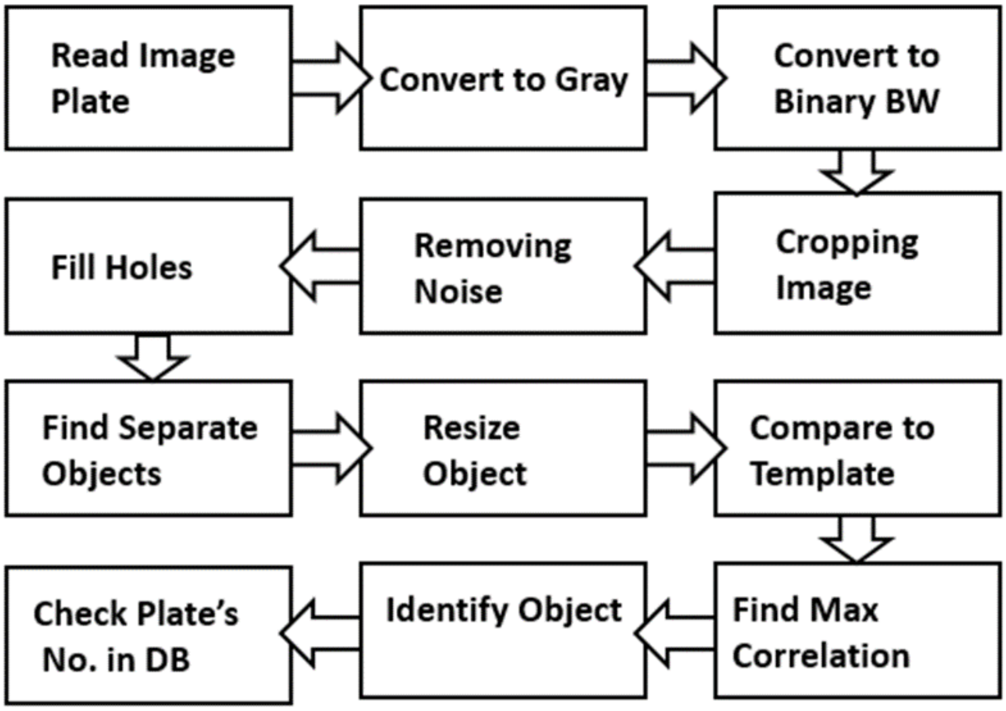
The aim of Smart Parking is to minimise congestion, save time, energy, and reduce pollution. This system will provide a web-based application to book a car parking space prior to coming to the car park. So, any user can make an online booking before they arrive at the location of the booked carpark. The system will also provide a mobile application to facilitate drivers to find a parking space while they are in their car. We assume there will be several Smart Carparks in a city. This will provide disciplined management of the parking problem and prevent cars roaming in and around carparks.

8.4 Algorithm for Managing Smart Parking

Here we describe the way this algorithm facilitates processing registration number plates at the main entry of the SPS. We have chosen to provide the main steps of the algorithm by means of Figure 8.3. It is worth mentioning that the convert step is for converting the three layers of matrix of a coloured image to one grey layer so that the processing will be easier and faster.

Figure 8.3

Main Steps for Detecting the ID of Vehicle's Number Plate



8.4.1 Pseudo Code of Proposed Algorithm

```
Input: Image from Camera
Output: String Plate_ID
Function Plate_Detection
RGB_Img = Read_Image_As_Matrix (Image)
RGB_Img = Gaussian_Filter (RGB_Img) // Remove Noise
GRAY_Img = RGB2GRAY (RGB_Img) // Convert to Gray
GRAY_Img = Unsharp_Filter (GRAY_Img) // To Reinforcement the Edges
WB_Img = Convert_To_Binary_Image ( GRAY_Img)
WB_Img = Morphology_Filters (WB_Img) // to Split the connected objects and Fill holes
WB_Img = Remove_Lines ("Strel-Disk filter")
Objects = Get_White_Object ( BWLable Function,  WB_Img )
Templates = Download_ Templates_of_Numbers_and_Letters (Path)
```

```
End_Result =""
Foreach Obj in Objects:
        Draw_Red_Rectangle (Obj.BoundingBox)
        Object = Resize (Obj, [Width Height])// According to Templates Size
        Max_Matching = 0
        Res = ""
        Foreach Temp in Templets:
                M = Find_Correlation (Temp, Object)
                If M > Max_Matching Then
                        Max_Matching = M
                        Res = Temp.ID
        End
        End_Result = End_Result + Res
End
Return End_Result
End Function
```

8.5 Online Booking System

The online booking system is a web application that shows all vacant positions for parking by time and location in a specific area which has been selected by drivers. The driver has to enter the expected time for parking, and their vehicle's number plate. Then the driver must pay online to confirm the booking (the price will be determined by the time, location, and duration). After payment, the status of the selected parking will be changed.

When the driver arrives at the location by using the available map in the system, the electronic gate will automatically check the eligibility of entry to the car park depending on the picture of car, by detecting the vehicle's number plate and checking the database for the booking table. In some cases, when there is an issue in the image processing function for plate detection, the driver can enter the booking ID at the gate, or just park in their booked position if there is no gate. Then, an employee who is responsible for verification will enter the car's number plate in the system to check if there is a booking, otherwise a violation will be registered against this car which would result in a fine.

8.6 Advantages and Disadvantages of Smart Parking System

Let us first discuss the advantages

8.6.1 Advantages

The main advantages are summarised in the following list:

1. Can be used in public parking or private parking.
2. Is easy to implement.
3. Avoids the physical search for parking in a crowded area during peak time.
4. Reduces traffic congestion and pollution.
5. Reduces the cost and energy usage compared to other parking solutions that needs Sensors, RFIDs, or Meters.
6. Supports allocating some spaces for drivers with disabilities.
7. Avoids violations and illegal parking.
8. Easy to use for drivers.

Now we shall discuss disadvantages.

8.6.2 Disadvantages

Although there are no significant disadvantages, but the following issues are worth considering:

- There is no physical lock for public parking in case of there being no automatic gate installed in the carpark.
- Drivers' behaver will not be studied at this stage (but will be in future works).
- In the proposed detection algorithm, we put specific conditions where the cards should stop for number plates to be detected easily.

8.7 Implementation of SMS

To prove the effectiveness and capability of implementing the proposed SPS, we have developed the required software to support it. Firstly, we implemented the OCR algorithm to read vehicle number plates through MATLAB for the proposed smart parking, then converted this code after testing it to the DLL library to allow it to be used by a .Net Framework like Microsoft Visual Studio (ASP.net C#), which we used for implementing the web application to manage the booking and tracking functions. As this discussion is technical, we chose to present it in Chapter X.

8.8 Future Trends

For future works, we have to focus more on employing machine learning (ML) techniques and IoT to provide more effective solutions, ideas, and advantages (Zantalis et al., 2019, Ayoub et al., 2020). We will propose many new ideas, such as:

a) Utilizing the parking system like an attendance system to also encourage companies and organizations to deal with the SPS, because that will greatly reduce expenses and provide a new method for attendance (Bai et al., 2021).
b) Enhancing the proposed idea to be suitable with smart schools and students being dropped off (Bahbouh, 2019).
c) Applying ML algorithms to study the behaviour of drivers and interactions with parking, in addition to predicting when parking will become available (Zantalis et al., 2019).

d) Utilizing vehicles to be mobile sensors in the city and collecting much useful information for more sophisticated services (Kurugollu et al., 2020).
e) Dealing with emergency cases like ambulance attendance, evacuations and relief functions (AlMohammadi et al., 2019).
f) Depending on the integration between Cloud and Fog computing in a Smart city for distributed management of parking as well as many other advantages (Pham et al., 2015, Abi Sen & Yamin, 2020)
g) Finding new methods to preserve privacy and security of user data with smart parking systems, which is considered to be one of the most significant challenges (Abi Sen & Basahel, 2019, Abi Sen et al., 2018, and Yamin & Abi Sen, 2020).

8.9 Usefulness of SMS

By presenting the idea of a smart parking system, based on automatic detection of the vehicle number plate, we are providing a supporting web system in order to enable drivers to book in advance from anywhere and at any time before arriving at the intended parking location, eliminating the need for drivers to search for a carpark for a long time or being forced to park illegally. We predict that there will be many smart car parks in the city as this will provide many benefits mentioned during our research. In the upcoming work, we will focus on employing machine learning algorithms for processing stored data, analysing parking behaviour and drivers' behaviour, and thus, the number of possible reservations, expected exit times for drivers, and other important information in organizing traffic can be predicted, allowing us to move to a smarter environment. We will also pay more attention to the issue of privacy so that the reservation and tracking system assures complete privacy for users that cannot be hacked or exploited by malicious parties.

CHAPTER IX - Data Privacy and Security of Road Users

Road users, including drivers and owners of the vehicles are required to provide their personal details to the administrative and management authorities of the roads. In order to get a driving license, private information must be furnished to the road authority. Vehicle owners and drivers are also required to furnish their personal details to acquire vehicle registration. Most toll roads require users to register online by providing their personal details including their bank account for payment. These details are used to identify their vehicle by number plate and charge tax from their nominated financial account to grant an uninterrupted passage through toll tax booths. Some booths also use RFID enabled tags to identify and charge toll tax from the vehicle owners. There are other situations like parking infringement, road accidents etc. when the road users, including pedestrians and passengers are required to provide their personal details.

Privacy is the right of users to determine and decide who can access their data and when and why the data will be accessed. Moreover, the data is not to be used for any applications or services that are not announced and have not gotten permission by the user. In addition, this data is not to be shared for any other party if the user doesn't want that. Finally, privacy concerns preventing identity of users to be discovered, avoid tracking, and blocking being profiled. In privacy there is no need to fully trust in any party beside the SP except in very special and narrow cases. While the security is interested in protecting confidential information, preserving the integrity. This ensures availability by blocking and mitigating any attack on both parties who exchange data between them.

Protection of personal data and safety of the road users is a big global problem. Possession of personal IDs and vehicle registration in the wrong hands can have devastating financial and life affecting implications. In this chapter, we discuss different ways to safeguard privacy and ensure safety and security of road users.

There are several known ways to protect privacy of the people in a variety of situations. We shall provide a review of these methods for users to choose one or more depending on their circumstances. Based on our review, we shall also provide a framework for protecting privacy and security of road users.

9.1 Privacy of Road Users

After the promulgation of the European GDPR law and its implementation in 2018, the issue of privacy protection has become very interesting, especially in the light of the great development in technology and the large number of smart objects that surround and monitor us at all times, in addition to smart applications that record everything we do anywhere. Transportation is an explicit example of the threat to privacy and security of users because new technologies and services have enabled the attackers to track users, identify them, and create profiles for each user. Many existing methods and approaches to protect privacy still suffer from numerous open issues and downsides.

Here we present an overview of a new approach that depends on the process of doubling the proposed protection methods and some existing ones to create integrated components for security and privacy which achieves advanced features and better protection in addition to fixing some of the existing issues of the available approaches. Our proposed approach has been applied to several previous technologies such as Double Cache and Double Obfuscation, in addition to Double Swapping and double mix-zone. Moreover, for security of very sensitive information there is double steganography technique. Amongst all previous techniques, this approach has been proven to be most successful and effective. The main objective of this research is to reorganize the previous technologies into a single approach to pave the way for other similar technologies to enhance the level of privacy in the Internet of Things environments and applications.

It is known that until now, privacy and security are the greatest challenges faced by new technologies and smart services and applications. To get more adaptive services, clients have to share their data on the network where many service providers will collect it in the cloud and analyse this data to get more information about the users and their behaviour then pose more sophisticated applications. However, that will violate the privacy of users and break many security barriers and expose the users to hacking from the outer attacker or a malicious SP itself if it is a malicious party.

Many methods are provided to preserve privacy of users, but unfortunately until now none of the approaches are free from anomalies and disadvantages.

In our proposed framework we proposed many smart applications and services, and at the same time depended on many smart objects and new technologies. So, we have to find insurance for the privacy and security of users, or our framework will not be useful nor trusted. For that we provide a component in our framework to achieve that by employing some selected privacy techniques in addition to some proposed techniques, to create a novel smart approach called “Double Approach” for preserving privacy of clients’ data and protecting security of very sensitive information.

So, our contributions in this thesis are:

c) Providing a new approach that contains several privacy and security techniques, which depend on doubling the protection process.

d) Achieving better and more advantages compared to any previous approach.

e) Integrating security and privacy.

f) Integrating the existed privacy technique and new proposed techniques.

g) Proposing three new techniques for privacy included in the double approach (double nickname, double swap, and double techniques).

h) Proposing an enhanced algorithm to protect security of the most sensitive information (double Steganography).

i) Employing the proposed approach with our smart framework for transportation applications and services.

j) Employing fog computing and its features to enhance the performance and efficiency of the proposed approach.

Note that we have published some of these methods as independent research papers to confirm the effectiveness of the proposed approach. In the fourth section, we will present some results of comparison and simulation, and finally some recommendations and future ideas.

9.2 A Review of Existing Approaches

Protecting the privacy of users has become an important issue that many researchers seek to provide solutions to in recent years, especially after some countries, such as in Europe, issued laws and rules that companies must adhere to in order to protect the privacy of their users, such as the GDPR. Protecting privacy means preventing any party, even the service provider themself, from building a profile on the user, revealing their identity, or tracking them, in addition to preventing the sale of user data to a third party without the user’s consent. The concern for privacy by users has also increased after the great development in smart devices and their applications that have spread everywhere around us, or what is known as the purposes of the Internet of Things. Lately, many companies have violated the privacy of their users under the pretext of providing more user-friendly services. For example, a smart watch company used some sensors in its products to detect what the user was writing, and some location-based service providers analysed the database they formed to discover many of the users' characteristics and then sold them to media companies, insurance, or employment companies.

There are many approaches and methods to preserve privacy but most of them suffer from one or more anomalies (Sicari et al., 2015). Here we provide a summary of important methods used for protecting users’ privacy.

9.2.1 Dummy Approach

Dummy Approach (Niu et al., 2015) uses dummies or surrogate peers. The main purpose of using a dummy is to conceal the real query by mixing it with a set of dummy (unreal) queries to mislead the SP. This method can be used to protect the query or location. The SP will not be able to identify the actual query, and hence would be misled to collect inaccurate information about the users. With this scheme, users are able to create dummy queries by themselves, and the user resources enable them to create 30 dummy queries for every real query. Amongst the weaknesses, this approach causes overhead on the user as well as the SP as the number of dummy queries grows, and after observing for a while, the SP can distinguish the user from others.

9.2.2 Obfuscation Approach

In the Obfuscation approach (Luo & Yang, 2017), the combination of the query and data of the user is changed before it is sent to the SP, unlike having to send many queries in the dummy approach. The level of privacy is related to the amount of noise and obfuscation on the query. Privacy can be increased at the cost of accuracy of results. In this scheme, users sacrifice the accuracy of results to protect their privacy. Moreover, the user has enough resources to recover the returned result. Its weakness includes (1) increasing privacy which would also increase the cost of processing, (2) Newer Obfuscation techniques require the user to send their area instead of the location, (3) this method also adversely affects performance and cost, (4) more importantly, Obfuscation is not suitable for smart street applications as it changes the locations of vehicles.

9.2.3 Double Obfuscation Approach

Double Obfuscation Approach (DOA) (Albouq et al., 2020) is a recent hybrid method to protect the privacy of users in LBS applications. It depends on obfuscation and Fog as the third party (TP) to enhance privacy compared to the traditional obfuscation, and addresses some drawbacks related to overhead and accuracy of results in the Obfuscation Approach (Lahe & Kulkarni, 2017). To achieve that, it bifurcates the obfuscation area (one for the user and another for fog) and divides the returned results into five parts with the help of fog. It provides the same functionality as in the case of the Obfuscation Approach, with additional overhead for processing. Its weaknesses are (1) The DOA applications result in overheads on the user and server, and the approach does not provide adequate protection for the data of the query.

9.2.4 Private Information Retrieval (PIR)

The purpose of Private Information Retrieval (PIR) (Kadhe et al., 2019, and Peng et al., 2017) is to provide privacy by utilising a large amount of data from the SP. This method assumes that the user can access a huge amount of data from the SP without the SP. It also assumes that the user has resources to store information of the whole city and deal with it. Accessing a huge amount of data from the SP may not be feasible at all times, which is a weakness of it. Another weakness is that it is not practical to use with smart devices of IoT, which are scarce resources. Moreover, some PIR techniques use encryption.

9.2.5 Cooperation among Peers

The main goal of the Cooperation (Zhu et al., 2013) approach is to reduce the number of contacts with the SP. In this approach, each peer in the same cell seeks the answer of their query from other peers, before sending it to the SP. In other variations of this method, peers collaborate with each other and send the same query to the SP to prevent profiling. It assumes that there are many users in each cell and most of them agree to send the same data to the SP. This is not suitable with smart street services.

9.2.6 Cache Approach

Cache Approach (Yamin et al., 2019) is similar to other approaches in caching some queries' answers and reusing them to respond to future queries. It assumes that there is an open access point with self-management for storing the result of previous queries of users. This method is effective only when the cache-hit ratio is increased, which is proportional to the privacy and performance of the query.

9.2.7 Blind Third Party Peers (BTP)

The BTP encryption is used by the Blind Approach, and its role is to change the identities of users. In the Blind Third Party Peers (BTP) (Yamin et al., 2019) approach, the user avails all the benefits of using a third party (peer) without having to reveal any data to them. There is a possibility of collusion between the third party (BTP) and the SP to breach users' privacy. Encryption may cause overload on some users' devices. BTP encryption usually results in more power consumption by users' devices. There are many other privacy schemes and some of them are variations of the other schemes.

We again emphasise that there is no method which provides absolute privacy protection, without any drawbacks. In other words, each method has one or more weaknesses. Also, not every method can be used in all circumstances. Use of a particular method will depend on the circumstances. In our current research, dealing with road users, we are mainly concerned with Location Based Services (LBS). To be practical and relevant, we shall provide a new idea which makes integration easier and enhances the level of performance of many existing techniques and algorithms.

With the help of the above description of existing privacy methods, we summarise them in Table 9.1.

Table 9.1

Survey of Excising Privacy Issues

Privacy/Security method	Disadvantages
Dummy	Overhead on User, and SP
	SP still has some real information about User
	SP can detect the real query by the time
	It is not easy to generate a strong dummy in the dynamic environment and moving objects
	Adversely affect the main service or application
Obfuscation	Overhead on the user to process the results
	Affects the accuracy of results of user's query
	Adversely affects the main service or application
	Attacker can detect the path of user's movement by the time in the dynamic environment
TTP	It can be the attacker and reveal the privacy of all clients
	It can be attacked and then all client's data will be disclosed
	It is not enough even if it is very trusted and related to government
Mix-Zone	It is easy to detect by attackers in the dynamic environment
	It requires user to change their IP also not only the nickname
Cooperation	There is no clear method to manage the relation between peers
	Any peer can also be malicious
	Can cause a delay in some cases which is not acceptable for many applications
PIR	Huge overhead on user
	Normal users with smart phone cannot use this approach
Cloak Area	It requires a TTP as Anonymised or cooperation between many peers
	There are many methods to select the cloak area size and diminution, however, in the end it will be as obfuscating area and has the same cons
Encryption	It requires trust between sender and receiver vs. client and SP
	In some cases, it will cause overhead on the client and SP
	Some algorithms are easy to break by a strong attacker

Steganography	The spatial domain algorithms can be detected and broken by a strong attack There are many cons in spatial domain algorithms and also other cons in transforming ones
Access Control	It is good but not enough to protect privacy

9.3 A Framework for Protecting Privacy and Security of Road Users

Location-based applications have become very popular in recent years, especially during the ongoing COVID-19 pandemic. The pandemic has intensified the trend of increased use of applications for electronic purchases and delivery services, to provide customers the ability to buy from anywhere and anytime, with great ease. However, there are some issues with these kinds of purchases and delivery services. In particular, the data collected by these applications has the potential of being breached for security and privacy. In particular, trust of the service provider cannot be taken for granted. In fact, the service provider may prove to be a source of real danger to the privacy of users, especially if the service provider itself is a malicious party. Thus, it is difficult for the user to determine which applications can be trusted, and who to share their home or business location with.

To solve the problem of privacy protection from the service providers, here we propose a unified platform that enables the users to gather all of their (main) locations and control access to these locations in one place. Then the user can share them with other applications, such as coding with a quick response (QR) barcode without the need to send accurate location data. Similarly, the user can also avail the GPS service for every purchase or request from any application. The QR will be deactivated once it is used by the service provider, after the order is delivered. Therefore, the service provider will not be able to exploit the data stored in it, which means greater protection for the user's privacy. The system will offer other features to the user and the service provider as well, such as dynamic and changeable location, accuracy, and organization of delivery. We have also implemented this system in a real manner to confirm its ability to improve the level of service in electronic purchase applications, in addition to improving the level of privacy of users' data.

9.3.1 A New Scheme to Protect Privacy of Road Users

Road users often deal with Location Based Services (LBSs) such as Google Maps. Protecting privacy from service providers of LBS is one of the main tasks of privacy protection schemes. Many techniques for protecting privacy have appeared in recent years. None of the schemes has been found 100% free of anomalies. Most useful and acceptable of the available schemes are those which make use of dummies or surrogate peers in different ways and techniques. By using dummies, all these schemes work on the principle of sending a false query that does not belong to the user to the service provider in order to mislead it. Another technique relied on obfuscation by adding noise or wrong information during the transmission process, for example changing the real location to another nearby location. And also, the cooperation technology, which relied on the cooperation of many users with each other to hide their identity from the service provider. Unfortunately, all these technologies cannot be used with ordering and delivery applications and services, which require the user to enter his correct data in addition to his correct location to ensure that the order reaches the chosen place.

Therefore, to solve this problem, it is necessary to rely on a Trusted Third Party (TTP), by building a reliable third party to manage this process smartly. At the same time, the user should not trust thousands of new applications and services that have appeared recently, especially with the COVID-19 pandemic, which greatly contributed to the trend towards electronic services being used and being relied upon. In the next section, the proposed system will be fully detailed, which is based on the TTP approach, in addition to the Choice and Accept policy, and the Access Control approach to ensure greater confidence and privacy for the user without affecting the performance of the service provided.

Location-Based Services (LBS) have become an essential part of most modern systems and services in various fields, such as transportation, health, communication, business, in order to transform them into more intelligent systems. Thus, most modern systems require the client to send his location to obtain a more adaptive service, such as alert services about weather, traffic, advertisements and offers, or the nearest hospital or restaurant, or the best way to reach a specific place and others (Bettini, 2018, and Yamin et al., 2018). The servers that provide such services are usually called LBS servers. In the ideal case for the LBS business model, the user sends their location to the service provider (SP) accompanied with the identity of the sender and the query they want according to the nature of the system, and the service provider returns a set of answers that correspond to the user's query and location (Sui et al., 2017).

But in exceptional cases, any malicious party can steal the information that the user sends, and sometimes the service provider itself may be a malicious party that exploits the customer data that it has in order to sell it to other parties, which is regarded as a violation of users' privacy (Abi Sen, 2020). Privacy can be defined as ensuring the protection of individuals' data. Location privacy is one of the types of data privacy, which refers to the ability to keep other parties away from knowing the whereabouts of people at the present time or previously specified times. And despite the issuance of laws in some countries to protect the privacy of individuals, such as the European GDPR law, these laws are not sufficient to guarantee privacy, especially with the great development of attackers' technologies and the resources used by them (Gupta & Rao 2017, and Chatzikokolakis et al., 2017).

9.4 Role of Earlier Methods to Protect Privacy

In location-based systems, privacy protection techniques are concerned with protecting one of the following components: the location, the query, the identity, because by collecting some data that contains these components and analysing them, the attacker can discover a lot of sensitive and private data about the user's behaviour, characteristics, work, religion, ethics and other private information (Chen et al., 2017).

Many technologies have been introduced to protect privacy. We will discuss the most important of them in the next section. In this research we seek to provide a different solution that enhances protection for privacy and facilitates the mechanism of application of various protection techniques (Asuquo et al., 2018, Abi Sen et al., 2018). The research suggests building a unified platform as a mediator between all location-based applications and services on the one hand and between the most important locations for each user. The platform enables users to control access to the added locations and protect them through aliases in addition to hashing functions and generating them in the form of a QR code (Abi Sen & Basahel, 2019) within the applications. The platform will provide other features for service providers and application owners together by managing and controlling order and delivery processes and improving their efficiency. Role of Earlier Methods for Protection of Privacy

Many techniques for protecting privacy have appeared, the most famous of which was the use of Dummy (Tiwari, 2016, Yamin & Abi Sen, 2018) in different ways and techniques. Proposed Privacy Protection System.

9.5 Proposed Privacy Protection System

We propose developing a unified central platform that would act as a trusted third-party (TTP). This platform would enable the user to add their data (like locations of their main places) only one time and managing this data with full access control. Thus, users would have the ability to modify or delete it at any time. Moreover, this platform will facilitate sharing data of users in many other location-based services (LBS) and applications according to their request via a secure method and protocol that does not attempt to breach privacy. These services and applications have become widespread in recent years, especially during 2020-21, with the ongoing COVID-19 crisis.

The proposed system would enable the user to create their own account with a pseudonym and link it with a phone number to ensure a multi-layer level of protection. After that, the user will add addresses and locations of his places, and these addresses may be under fake names as well. Thus, instead of having to re-enter this data and save it in every delivery application or service that requires the location, the platform will provide a unified API for these applications. It is sufficient for the user to enter his phone number, which will be sent to the platform to verify its existence, and then a one-time verification code will arrive on the user's phone. Then the user will enter the code, and if it is correct, all the names of the addresses added by the user will be displayed on the platform to choose the place to deliver the order.

The user will not need to activate the location service here or locate the receipt on the map, which means that privacy is greatly enhanced. Thus, the application will not need to store the user’s location data completely, but rather it is enough to store the name of the region of the location to help the user in the process of organising the distribution in addition to storing the URL resulting from converting the Hash-Code into a QR code.

In other words, the precise location of the user will not be kept in the database of any application at all, which will also enhance privacy significantly. The application will only print the resulting QR on the user’s order. Thus, when the employee of the application or the delivery company wants to deliver the order, it is sufficient for the employee to scan the QR to reach the user’s request for permission to access and if approved, the employee will be shown the user’s location associated with Hash-Code in the platform on the map. Once the request is delivered to the user, the QR code will be deactivated and therefore it will no longer be usable, which will protect the user's privacy from collecting historical data and analysing it by any malicious application.

The application will only be able to obtain the location once at the time of delivery, and it is valid for one time and needs approval from the user, which makes the manipulation a complex and ineffective process. More than that, the use of the QR will allow the user to modify his location at any time before scanning the QR without any effect on the QR or the service's application data, and this allows the creation of a dynamic QR, meaning the possibility of modifying the location of receipt in the event of an emergency or reason for that.

Finally, the API of the platform will facilitate the work of applications that provide services. These applications will no longer need to care about managing and protecting customer locations, location modification processes, and other operations related to the location of delivery and contact information. The platform will provide a future of additional statistical services and reports on the request of each service provider or the request of a specific user while enabling the user or service provider to fully manage their data without disclosing any privacy-related information.

The following is the perception of the proposed system. In the first figure, the user adds a new address in any fictitious name by specifying the appropriate location and time to receive the order. In the second form, the user can manage all his locations and their data with the ability to modify or permanently delete this data. While the third figure shows an example of working with an API in an application that needs a location service. Finally, the last figure shows the method for generating the QR and the process of printing it on the delivery notice. Once the QR is scanned, the employee will be able to access the user's location after his approval and only once.

Figure 1

Proposed Interface for Adding a New Address

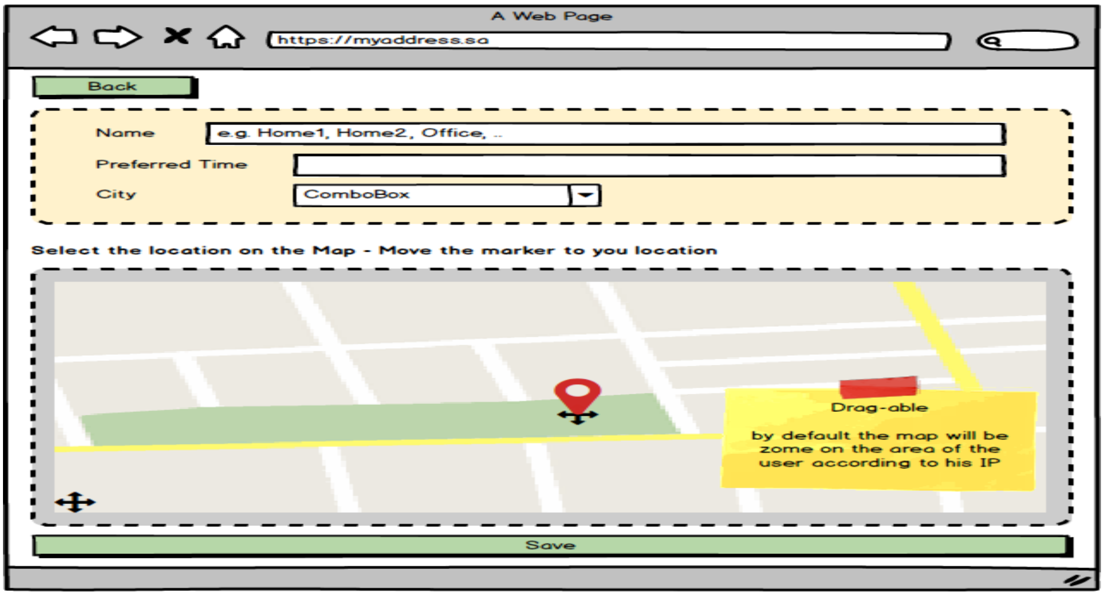


Figure 2

Proposed Interface of Managing Addresses by the User.

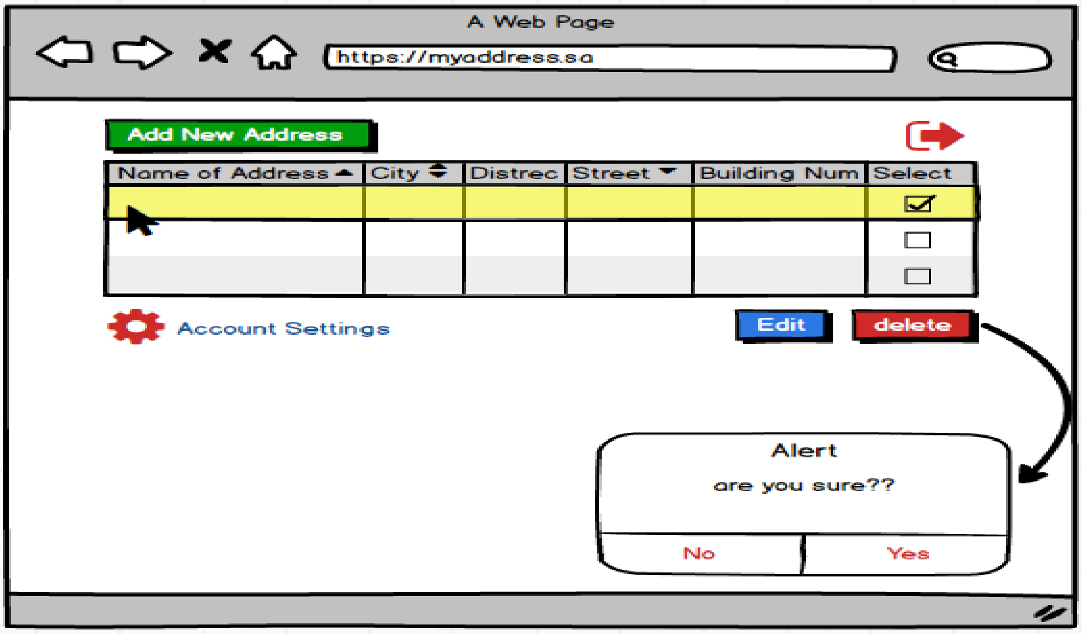


Figure 3

Proposed Interface for Requesting an Order

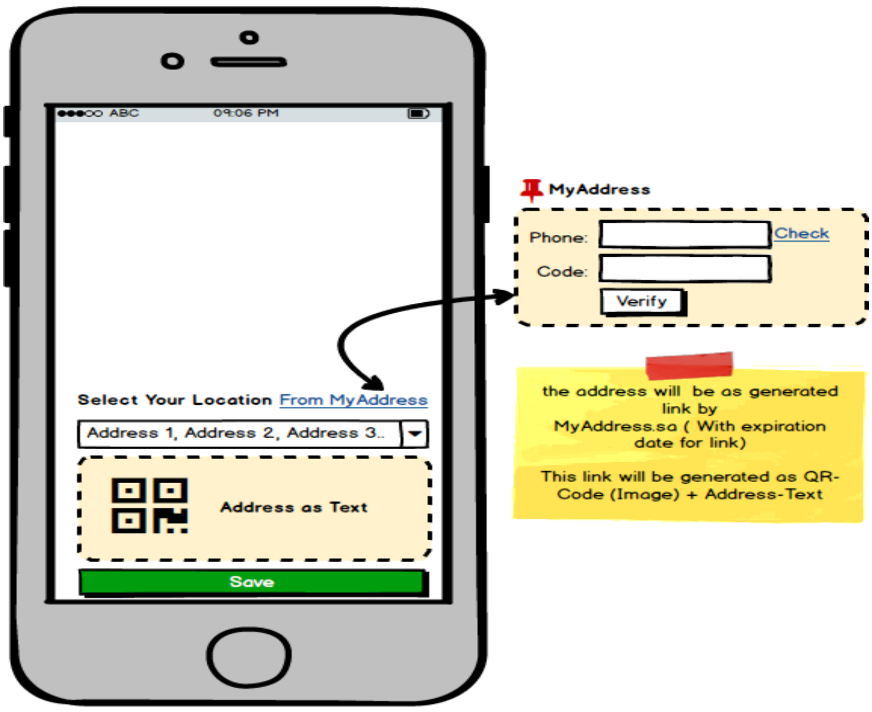


Figure 4

Proposed Interface for Scanning the QR and Showing User's Location on the Map

In chapter 10, we shall show some real interfaces of developed framework by using ASP.Net C # language with SQL Server database, using Microsoft Visual Studio 2019 platform. These include the login page, adding a new location on the map, and finally how to raise an invoice and print it for the driver or delivery workers.

9.6 Advantages of the Proposed Privacy Protection System

In this chapter, we have presented the idea of building a unified platform that would be a reliable alternative for the user to deal with thousands of applications and location-based services. Several privacy protections concepts (TTP, Choice and Accept, and Access control) have been incorporated to ensure a better level of flexibility in user control over privacy. The proposed platform also saves a lot of effort of the user, so he no longer needs to run a location service or work with maps repeatedly, and, more importantly he does not have to store his own data in different databases for delivery applications. Finally, the proposed system improves the performance of delivery applications and provides an innovative idea to organize this process in a way that preserves the privacy of the user and gives them flexibility to modify at any time. The proposed platform has already been built and is being adopted after cooperating with a good number of related applications and services in the Kingdom of Saudi Arabia.

9.6.1 Advantages

Finally, we list the main advantages of the proposed platform:

a) Protects the privacy of the user from all applications that provide LBS, like delivery.
b) Saves time, effort, and resources of the user, where he/she will manage all their data one time and in one place.

c) Enhances the privacy of user identity and locations by utilizing the TTP, Authentication, Nickname, Access Control, and Request Permission, and Encryption techniques together.
d) SPs will not need to worry about managing and protecting their customer's data
e) Provides some other features for clients like reports, and dynamic QR-codes for location.

9.6.2 Disadvantages

The main disadvantage of the proposed platform can be regarded as having one point of failure, which can have an effect on both the functionality and the privacy issues. This issue can be relaxed depending on whether there is a multi-trusted server, and by employing Blockchain between them. This will be explored in our future work.

CHAPTER X - Simulations and Background Results

In this chapter, we shall provide simulations and background results, in a sequential manner, according to our proposed solutions at each level. First of all, the details of technology used for different levels of the proposed traffic management system are described.

For the first level, we have implemented the image processing algorithm by MATLAB on virtual and real images in Chapter 3. Then we have applied simulations to calculate the improvement in rate of the waiting time for each vehicle in an ordinary traffic light as well as the proposed solution for STL.

At the second level, for the drone idea, we have used the same algorithm of image processing, with different settings related to distance of drones. To make it useful for updating street status applications, an Android application was used. To analyse Tweets, we have utilized the proposed TM-algorithm by Python on selected data, which has also allowed for checking precision & recall results.

For the third level, we have proposed solutions and guidelines receiving benefits from the collected big data, including the steps for managing this data in ML and DM.

At the fourth level, which deals with the Assistant Application, we have implemented an algorithm for OCR for vehicle plates by MATLAB in the proposed smart parking. Then we have implemented a web application to manage accounts by Asp.net-C#. Also, we have implemented a web application by Asp.net for public transport (School-Bus) and another Android application for First Aid.

Finally, in the layer of security and privacy, we have made simulations to ensure the effectiveness of our proposed approach. Then, we implemented an algorithm proposed for Steganography “Multi-layers Protection” for highly sensitive data by C#.

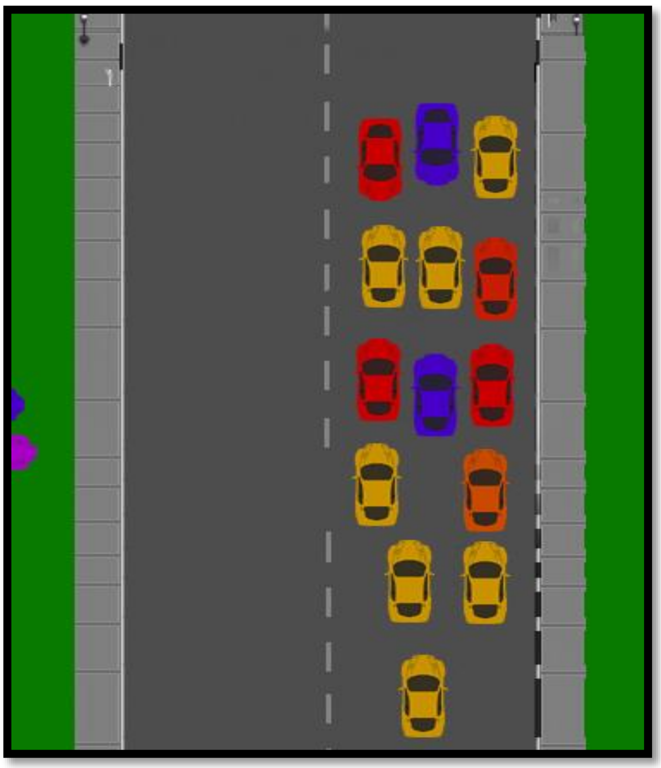
10.1 Application of Image Processing Algorithm on Virtual Picture Frame

First, we shall provide details of how the algorithm is applied to process the number of vehicles in chapter 4, including an explanation for each step. Here we used the MATLAB framework, which is a powerful tool for image processing. In the first step, as shown in Figure 10.1a, we have designed a virtual street with some vehicles, then proposed that the camera is situated at a higher position. Then we read the image using MATLAB by using function ImRead (Im). We have followed several steps which are outlined:

10.1.1 Step 1

To begin with, the image is read as matrix.

Figure.10.1a
Image matrix



10.1.2 Step 2

Then we converted the image from RGB to grey to delete colour effects. Usually, this step is used to isolate or remove the effect of colour and to prepare the image for the next step, as shown in Figure 10.1b. With MATLAB we use Rgb2Grey to convert the image into grey colour.

A greyscale image, M pixels tall and N pixels wide, is represented as a matrix of double data precision type of size M×N. Element values denote the pixel grayscale intensities in [0,1] with 0 signifying black, and 1 as white. We convert image from RGB to grey to speed up the procedure of the processes to delete the colour effect, as shown in Figure 10.1c.

Figure.10.1b

Image matrix (grey)

10.1.3 Step 3

A filter is applied for Noise Reduction from the image using Gaussian filter. Small invisible noise is removed, which may hinder the image processing and cause an error in the object counting process.
Figure 10.1c
Image matrix (Gaussian & Sharp Filter)

10.1.4 Step 4

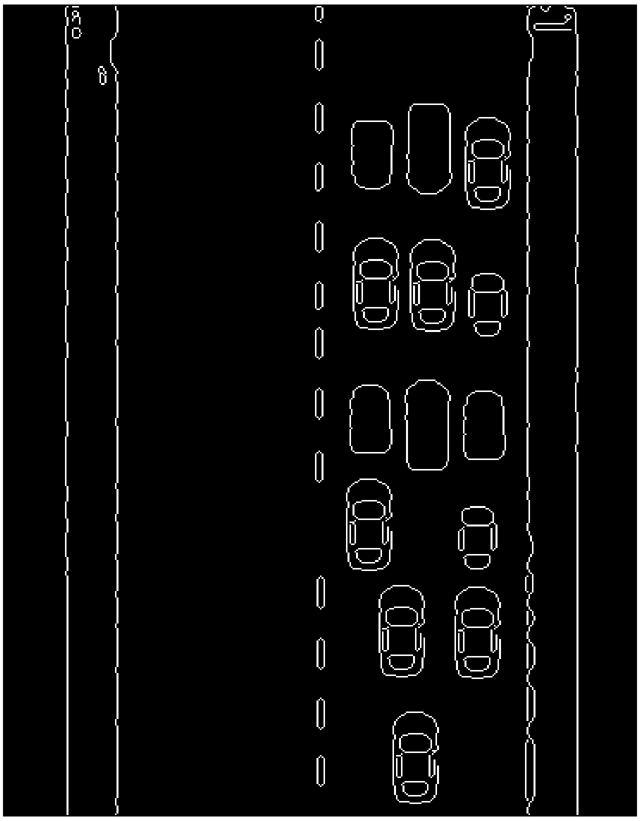
A filter is applied for objects in the image as Sharp Filter. Increasing the sharpness of objects is very important for applying the edge detection filters, as it is important to have the objects in the image be clearer. The result of applying these two steps (3 and 4), is presented in Figure 10.1.c.
Figure 10.1.c
Image matrix (Gaussian & Sharp Filter)

10.1.5 Step 5

An Edge Detection Filter is applied to detect all edges in the image and convert the image to black and white binary (0 & 1) format. We use the Canny Filter for this step, which is the most widely used edge detector, and considered the best for "Edge Detection". It relies on five important steps, namely: (1) Noise reduction, (2) Gradient calculation, (3) Non-maximum suppression, (4) double threshold, and (5) Edge tracking by hysteresis. However, in MATLAB, there is only one command for calling the Canny Filter and getting the next result as shown in Figure 10.1d

Figure 10.1d

Image matrix (Edge Detected – Canny Filter)



Morphology filters are applied, which allow operators to dilate, erode, open, and close, to process previous images and grow or shrink the white objects in the image. We have used "Closing" filter to connect the lines of the edge correctly and overcome a mistake that appeared in the image after applying the Canny Filter due to noise.

Closing will remove the very small holes in the white objects, while “Filing” filter will fill each closed area with white colour and make it a separate object, to make it easier for counting.

10.1.6 Step 6

Finally, by applying Opening and Removing Lines Filter, we increase the smoothness of the previous white objects. Moreover, the opening filter is used to remove the weak connection between two objects thus ensuring the separation between objects.

The remaining lines were removed by using the STREL command. These operations are depicted in Figure 10.1.e and Figure 10.1.f.

Figure 10.1.e
Image matrix (Closing and Filling Filters)

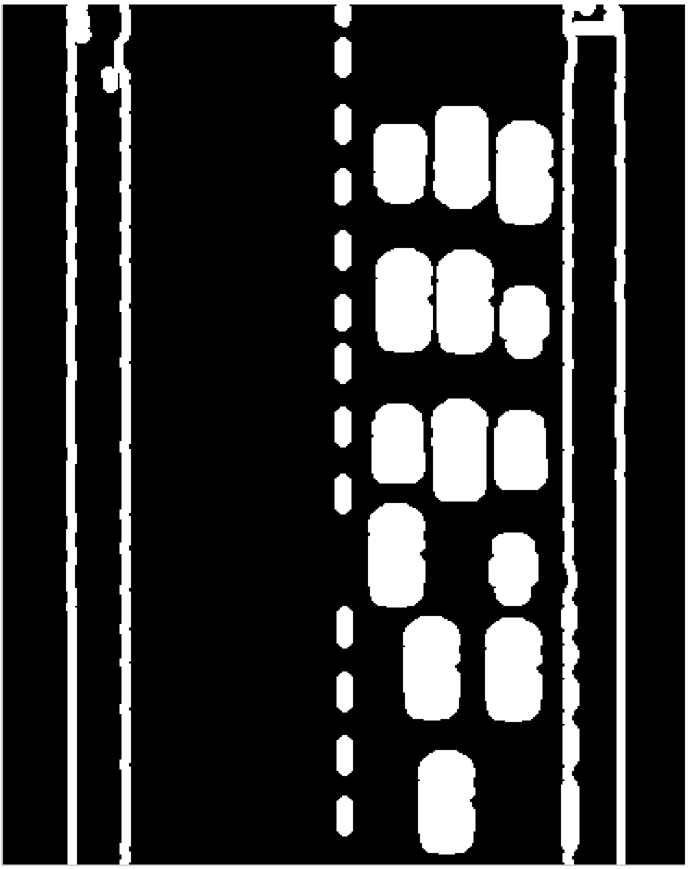
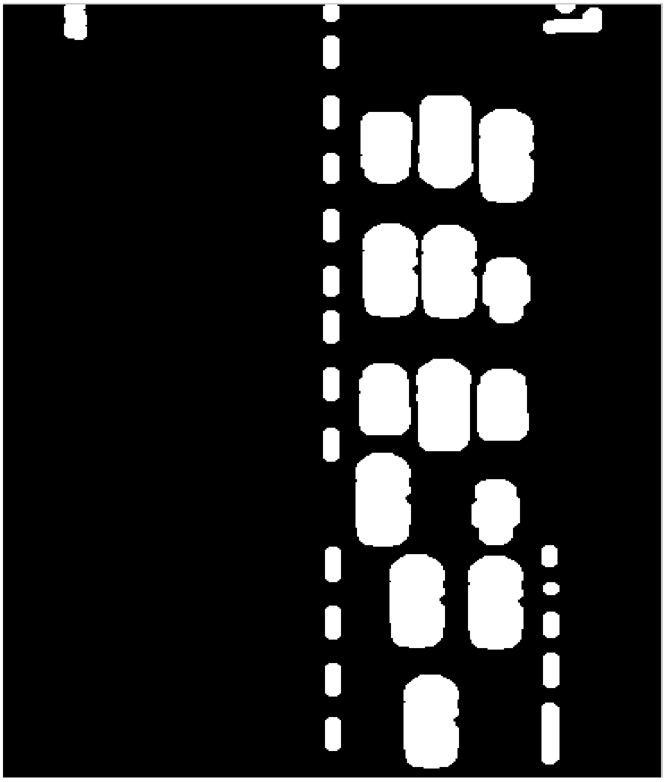


Figure 10.1.f

Image matrix (Opening and Removing Line)



10.1.7 Step 7

BWLABLE function is applied to represent all objects in the image and their number as a matrix. This function enables the user to code many important properties for each object in matrix form, like area of object, perimeter, centre, radius, number of white pixels, and so on. According to the original image size and the position of the Camera, an administrator can determine the expected object size for one vehicle (e.g., M). The final image is shown in Figure 10.1.g.

Now for each object we compare its area with M and apply the following algorithm

1 if it is larger than 2M then Number of Vehicles (N)=N + Area/M

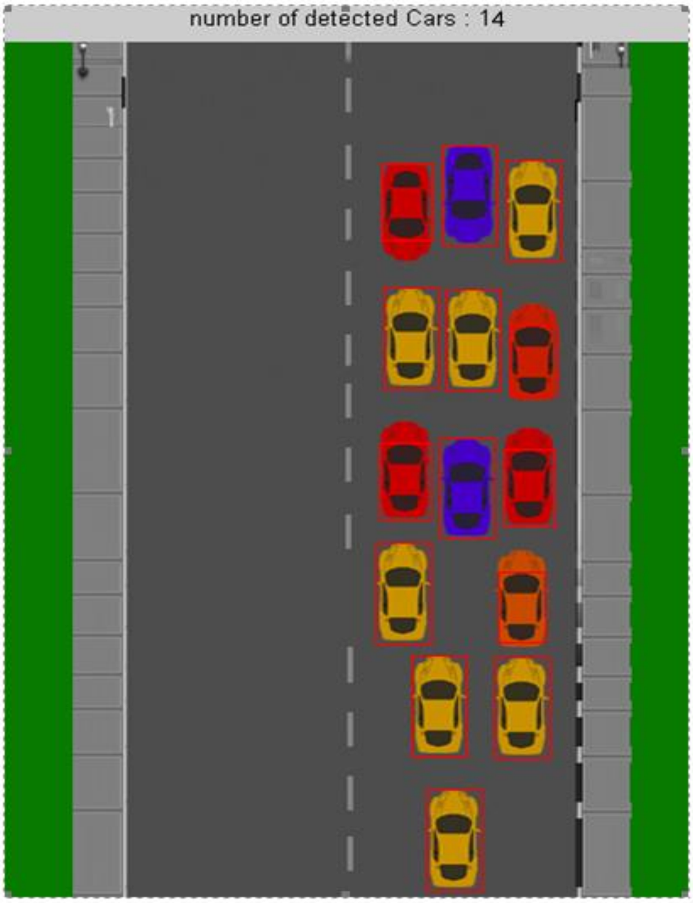
2 if it is smaller than M/2 we will ignore it

3 else N = N+1

4 Return N

Figure 10.1.6

Image matrix (Edge Detected)



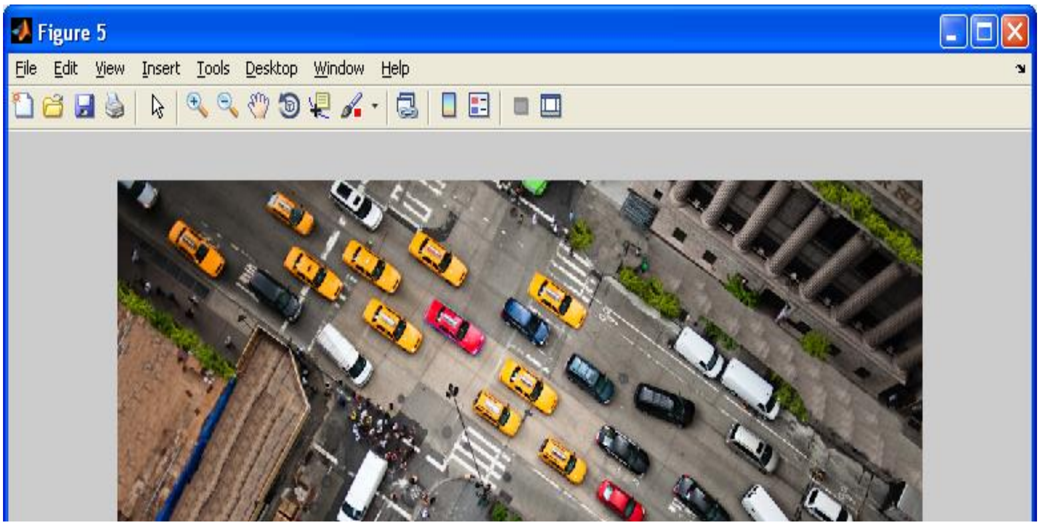
10.2 Testing on Real Picture

We have used MATLAB to apply the proposed algorithm of counting the number of objects/vehicles in each street. Consider first a Real Image as an example: Figures 5 to 10 below show the transformations of this image by applying the steps of the algorithm described in section 9.1 above.

To begin with, as shown in Figure 10.2a, we read the image of street received from the traffic light camera or drone camera. Then we presented it on MATLAB to create a new figure.

Figure 10.2a

Example of an Image



Next, as shown in Figure 10.2b, we have saved the same image after converting it from RGB to Grey in MATLAB. In addition, we applied Gaussian Filter on the same image to remove the noise.

Figure 10.2b

Example Image (Grey)

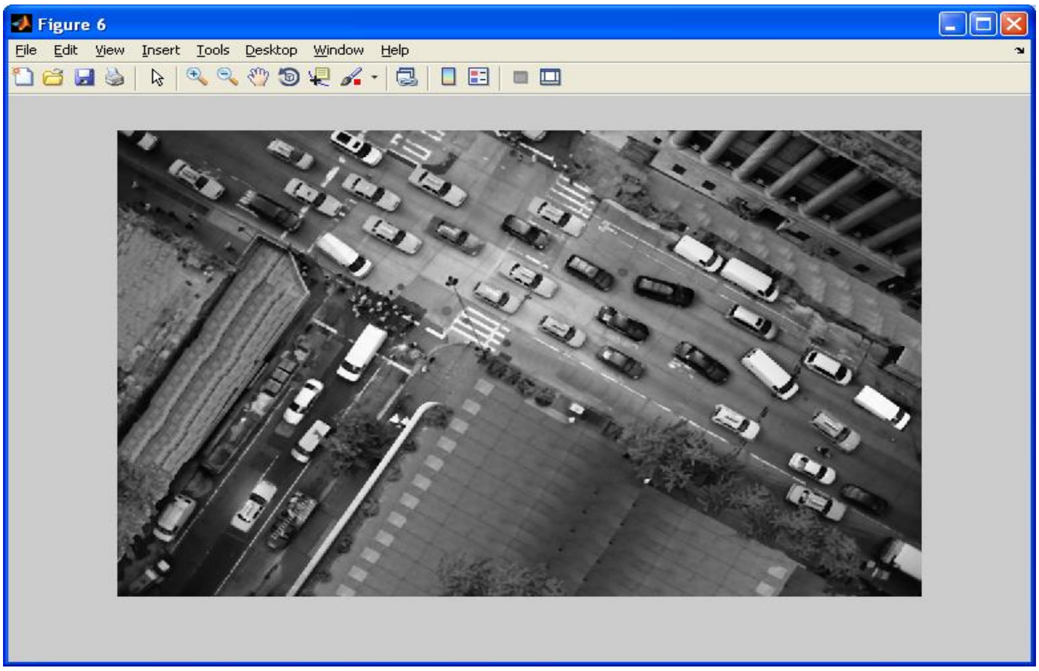


Figure 10.2c

Example Image – Edge Detections

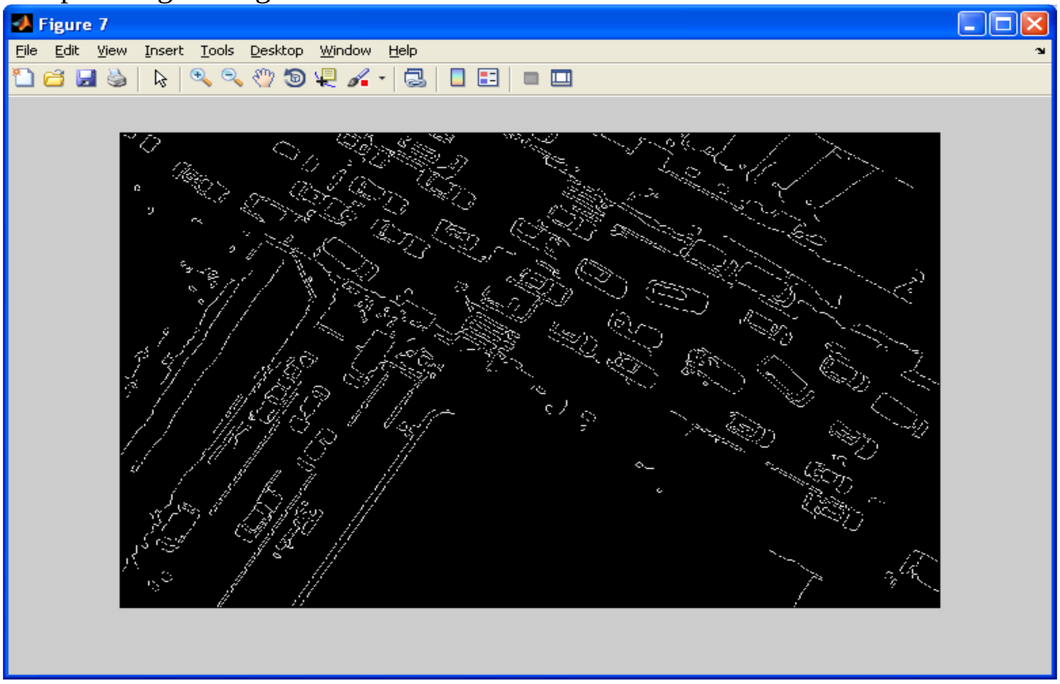
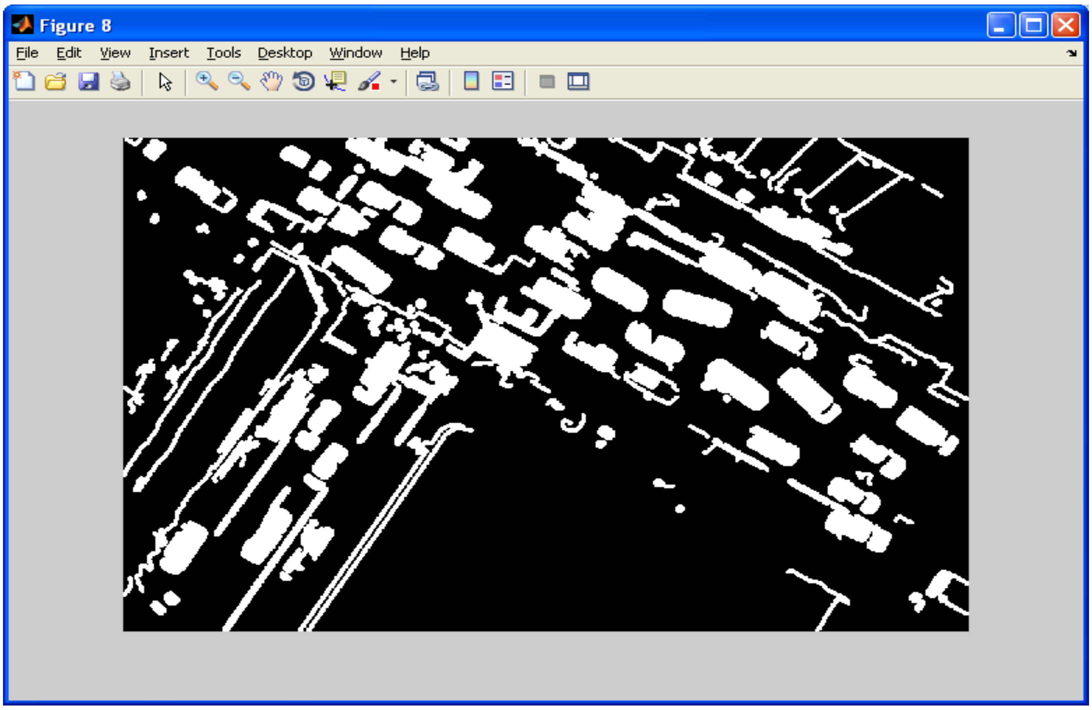


Figure 10.2d

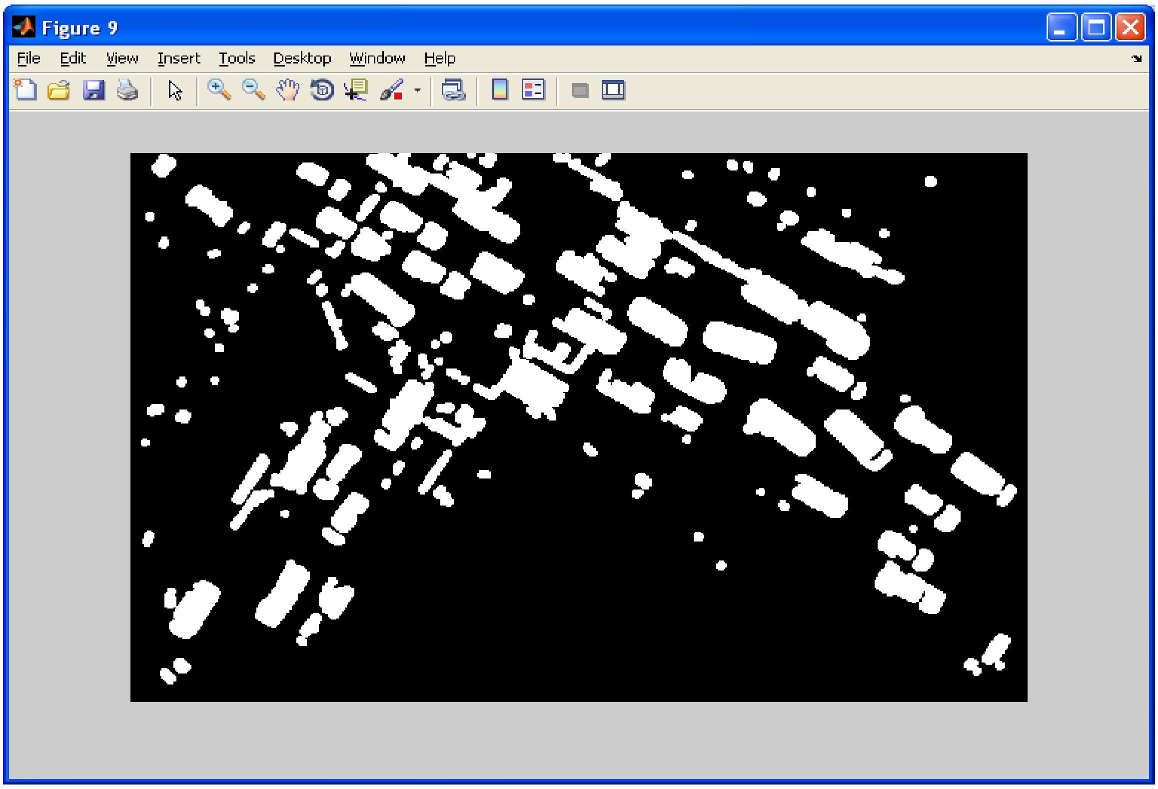
Example Image – Filling



Then we applied the Canny filter, as shown in Figure 10.2c, to detect the edge of all shapes in the previous image. As can be seen, the shape of vehicle is different from streets, building, and other objects. Note that the image will be converted to Black and White. After that we apply some Morphology filters (closing, opening, and Fill) to remove the very small noise, strengthen the connection around each object, then fill each closed shape of object in white colour, as shown in Figure 10.2d. In the next step, we have used the Morphology filter to remove all lines in the image, which will help to display only the vehicles shapes in addition to some small objects on the street, as shown in Figure 10.2e.

Figure 10.2f

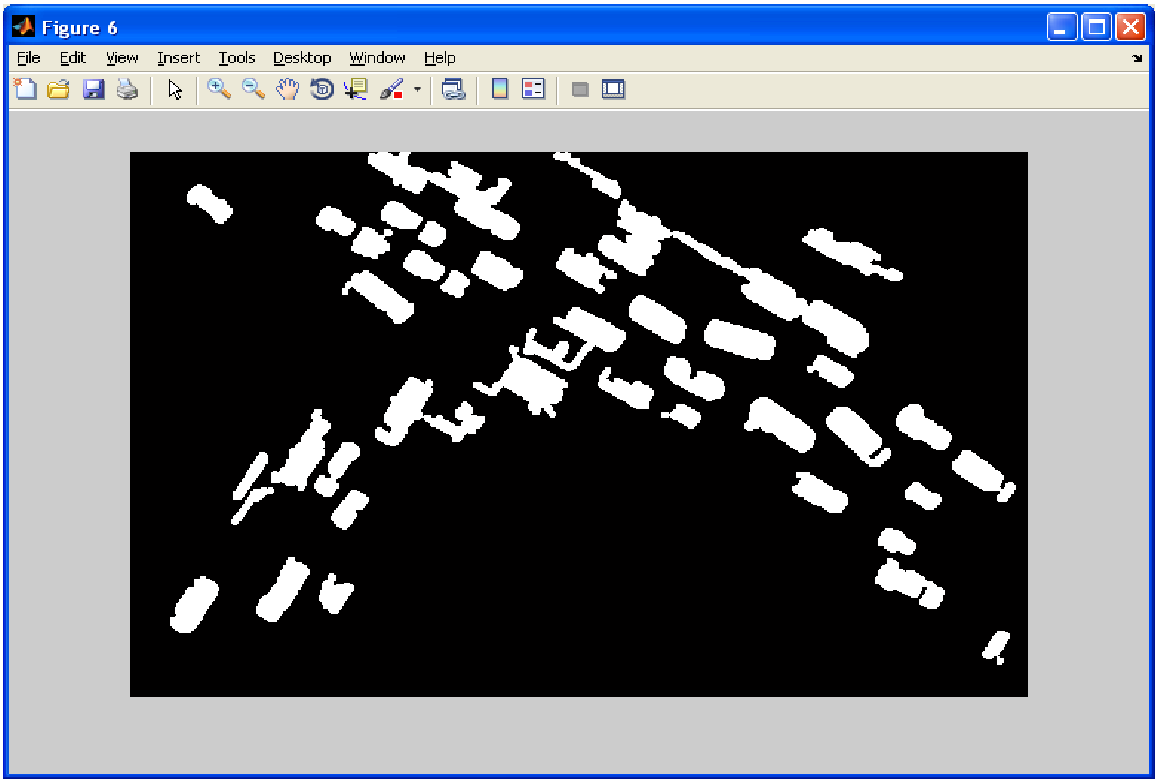
Example Image – Opening and Remove Lines



We chose threshold for minimum size of accepted objects (according to the position of camera). Then we removed all objects which didn't achieve the condition of size. In fact, few undesirable objects had still remained but this is acceptable as they were not going to have a significant effect on the rate of crowding in each street in general (Figure 10.2f). It should be noted that there are some connections between some objects. In this situation, we had two options: first, to use morphology filters to disconnect the object by repeating the opening filter, and the second option is what we used because it turned out to be more effective in cases of the vehicles being very close to each other(Figure 10.2g)..

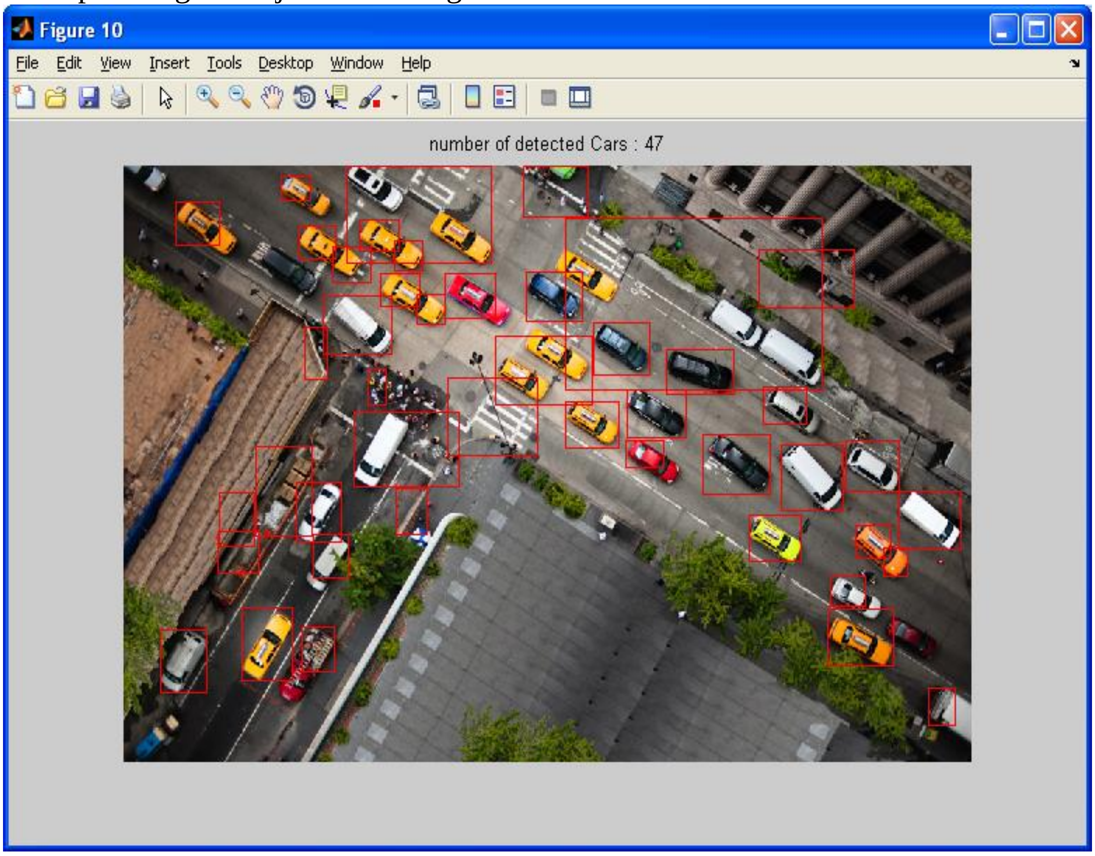
Figure 10.2g

Example Image – Removing Small Objects



As shown in Figure 10.2h, we have presented what we detected or achieved after going through the processes of previous steps. We have drawn red rectangles on each object to show them clearly and categorically. As can be seen, there are some rectangles which contain more than one object. The reason for that is already discussed in the previous paragraph. To deal with this issue, we also imposed a threshold for the max size M for object, then we divided the size of each rectangle if it was larger than M to recreate several objects in this iterative process. Finally, we counted the vehicles.

Figure 10.2h
Example Image – Objects Counting



By using this method, we achieved another advantage in our algorithm which didn’t exist in the RFID/WSNs methods, where our system takes in to consideration the size of vehicles. So, the big track will not be considered as a small car.

Note. When scanning more than one street simultaneously, the result may not be completely accurate. The accuracy is optimum in case of Single Street scanning. Moreover, we can reduce the size of each object to enhance, which enhances the accuracy of the end result. Finally, as we are concerned with the extent of congestion, accurate estimation of the number of vehicles is not a critical issue.

Note. In our example, we have used general image to make a point that our system can find the approximate number of vehicles with good accuracy. But in reality, each image would be for one street only, so we have four images for an intersection. For error, we have explained that we have used the justification step which takes the size of the detected object in consideration and divides it by the average size of a vehicle in each intersection which will be enabled to be updated by admin.

10.3 MATLAB Code for Image Processing Algorithm

In this section, we shall provide technical details of our experiments in MATLAB for verifying Image Processing Algorithms for STL. The main aim of the section is to provide details of the function outputs from experiments with image processing. The inputs of each function are an image and two thresholds. The details of the function Output of the image processing are as follows.

Function output = *Get_Objects_Num* (Image1, Threshold1, Threshold2)

MATLAB Code of Image Processing Algorithm

```
function output = Numvehicles1(image1,size1,doublesize)
%gray img
x1=imread(image1);
x2= rgb2gray(x1);
imshow(x2);figure;
J=im2double(x2);
x3 = medfilt2(J);
imshow(x3);figure;
x4=edge(x3,'canny',0.3);
imshow(x4),figure;
x5=imfill(x4,'holes');
x6=bwmorph(x5,'close',inf);
x6=bwmorph(x6,'dilate',1);
%x6=imerode(x6,[0 1 0;1 1 1;0 1 0]);
x6=imdilate(x6,[0 1 0;1 1 1;0 1 0]);

x7=imfill(x6,'holes');
imshow(x7);figure;

x8=imopen(x7,strel('disk',5));

imshow(x8);figure;
x8=imerode(x8,[0 1 0;1 1 1;0 1 0]);
%x7=imerode(x7,[1 1 1;1 1 1;1 1 1]);
x8 = bwareaopen(x8,size1);
%x7=imerode(x7,[0 1 0;1 1 1;0 1 0]);

imshow(x8),figure
[l n]=bwlabel(x8);
props=regionprops(l,'Area');
numob=0;
for i=1:size(props,1)
```

```
  if props(i).Area>doublesize
     %props(i).Area
     numob=props(i).Area/doublesize;
     numob=round(numob);
  end
end

stat = regionprops(l,'BoundingBox');
str = sprintf('number of detected Vehicles : %d', n+numob);
imshow(x1); title(str); hold on;
for cnt = 1 : length(stat)
   bb = stat(cnt).BoundingBox;
   rectangle('position',bb,'edgecolor','r');
end
bigBox_Contain=numob
xxx=n+ numob;
output =xxx;
```

10.4 Simulation Algorithm

In order to measure and validate the rate of enhancement which is achieved by the proposed algorithm for Managing the Smart Traffic Light, we have applied a simulation for calculating the average waiting time in the case of our proposed scenario, as well as in the case of a static scenario, which is practiced in many places.

The details of the simulation's hypotheses are:

- We have an intersection of four streets. The user can input the number of expected cars for each street appearing in a 2-hour duration. We have generated a random number of new vehicles entering each street during the designated time period.
- Each street will apply green signal for 30 seconds and red for 90 seconds. The complete cycle would take 120 seconds. (This can be readjusted, if desired).
- There are two lanes in each street, which means that two vehicles can pass together when the green signal is active.
- The rate of delay will be 4s for each lane. After setting our parameters, the process was repeated several times and the average waiting time was calculated.

MATLAB Code:

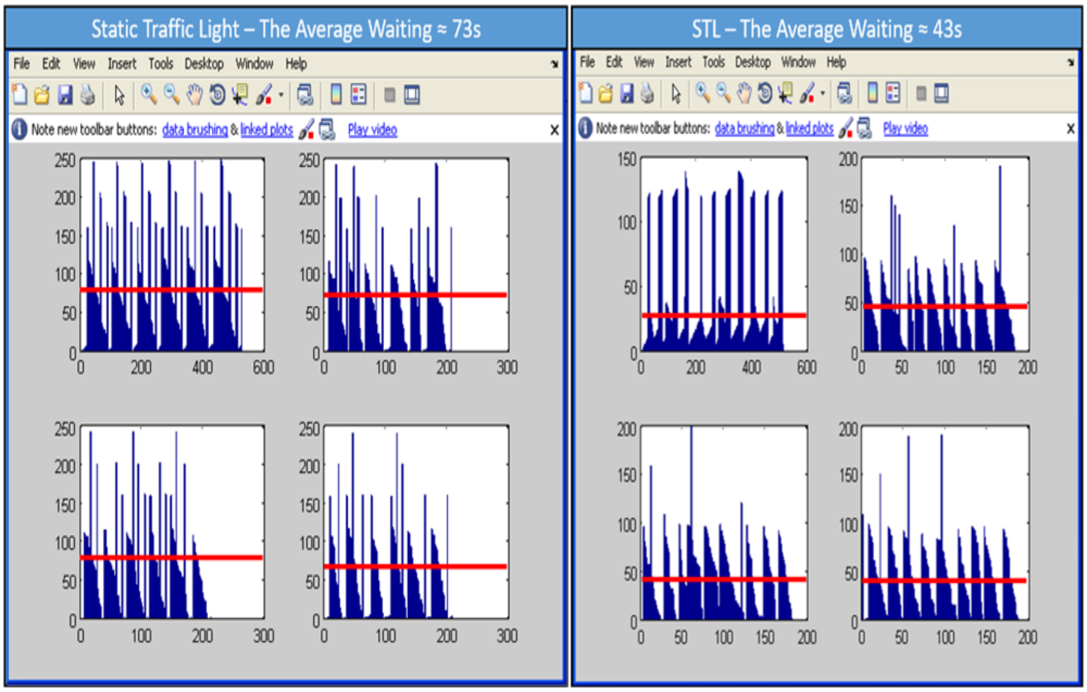
```
function [late4one , xbar1] = rand_time1(time,vehiclenumber)//for each street
clc
x1=round(time*rand(1,vehiclenumber));
x1=sort(x1);
% x1=[1 3 4 5 6 8 10 11 20 20]
%--------------------------------------------
I=0;
D=90;
D4=120;
L=2;
S=4;
%x1(2)=[]; % remove element form vector
index=1;
late=0;
xbar=[];
%-----------------------------------------------
while (numel(x1)>0 & index <= numel(x1))
if(x1(index)<(I+1)*D)
  %--------------------------------------------
  z=mod(x1(index),D4);%1
  if z>D
     z=D4-z;
  else
     z=0;
  end
  %--------------------------------------------
  late1 =  floor((index-1)/S)*L + D4*(I-floor((x1(index)-1)/D)) + z;
  xbar = [xbar late1];
  late = late + late1;
end
%floor((index-1)/S)*L
newTime=x1(index)+floor((index-1)/S)*L;
if (newTime > (I+1)*D)
   I=I+1;
   x1=x1(index:end);
   index =0;
end
index=index+1;
end
xbar1=xbar; % Drow Bar Chart in Matlab %bar(xbar);
late4one=round(late);
end
```

Simulation - Testing for (1,000, 500, 200, 200, 200) replicates per scenario. Initially, the time duration for testing was set to 1000s. The other parameters representing the number of vehicles in each street were distributed randomly during this period.

By Applying the Static Current Managing for Traffic Light, the Average wait for each object was found to be 72s (Figure 10.3).

Figure 10.3

The Average of wait time in the Traditional Traffic Light



After applying the proposed algorithm to manage traffic lights, the average waiting time was found to be 43s, a reduction of 30s for each object.

Thus, for 1100 objects, the total reduction in waiting time would be 1100*30 = 33000s.

Note: There are cameras for night mode, so there is no problem here. Typically, peak times in Saudi Arabia occur in the morning and afternoon.

10.5 Alternative Ways of Counting Vehicles

As discussed in chapter 4, instead of using image processing method to count vehicles, RFID tags or sensors can be used. Sensors can send notifications to fog nodes when each object crosses a certain point, while in the case of RFID, each smart vehicle can send a notification to the smart traffic light when it is in its range. However, this would require every vehicle to use an RFID, registered with the Roads & Safety Management department of the country or city concerned. This has proven to be difficult to enforce. However, there are other factors to consider for choosing between image processing and RFID-based methods such as feasibility and economic considerations.

Now we shall move onto the technology discussion related to Street Status (chapter 5).

10.6 Level 2 - Interface for Android Applications of Street Status on Simulator

We have used Android with Java to develop this application, which enables users to contribute to addressing and controlling traffic issues, which is quite handy and helpful to control congestion. We depend on google map and GPS service to get the real location of users. The users can then add labels on the map in this location if they face any traffic issues with adequate details, which would help the traffic management determine the kind of issues being faced and the way to solve them. All users can view all labels on the map, and they can also vote for more confirmation. However, for voting, the users have to be in vicinity of the label.

Figure 10.4
Main interfaces in the proposed application for street status.

10.6.1 Level 2 - Tweets Analysing

For tweet Analysis, we have applied a small number of selected tweets (about 100 tweets) and compared the results of classification using three different algorithms, namely: Support Vector Machine (SVM), Linear Regression (LR), and Nearest Neighbour (NB). Incidentally, the SVM gave us the best result, followed by LR and NB.

We have Python to achieve our results with NLTK library of NLP. The NLTK has many useful functions for dealing with text, including cleaning, removing stopwork, normalization text, stemming and lemmatizing, position of Speech POS, chunking, etc.

We have implemented the proposed algorithm, and the next figures show the results of accuracy, score and precision. In reference to Figure 10.5, we now provide general information widely available on the internet.

Figure 10.5

Actual Class vs. Predicted Class

	Predicted class		
Actual Class		Class = Yes	Class = No
	Class = Yes	True Positive	False Negative
	Class = No	False Positive	True Negative

True Positives (TP)

These are the correctly predicted positive values which means that the value of actual class is yes, and the value of predicted class is also yes. For example, if actual class value indicates that this passenger survived and predicted class tells you the same thing.

True Negatives (TN)

These are the correctly predicted negative values which means that the value of actual class is no, and value of predicted class is also no. For example, if actual class says this passenger did not survive and the predicted class tells you the same thing.

False positives and false negatives occur when the actual class contradicts the predicted class.

False Positives (FP)

FP occurs when the actual class is no and predicted class is yes. If actual class says this passenger did not survive but predicted class tells you that this passenger will survive.

False Negatives (FN)

FN occurs when the actual class is yes but the predicted class is no. For example, if the actual class value indicates that this passenger survived and predicted class tells you that the passenger will die.

Once these four parameters are understood, then we can calculate Accuracy, Precision, Recall and F1 score.

Accuracy

Accuracy is the most intuitive performance measure, and it is simply a ratio of correctly predicted observation to the total observations. One may think that if we have high accuracy then our model is the best. Accuracy is a great measure but only when you have symmetric datasets where values of false positive and false negatives are almost the same. Therefore, you must look at other parameters to evaluate the performance of your model. For our model, we got 0.803 which means our model is approx. 80% accurate.

Accuracy = TP+TN/TP+FP+FN+TN

In the above accuracy calculation, we divide the right results (which the model said it is true or false and in real it is same) on the number of all tested results. While the precision depends only on the positive results where as it is true or false and the percentage to true from true and false. Actually it is related to Figure 10.5.

Precision

Precision is the ratio of correctly predicted positive observations to the total predicted positive observations. The question that this metric answers is, "of all passengers that are labelled survivors, how many actually survived?" High precision relates to the low false positive rate. We got 0.788 precision which is a highly adequate level.

Precision = TP/TP+FP

Recall (Sensitivity)

Recall is the ratio of correctly predicted positive observations of all observations in the actual class – 'yes'. The question recalls answers is: "Of all the passengers that truly survived, how many did we label?" We have got a recall of 0.631 which is an adequate level for this model as it's above 0.5.

Recall = TP/TP+FN

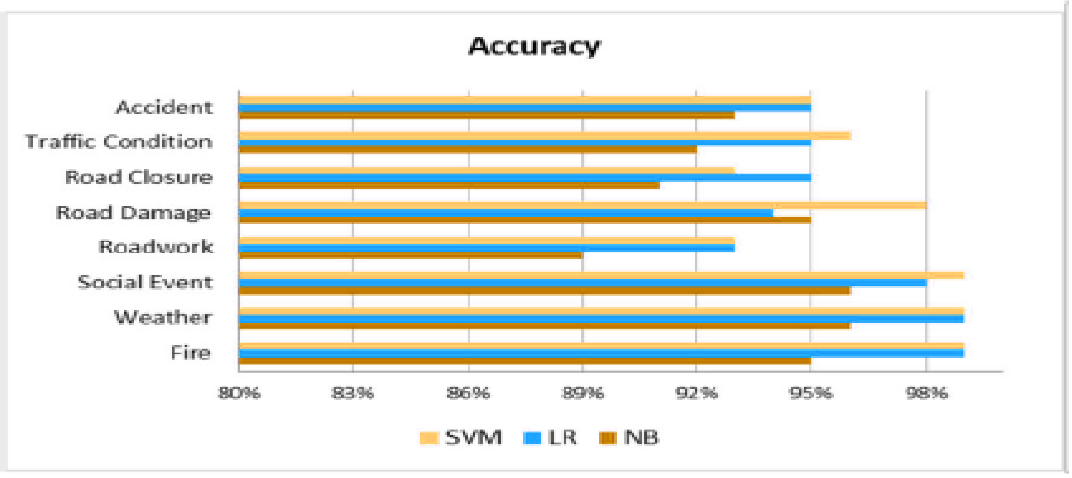
F1 score

F1 Score is the weighted average of Precision and Recall. Therefore, this score takes both false positives and false negatives into account. Intuitively it is not as easy to understand as accuracy, but F1 is usually more useful than accuracy, especially if you have an uneven class distribution. Accuracy works best if false positives and false negatives have similar cost. If the cost of false positives and false negatives are very different, it's better to look at both Precision and Recall. In our case, the F1 score is 0.701.

F1 Score = 2*(Recall * Precision) / (Recall + Precision)

Figure 10.6

Comparison - Accuracy Metric



Accuracy is a metric used to evaluate classification models. Essentially, accuracy is the fraction of predictions the model got right:

Accuracy = Number of correct predictions /Total number of predictions.

Figure 10.7

Comparison – Precision Metrics vs Recall

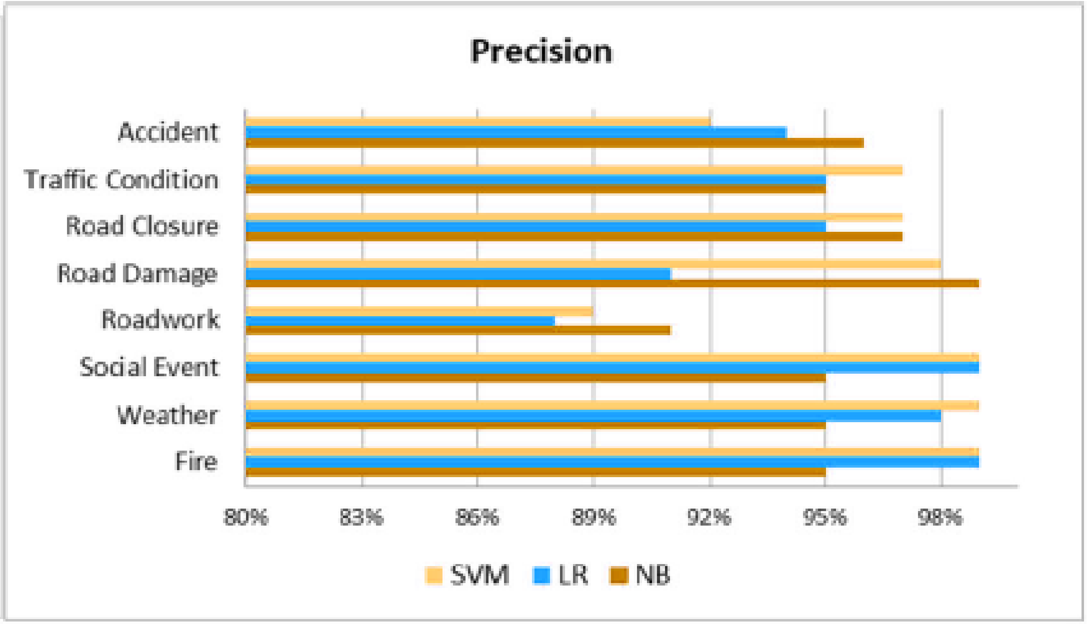
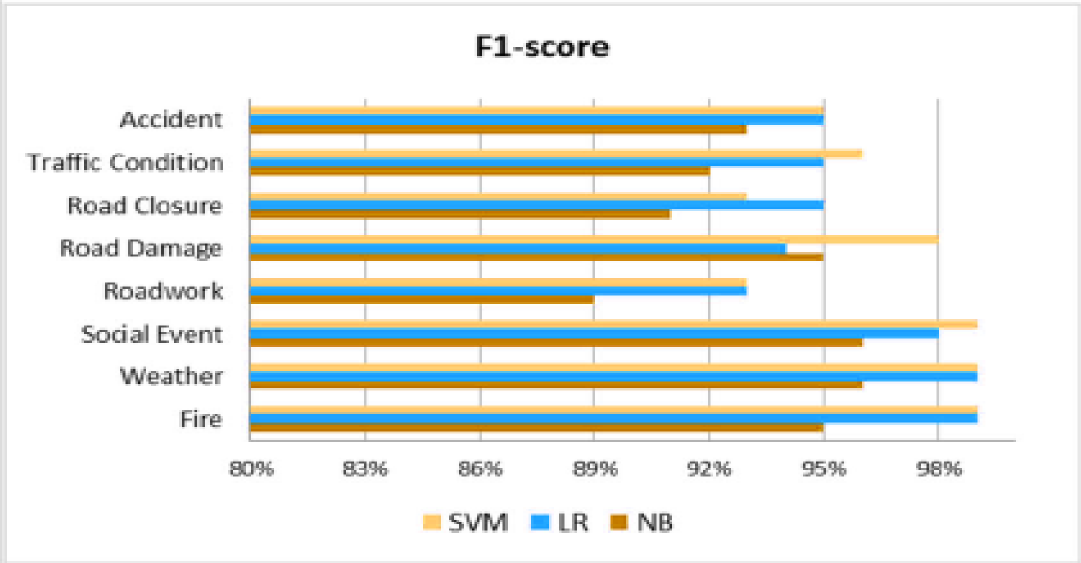


Figure 10.8

Comparison – F-Score Metric



F-Score Metric is a measure of the accuracy of a model on any given dataset. This metric assesses binary classification systems, which categorize examples into either ‘positive’ or ‘negative’. Basically, the F-Score metric combines the recall and precision metrics of a model, and it is interpreted as the harmonic mean of the model's recall and precision.

10.7 Testing the Proposed Algorithm for Smart Parking

Now we shall provide a technical basis for the proposed Smart Parking presented in chapter 8. The main steps for testing in the proposed Algorithm to detect a car's plate number is illustrated with a real example. The process is shown in steps:

In the OCR algorithm, we also used MATLAB to process the plate numbers of vehicles. We have developed a simple algorithm for this goal because it is printed text, not handwriting. We read the image and resize it, then we convert it to grey, then black and white. Then we crop the image to keep the English part. Next, we use the morphology filters to fill each object (character) and remove the small noise from the image. Finally, we separated each object by using the BWLABLE function in MATLAB and drew a red rectangle as a border for each one.

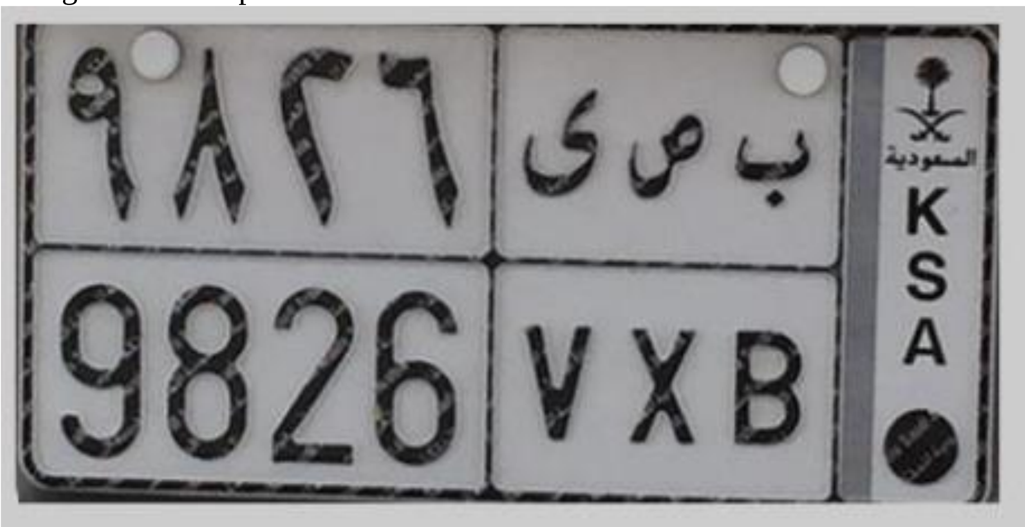
For each object we resized it to be similar to the templates size, then we compared it with each template by using correlation "Corr2 Function" for the similarity rate. The maximum similarity will be the matching object. The steps are shown below

a) Read Image of the Registration Number Plate as shown in Figure 10.9a

b) Convert image to black and white, as shown in Figure 10.9b
Figure 10.9b
Conversion of the number plate to a B &W image

Figure 10.9a

Reading the number plate



c) Crop image and cut just English Part as shown in figure 10.9c

Figure 10.9c

Cropping the number part of the image

d) Use filter (in MATLAB) to process image, as shown in Figure 10.9d

Figure 10.9d

Processing image by filtering

e) Take white letters or numbers from the last image, as shown in Figure 10.9e

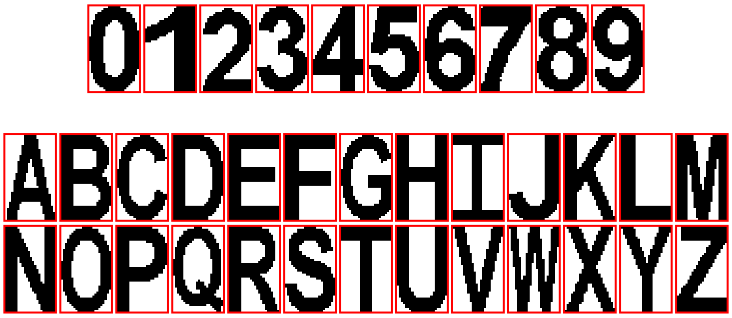
Figure 10.9e

Processing image by filtering

f) Compare each object with a data set and detect it as text, see Figure 10.9f

Figure 10.9f

Detect the registration number



As a result of applying the above steps of the algorithm in the example, the number of the vehicle was correctly recognized as ‘9826**VXB**’.

The next set of figures show the execution of the algorithm on MATLAB. We designed our experiment from this in our case. When the user opens the form, there are six phases for processing in background. The user would show the result of each phase only in axes 1, 2, 3, 4, 5 and 6. Then the end result of the plate number will be shown in the textbox. Firstly, users need to select the image, then the process would start.

10.8 MATLAB Implementation

The main steps of MATLAB Implementation are demonstrated in figures 10.10a, 10.10b, 10.10c, and 10.10d. Figure 10.10a presents the source of the interface that we designed in MATLAB GUI to test our system, where this interface has 6 image boxes to show the results of testing (the phases of detecting the plate number).

Figure 10.10a

Figure of executing the MATLAB code and interface of testing

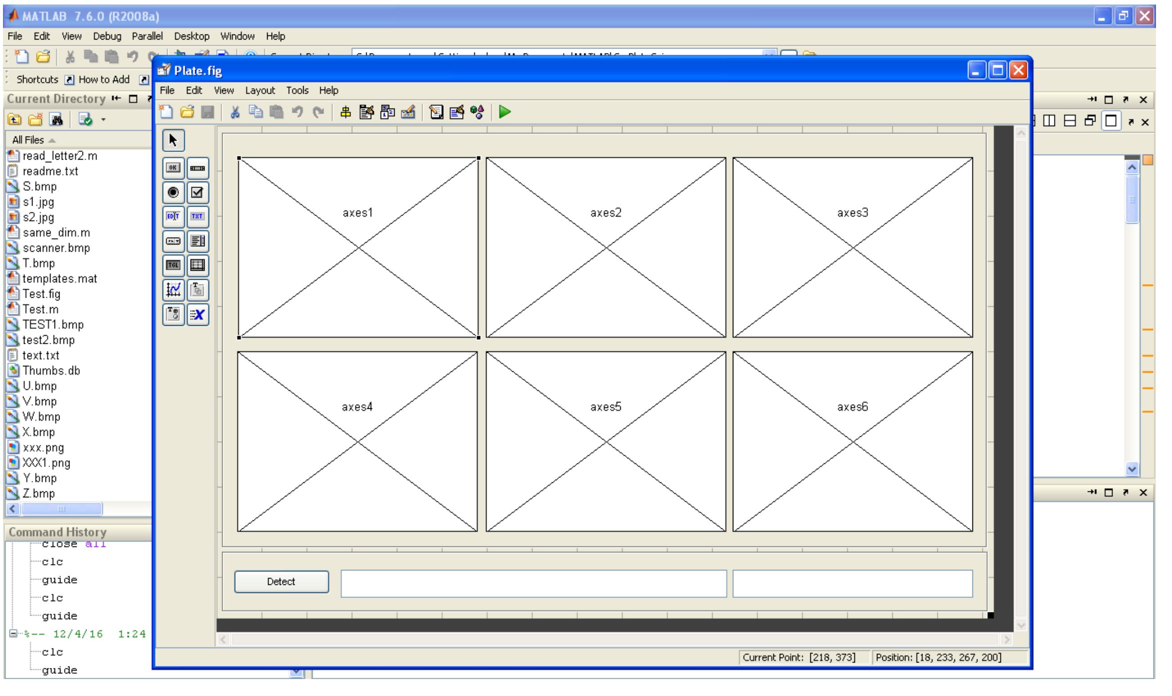


Figure 10.10b

Figure of selecting test image (car plate)

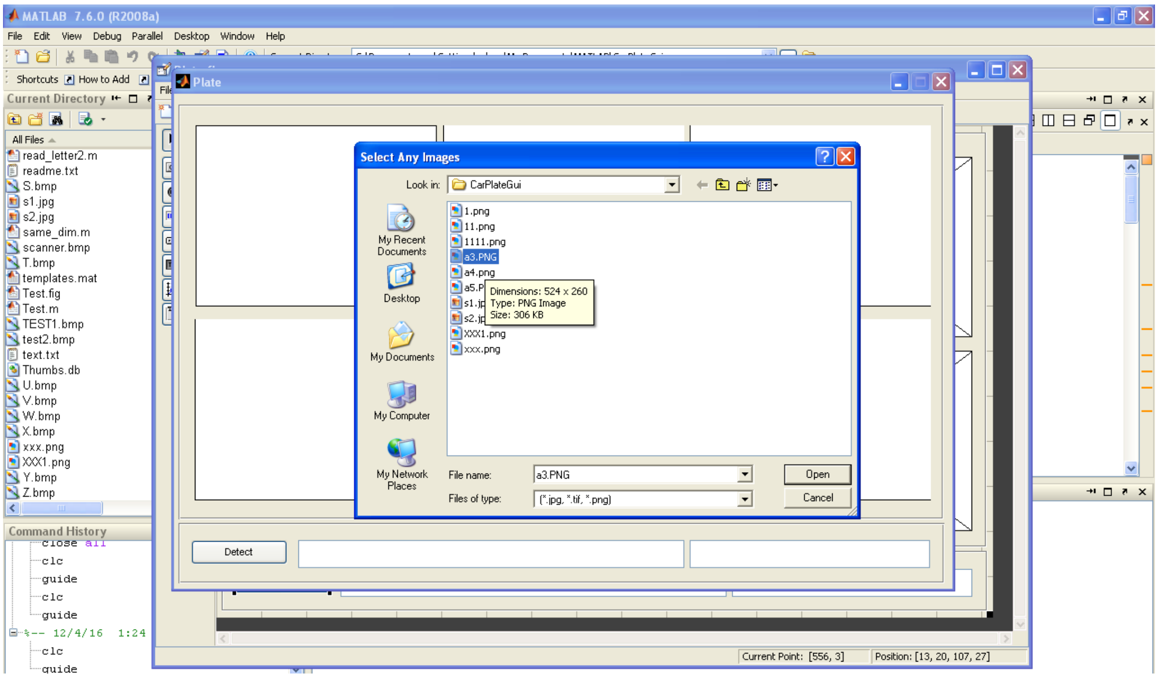


Figure 10.10c

Result after executing first example

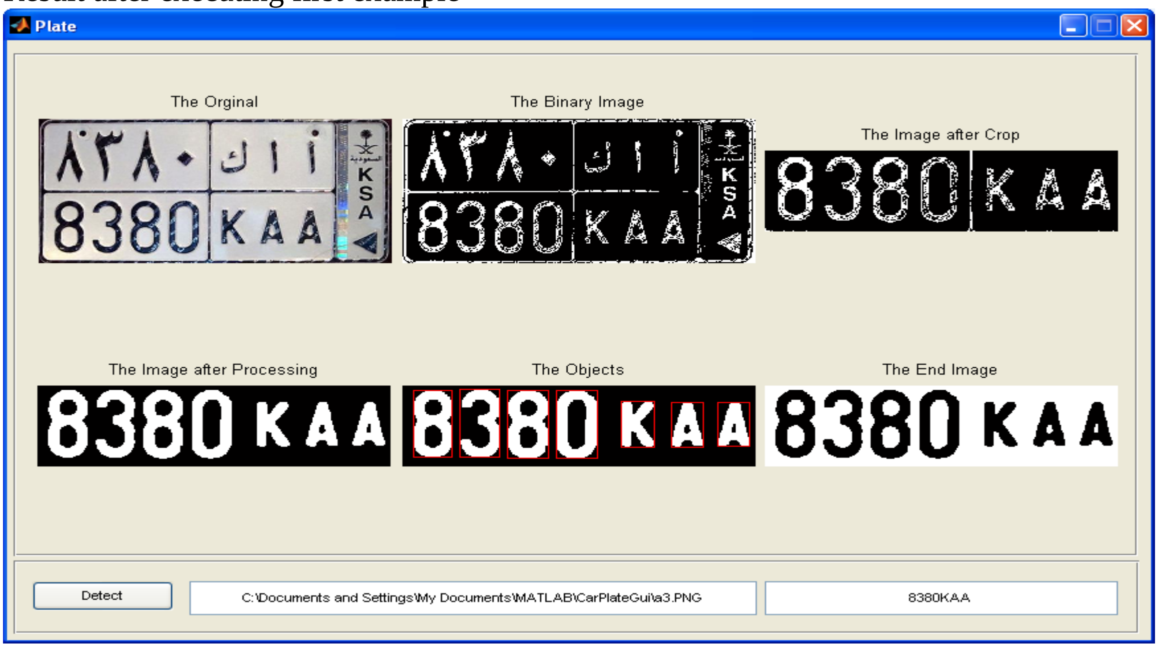
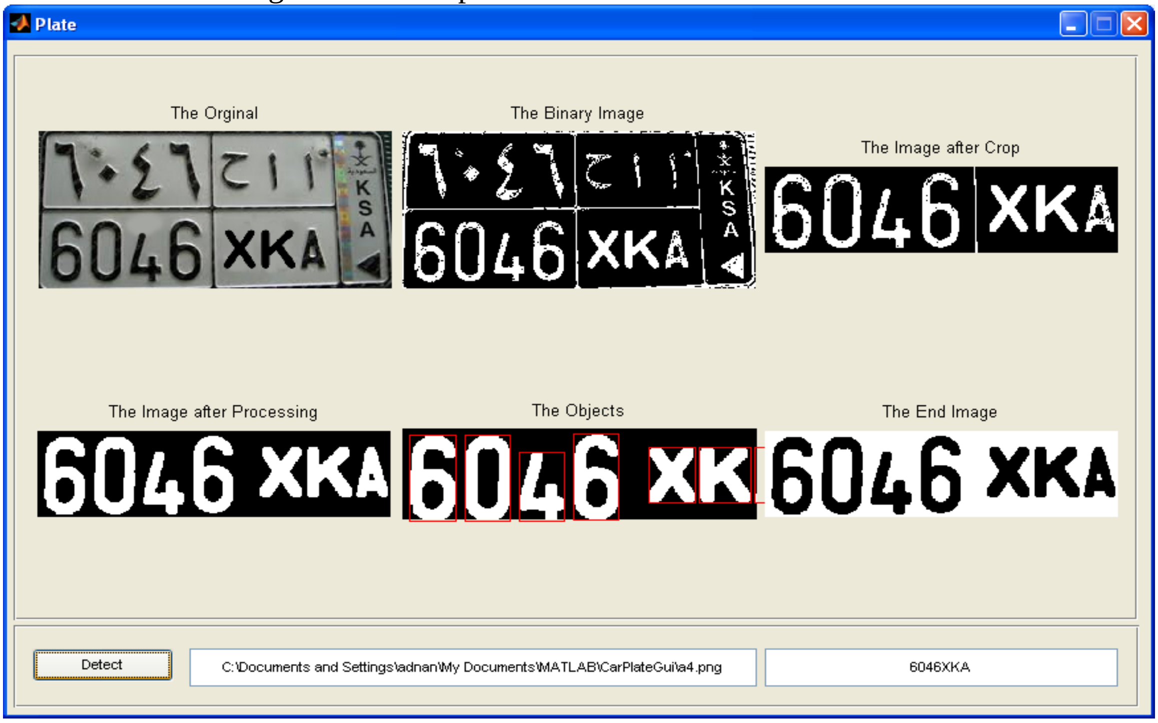


Figure 10.10c

Result after executing second example



10.8.1 Code for Image Processing

Now we present some parts of the of Code for Image Processing

```
function result=FBWlableCar(imagepath)

X = imread(imagepath);%'a5.PNG'
imshow(X); figure;
h=fspecial('unsharp',0.5);
X=filter2(h,rgb2gray(X))/255;
X_bw = 1-im2bw(X,0.2);

[rows cols]=size(X_bw);

imshow(X_bw);figure;
X_bw=X_bw(rows/2+10:end-5,10:9*cols/11);
imshow(X_bw); figure;

%X_bw=imfill(X_bw,'holes');
x6=bwmorph(X_bw,'close',inf);
x6=bwmorph(x6,'close',inf);
```

```
x6=bwmorph(x6,'close',inf);
x6=bwmorph(x6,'close',inf);
x6=bwmorph(x6,'close',inf);
%x6=bwmorph(x6,'dilate',1);
x6=bwmorph(x6,'dilate',2);
x6=bwmorph(x6,'close',inf);
x7=imopen(x6,strel('disk',5));

imshow(x7); figure;
[l n]=bwlabel(x7);
%imshow(l == 1);figure

stat = regionprops(l,'BoundingBox');
imshow(x7); title('The numbers'); hold on;
for cnt = 1 : length(stat)
   bb = stat(cnt).BoundingBox; %% because it struct
   rectangle('position',bb,'edgecolor','r');
end

%figure;
file_name = 'D://XXX.png';
%file_name = 'XXX.png';
x7=1-x7;
imshow(x7);
imwrite(x7,file_name);
%wtime = toc
%fprintf ( 1, '  MY_PROGRAM took %f seconds to run.\n', wtime );
%result=FOCR();
result='the XXX.PNG is created on D driver, use FOCR function to continue '…';
FO''('')
end
```

Recognition Characters

```
comp=[];
load d:\\templates
for n=1:36

   sem=corr2(templates{1,n},imagn);
   comp=[comp sem];
end
vd=find(comp==max(comp));
%*-*-*-*-*-*-*-*-*-*-*-*-*-*-
```

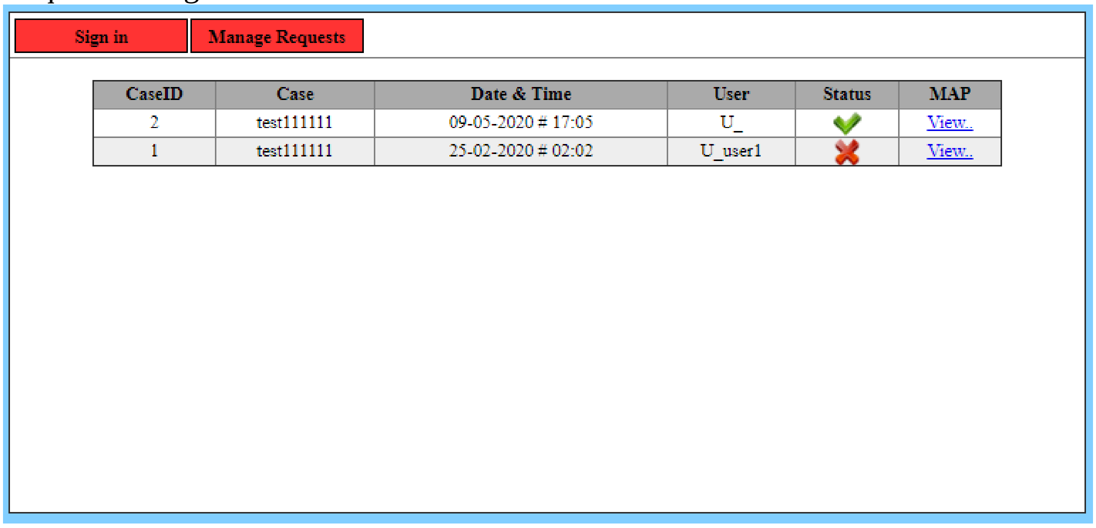
10.9 Ambulance Application

Now we provide technical details used in the Example for Assistant Apps in Chapter 7.
The Ambulance Application is developed by PHP for the administrative side, along with the Android app for normal users. It is an example to show that smart traffic can be effective in many ways in a variety of situations, including health.

This app would enable users to call and effectively access the nearest ambulance. The location of the user would be sent to the Ambulance Management, and the manager of health services would be able to instantly look at the location of the user. Moreover, the manager would also be able to look at the status of availability of Ambulances in the vicinity of the user. In this manner, an ambulance can be sent to the location of the user in very little time. The maximum time of ambulance arrival in urban areas in Australia is 7 minutes. Various steps in the process are depicted in Figures 10.11a to 10.11c.

Figures 10.11a
Login interface of administration

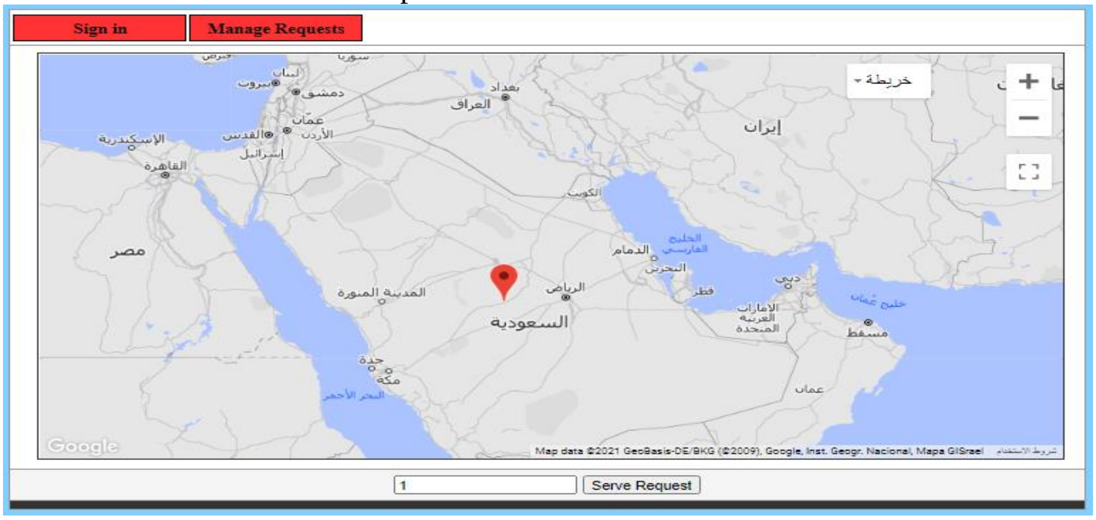
Figures 10.11b
Request management interface



CaseID	Case	Date & Time	User	Status	MAP
2	test111111	09-05-2020 # 17:05	U_	✔	View..
1	test111111	25-02-2020 # 02:02	U_user1	✘	View..

Here admin receive a request with accurate accident location information from the nearest fog node, then admin can send a notification to the nearest ambulance to assist with this incident quickly.

Figures 10.11c
Location of accident on the map



Finally, we provide technical details of the Framework for Preserving privacy of users' locations, which we have presented in Chapter 9.

Many services and applications that are discussed in this work request data, such as the location of users, and that can adversely affect user privacy. So, many users may reject dealing with smart services if there is no trust that this service or system will uphold their privacy and security of their data.

We proposed this framework to be a central base for users to save their locations with a nickname, and then when he or she wants to deal with any other application that requires the user's location (i.e., delivering apps), this app has to integrate with the proposed framework, then user will just put their phone number and a received random generated code to retrieve the nicknames from the base, and then they will select one of them.

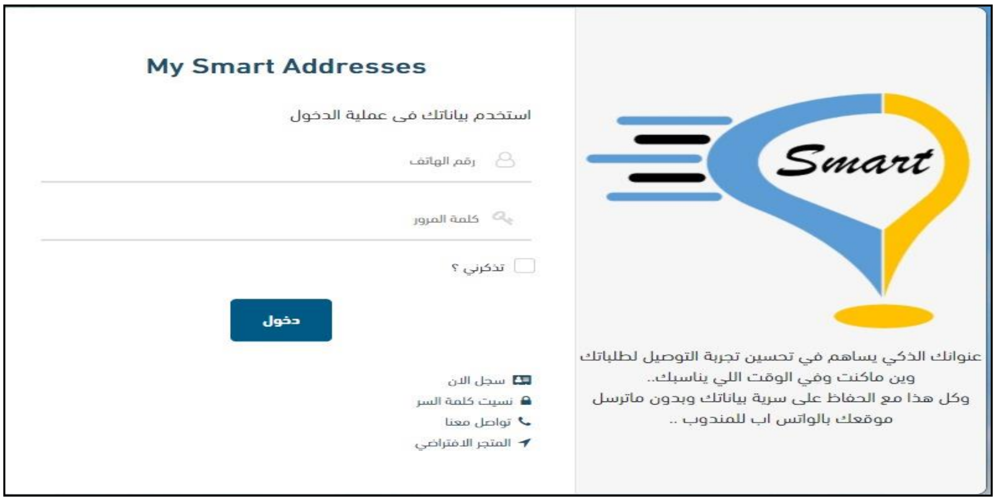
It should be noted that the user will not need to turn on their GPS service after this point, moreover, they will not share their location with any new application or service.

The shared nickname will convert to a QR code. When the driver needs to deliver the order, they scan the QR, then the user will receive the request. If the user accepts, the driver will view the map to the destination location. After this, the QR will become inactive. Hence, the data of user' location will not be saved in any SP database.

In regard to the Proposed Interface for Adding a New Address, the Proposed Interface of Managing Addresses by the User, and the Proposed Interface for Requesting an Order, the operations discussed above are shown in Figures 10.12a to 10.12c.

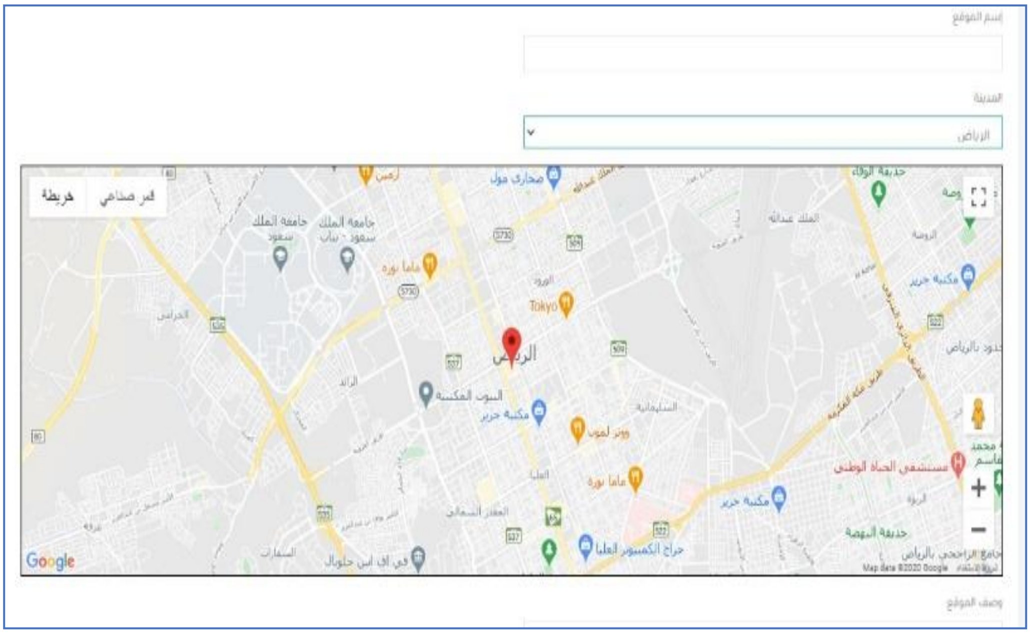
Figures 10.12a

Snapshot of the First Page of Implemented Framework



Figures 10.12b

Location on the map



Figures 10.12c

Example of Generating QR Code on the Invoice

CHAPTER XI - Summary and Conclusions

There is no solution to eradicate all problems of traffic, certainly not overnight. In this research, we proposed a comprehensive system to identify, and solve problems associated with traffic and road users.

We have proposed a framework to build a unified platform that would be a reliable alternative to handle individual traffic issues. As we can see, the proposed system uses the latest technologies which guarantee highly effective solutions to traffic issues. Indeed, we have provided alternative technologies to give a choice in cases of location, environment and costs. As part of the proposed framework, we have provided several novel ideas and critical applications. Our proposals of Smart Traffic Light and that of Parking are novel. Although some researchers have discussed some form of smart lighting, they are not as innovative as what we have provided. We didn't find anything similar to our proposed system of traffic lights in current literature. Researchers have completely ignored the issues of privacy and the security of road users' data. We have provided an extensive and innovative solution to protect privacy and ensure data security of the drivers, vehicle owners and other road users. In particular, we have discussed several privacy protections concepts (TTP, Choice and Accept, and Access control) which have incorporated them to ensure a better level of flexibility in user control over privacy. The proposed platform also saved a lot of effort on behalf of users, so they would no longer need to run a location service or work with maps repeatedly, and the most important thing is to not store their own data in different databases for delivery applications that have recently spread widely.

As far as possible, we have provided algorithms, simulations, and extensive discussions to authenticate our proposals. We hope that the proposed platform would be built and adopted after cooperating with a good number of related applications and services in many parts of the world, especially where congestion and other issues are critical, including the Kingdom of Saudi Arabia. Now we shall provide an in-depth summary of our achievements in this thesis.

A. An innovative and comprehensive framework for traffic management

An innovative and comprehensive framework for traffic management has been proposed, which is backed by a novel model which includes several functions that should be accomplished to reach a satisfactory level of traffic management. The proposed traffic management includes a smart traffic light system which would use Machine Learning, Sensor networks, RFID, IoT and other technologies. The proposed traffic light system would be dynamic in the operational sense and would function in a smart way to clear the traffic at intersections, unlike any existing traffic light system.

The proposed framework of building a unified platform would be a reliable alternative to handle individual traffic issues. As we can see, the proposed system uses the latest technologies which guarantee highly effective solutions to traffic issues. Indeed, we have also provided alternative technologies to give a choice in cases of location, environment and costs.

As part of the proposed framework, we have provided several novel ideas and critical applications. In addition to the proposed Traffic Light system, proposed Smart Parking System is also novel. Although some researchers have discussed some form of smart lighting, it is not as innovative as we have proposed. We didn't find anything similar to our proposed system of traffic lights or that of Smart Parking.

Researchers have completely ignored the issues of privacy and security of the data of road users. We would provide an extensive solution to protect privacy and ensure data security of the drivers, vehicle owners and other road users. In particular, we shall discuss several privacy protection concepts which are being used in different contexts, predominantly associated with location-based services, which are relevant to traffic management. The proposed platform for privacy and security is also easier for the user to use location-based services. We shall provide dedicated applications to access location-based services, which would eradicate the need for them to work with maps repeatedly. That in turn would eliminate the need for users to store their data in different databases for delivery applications which have recently spread widely and are controlled by third parties.

In order to avoid serious accidents due to hazardous conditions on the road, we have proposed ongoing monitoring of the vulnerable sections of roads. Proposed solutions backed by tweet analysis, database management, and data analytics (traditional and big data) would be very effective to save lives and property by avoiding pileups and accidents. We hope that the proposed platform would be built and adopted after cooperating with a good number of related applications and services in many parts of the world, especially where congestion and other issues are critical, including the Kingdom of Saudi Arabia.

B. Smart Traffic Management System

In chapter 4, we have provided a detailed discussion of different levels and functionalities of the proposed Smart Traffic Management System (STMS) framework. Proposed STMS is novel because it deals with most of the critical issues and problems associated with traffic management. The framework depends on many contemporary technologies. In particular, it advocates the use of Fog computing. The Smart Traffic Light (STL), which we have also described in detail, is a centrepiece of our research in this thesis. As can be seen, the proposed STL is remarkably different to any systems in operation globally, and presented by any earlier research, to the best of our knowledge. The system is based on accurately assessing the congestion levels on different streets, by means of three different methods, including Machine Learning. Based on the congestion level, the traffic lights will be managed dynamically. We have provided algorithms and implementation details including simulations of the machine learning method on real traffic frames in Chapter 10.

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C. Smart Traffic Lights for managing Intersections

Smart traffic light (STL) is one of the central and most important components of the proposed STMS. Some of the common causes of congestions are inadequate roads, indiscipline, and poor management of traffic at intersections. Controlling and managing traffic at busy intersections is an important issue to the whole world. To regulate smooth traffic movement, busy intersections require development, installation, maintenance and management of Traffic Lights. Traffic congestion at intersections is one of the problems which can be fully or partly solved by applying available technology and tools in deploying Traffic Lights. Given the need of millions of intersections in individual countries, considerable investment is required but that would be justified due to the benefits, including possible reduction in road related deaths and injuries. Alternative solutions, namely construction of bridges, tunnels, and multilayer roads, are even more costly than the cost of technology to manage intersections.

D. Integration of new technologies for transformation to smart transportation

Proposed STMS uses many modern technologies and tools including IoT, Wireless Sensor Networks, Digital Street, RFID, Cloud Computing, Fog Computing, Image Processing, High Resolution Digital Cameras, Tweet Analysis, data management, big data analytics, and decision support systems. These technologies themselves inherit several other technologies. These technologies will be required to realise different levels and models. For example, assessment of road conditions at selected places is a task often neglected by most of the city administrators. They only wake up to the reality when they see some nasty accidents due to fire or the black snow cover on the road. We have advocated continuous monitoring of vulnerable sections of roads to avoid hazards and crises. This activity would generate a huge amount of data, which would require big data analytics. Other activities in the STMS framework also generate large volumes of data to be analysed. One may argue that these are costly exercises. However, saving lives is much more important than saving money. These technologies and tools combine to provide novel solutions to manage and solve most traffic related problems, create and spread awareness, and provide guidance to road users.

E. Tweet mining and their classification

The STMS, when in operation, would generate enormous data, which would include vital information to guide future traffic management. We advocate text mining, as part of Natural Language processing (NPL) on the data generated by different layers of the STMS. Part of the information can also be gained from tweet analysis. All the historical and operational data from different processes of the STMS can be stored in a multi-purpose database system or data store, which could allow big data analytics, in addition to conventional ways of analysis. Then stored data can be mined to extract useful information, which can be stored in a knowledge base. This aspect of traffic management is often neglected by most traffic management organisations. In this way, the traffic management can use this information to make informed, improved and justified decisions. As part of STMS design and implementation, we have provided full details of text mining and tweet analysis, supported by appropriate algorithms to extract relevant information from tweets.

F. Mobile application for tracking the status of main streets and sending notifications to users

Many disasters could be avoided if the road status is continuously scanned at vulnerable locations. In extreme heat or cold situations, and proper warning and awareness of the potential hazards on the roads should be communicated promptly to road users. Timely information can efficiently be gathered by continuous monitoring of road conditions on vulnerable points. We have provided methods and ways for monitoring the status of roads and streets at vulnerable sections. As shown, the STMS framework is supported by several APIs to update the status of streets in several respects like pollution, accidents, road closures, environmental hazards, and other issues. We shall provide details of these APIs.

G. Taking Advantage from the Historical Data

Data which is generated by managing and serving streets is very useful for future improvements. It involves creating useful historical data and applying Machine Learning (ML) and Data Mining (DM) algorithms to extract useful information from the historical data (accidents and traffic data by the time) for decision support.

The STMS framework has a component of Machine Learning (ML) and Data Mining (DM). The first step for realising these is to create historical data about roads, accidents and other events, which requires database skills and Machine Learning. The historical database would very soon contain a huge amount of data, requiring data mining skills.

H. Smart Parking and other assistant applications

Smart parking is one of the most important components of the assistant applications included in the STMS architecture. The proposal of assistant applications for smart transportation also includes Pollution Reading and Updates, Managing places of interest (POIs), management of public transportation, marketing, and safety. It is evident that proper implementation and management of these applications can effectively reduce congestion and improve overall traffic management.

Finding parking, mainly at the peak times in town and city centres, contributes to congestion. One of the components of the proposed model of traffic management is Smart Parking. What we have proposed in Chapter 8 for Smart Parking is innovative and novel as it would propose a fully automated parking system with many options including remote booking and cancellations. The proposed system uses modern technologies including Sensor networks and RFID. In particular, as part of future research, we have provided a framework for Smart parking using an API to update the status of parking in different locations. Full details of this research are presented in chapter 9.

I. Privacy and Security of Road Users

Road users encounter several services where they are required to furnish their personal details, including their location address, vehicle registration details, date of birth, and financial details. Registration office, toll collectors, credit collectors, APIs, and many location-based services (LBS) would often seek such information from road users. These details, or even one of them, are enough to get full access to users' personal information and their whereabouts. If this kind of information is possessed by scrupulous people and criminals, there can be serious implications to property and health of the concerned road users. In particular, the Service Provider (SP) of LBS cannot be trusted so there must be mechanisms in place to hide personal information from SPS. Most traffic management do not offer any privacy protection mechanism for road users as part of traffic management.

We have provided a new approach (with multi-methods) to address privacy and security issues in the Transportation domain. As part of the STMS, we have also provided a framework to protect privacy and security of road user data. This framework takes most of the well-known privacy methods into consideration. As part of future research, we shall provide an overview of privacy methods available to protect the privacy of service users in location-based services. We have also provided a new method to safeguard the privacy of road users.

We have also demonstrated the effectiveness of the proposed system by applying it to crowded streets. Our solutions are parts of a comprehensive framework. In this thesis, we have also discussed security, privacy and trust aspects associated with road users and transport users.

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Appendix A

List of Papers, where the candidate is an author

1. Alharbi, A.S., Halikias, G., Rajarajan, M. et al. A review of effectiveness of Saudi E-government data security management. Int. j. inf. tecnol. (2021). https://doi.org/10.1007/s41870-021-00611-3 (Indexed in Scopus)
2. Alaboudi, A., Alharbi, A.S. Impact of digital technology on Saudi students. Int. j. inf. tecnol. (2020). https://doi.org/10.1007/s41870-020-00451-7 (Indexed in Scopus)
3. Alharbi, A.S., Halikias, G., Yamin, M. et al. An overview of M-government services in Saudi Arabia. Int. j. inf. tecnol. 12, 1237–1241 (2020). https://doi.org/10.1007/s41870-020-00433-9. (Indexed in Scopus)
4. Alaboudi, A., Alharbi, A.S. Impact of digital technology on Saudi students. Int. j. inf. tecnol. (2020). https://doi.org/10.1007/s41870-020-00451-7 (Indexed in Scopus)
5. S. Alharbi, S., Halikias, G., Basahel, A. M. et al. Digital Governments of Developed Nations and Saudi Arabia: A Comparative Study. IEEE Xplore Proceedings of 7th International Conference on Computing for Sustainable Global Development (INDIACom), New Delhi, India (2020), pp. 255-260, doi: 10.23919/INDIACom49435.2020.9083686 (Indexed in Scopus and SCI)
6. Alharbi, A. S. Challenges in Digital Transformation in Saudi Arabia Obstacles in Paradigm Shift in Saudi Arabia. IEEE Xplore Proceedings of 2019 6th International Conference on Computing for Sustainable Global Development (INDIACom), New Delhi, India (2019), pp. 1287-1291. (Indexed in Scopus and SCI)
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12. Alharbi, Awad. An Evaluation of Cloud Computing among Technical Colleges in Saudi Arabia. American Academic & Scholarly Research Journal (2016). Volume 8(6). Available: http://aasrc.org/aasrj/index.php/aasrj/article/view/1887

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