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Title: Intelligent Transportation System in Developing Countries.

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Abstract:

With the rapid urbanization, smart city concept is becoming popular day by day. One of the major element of the smart city is its transportation system. To make the traffic management system better different technologies have been used in different developed countries. However, the scenario is different in many developing countries. They have to face several challenges when it is about to implement an Intelligent Transportation System. The aim of the thesis is to shed light on those challenges faced by developing nations. The study will also explore how emerging technologies such as, Artificial Intelligence and Deep Learning can help the developing countries to overcome all of their challenges as well as current problems in the transportation sector to make their life better, safer and easier. But using these technologies in the transportation requires to process tremendous amount of data that can have a pernicious effects on a citizen's privacy. So the project will also consider these privacy issues and will discuss how to mitigate them.

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Chapter 1: Introduction

A smart city can be described as an urban improvement vision which integrates or merges information and communication technologies, large infrastructure, digital frameworks, security with economic and social feasibility (Dubey et al., 2017). The objective of any smart city should be improving citizen welfare as well as quality of government services so that they can ensure the better quality of life for residents, economic competitiveness for different industries and a sustainable environment. With the help of ICT, city authority can communicate straightforwardly with the residents to broadcast the events in the city as well as provide updates on how the city is developing. In order to handle all the inefficiency, information and data need to be assembled which can be gathered from various sources using different sensors (Rizwan, Suresh, & Babu, 2016).

As stated by the United Nations Population Fund, in the year of 2025, 64% of the world's population which is approximately 5.2 billion people, will live in urban areas. By 2035, this number will be roughly 66%, or 6 billion people. This represents a massive challenge of how we are going to build and manage cities in a way that will improve the lives of billions of people. To cope up with that challenge, engineers worldwide are searching for new approaches and solutions to improve city transportation, water and waste management, energy usage etc. With the availability of new technology such as the Cyber Physical Systems, 5G and data analytics, it is now possible to improve the operation of cities and the lifestyle of urban citizens (Sharif et al., 2017).

One of the major elements of a smart city is the Traffic management system. As population is growing rapidly in metropolitan cities, urban mobility is increasing, causing traffic congestion on roads to become a common feature. But nowadays, traffic clearance is not the single major priority of traffic management. Pollution and accidents, etc. have become major problems which need to be tackled for a better ecosystem as well as a hassle free transport system. However, traffic jams do not just kill people's time, in some cases, it causes criminal activities such as snatching of mobile phones at traffic signals in certain crowded metropolitan cities (Javaid et al., 2018; Dubey et al., 2017).

So in order to reduce the high rate of accidents, prevent traffic congestion, minimize carbon emissions and air pollution and to increase the safety and reliability along with better traffic flow- Intelligent Transportation System plays a crucial role. This novel technology can be deployed in different fields such as transportation management, traffic control and so on (Qureshi, & Abdullah, 2013).

The universal purpose of ITS is to make decisions based on static or real-time traffic information. ITS tools are able to collect, process, integrate and supply information around transportation networks. After processing the collected data, an ITS can offer real-time information about current road conditions to the authorities and individual travelers in order to help them make better, safer and smarter decisions. Compared to traditional traffic management systems, ITS incorporates different technologies (wired, wireless or Artificial Intelligence), communications-based information processing, electronics and control algorithms into the system's infrastructure and in the vehicles themselves; to improve safety, reduce congestion, and enhance productivity (Paul et al., 2016). However, as this system needs a ton of data for processing and decision making purposes, it faces some challenges regarding privacy and security issues.

1.1 Motivation:

This study will focus on how the Intelligent Transportation System differs in the context of developed and developing countries where the problem of congestion, capacity and safety affects the mobility of people in developed and developing nations in a similar way. The goal of deploying the Intelligent Transportation System is to improve efficiency as well as safety of the road transportation system and there are a huge number of success stories in various developed countries like Japan, South Korea, Singapore, United States, Australia and United Kingdom (Singh, Bansal, & Sofat, 2014).

There are different technologies that can be used in the field of ITS and for that reason the transportation model differs across different countries. With the current technological trend, Artificial Intelligence and Deep Learning became very popular for developing Intelligent Transportation Systems and this research aims to analyse the implications of adopting these technologies for an ITS. But using these technologies in the field of ITS require to analyse huge amounts of data which can raise several privacy and security concerns which will be taken into consideration in this project as well.

However, benefits of ITS infrastructure have not been explored yet by many developing countries for improving their operational efficiency of existing infrastructure. In many cases they are unable to utilize ITS technologies as it requires huge investment. Nevertheless, developing countries can always have a latecomer advantage in the development of ITS systems. They can adopt existing proven ITS technologies from the developed countries to make the ITS deployment much cheaper (Khan et al., 2014). However, the situation is quite different in developing countries compared to a

developed one. There are several challenges a developing country has to face while deploying such a system which will be explored in this study.

1.2 Problem Definition:

The objective of the project can be summarized in the following research questions:

- *What are the challenges a Developing country has to face while deploying a smart traffic system?*

To answer this question we will compare the situation of both developed and developing countries using the PESTLE framework. The challenges or external factors that influence the deployment of an Intelligent Transportation system will be presented in terms of politics, economics, social norms, technology as well as environmental factors which are the components of the PESTLE framework. In the next step, we will look into the technologies that can help the developing countries to overcome different challenges and problems in the transportation sector which leads the next research question:

- *What are the implications of Artificial Intelligence and Deep Learning in the field of Intelligent Transportation System to make a better traffic management system that can create value for both the Government and citizens of a developing nation?*

The implications will be discussed in terms of service features, technology, and value chain which are the components of the digital ecosystem framework. Finally as mentioned earlier there are several privacy and security issues related to ITS which are too important to ignore and generates the last research question of this thesis:

- *What are the privacy and security related issues an Intelligent Transportation System has to deal with and how they can deal with these issues in the context of a developing country?*

However, to answer this question we will use the last component of the digital ecosystem (Societal Environment) as this element considers the barriers for a business or a service.

Nevertheless, the reason we will consider the situation in developed countries as well is to get the idea of how they are using different technologies to solve different problems which can be applied in the scenario of a developing country.

1.3 Structure of the report:

In the next chapter; Chapter 2, the methodology will be presented to give the idea of what kind of empirical evidence is being used in this study and how this information is being obtained. In Chapter 3, analytical frameworks that will be used for analysis will be discussed to give the reader a general idea about the frameworks. Chapter 4, 5 and 6 will present the literature review focusing on the overall structure of Intelligent transportation system, AI and Deep learning technology in the field of ITS and privacy issues related to ITS respectively. Chapter 7 will present the actual obtained empirical evidence of the case study where the findings of the expert interviews will be discussed in Chapter 8. In chapter 9 the empirical evidence together with the theory will be analysed. Finally, a discussion of the findings will be presented in chapter 10.

1.4 Potential Limitation:

The aim of the project was to conduct expert interviews with several people, with different backgrounds from different countries. Even though a lot of people were approached for interviews, the researcher did not succeed in getting more than two interviews. But the positive side was one interview was from a well-known Danish company and another one was a recent startup in Bangladesh. So both were valuable to evaluate the difference between developed and developing countries.

Another limitation was that this research did not dive deep into the policy factors that can be used to solve privacy issues due to data scarcity.

Chapter 2: Methodology

In this chapter, we will discuss the methodological approach for the project. In order to visualize all the steps that are interlinked and will be performed over the duration of the project, a diagram will be created. However, a mixed-methods approach will be used here combining the case study along with expert interviews to conduct this thesis. A mixed methodology case uses a qualitative-quantitative approach where qualitative work (literature review, case study) with expert interviews is the primary source to collect data. Nevertheless, quantitative analysis of the expert interviews can reduce researcher bias and can increase the credibility of the findings. Finally, a deductive approach will be used in this project where the hypotheses are being developed first based on existing theory, and the findings will be served as an exploratory analysis (Muskat, Blackman, & Muskat, 2012). A clearer explanation of using the cases can be read in subsection 2.2. And, Subsection 2.3 will include more details about the expert interview.

2.1 Overview of Methodology:

As shown in the figure below, the blocks represent the methodological flow that will be conducted throughout the whole project. After choosing the topic, the sequential step was to gather and review literatures of relevance to get an overview of the intelligent transportation system, what are the applications, what kind of technologies are being used in this field. Though there are different technologies that have already been used in a conventional way, using advanced technologies like Artificial Intelligence and Deep Learning can bring dramatical change in the field of ITS. Again these technologies require huge data processing which raises privacy and security concerns. So, for the technical aspects of the problem formulation, the aim is to acquire a deeper understanding of Artificial Intelligence and Deep Learning as well as the privacy issues related to the ITS, which will be discussed broadly in separate chapters as a part of literature review.

Analytical framework will be chosen through which case studies will be conducted as well as analyzed along with the findings from expert interviews and literature review. After analysing all the information gathered in every part of the project the research questions will be answered.

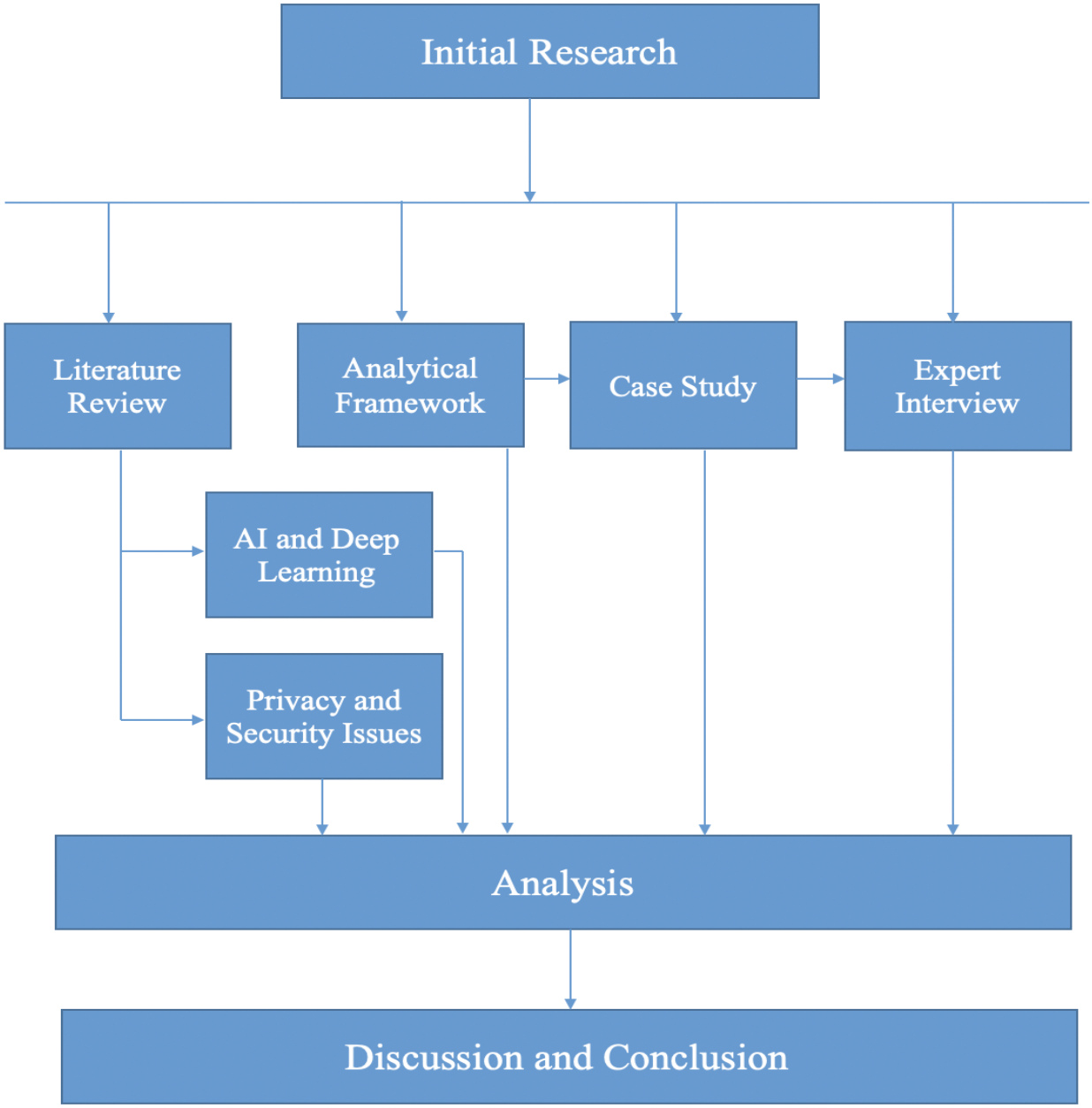

Fig 1: Overview of Methodology

2.2 Case Studies:

Typically, a case study can include organizational decision-making, community studies, innovative projects, economic development, and so on. Case studies are quite commonly used for either descriptive or explanatory purposes, to describe and evaluate different situations or to test explanations of a specific event. Case studies can be utilized as good empirical evidence that can provide qualitative data to get a better overview of a technology as well as a company (Yin, 1981).

Here, five case studies will be presented to get a better idea on how Artificial Intelligence and Deep Learning can help promote Intelligent Transportation Systems. The project decided to use analytical framework (PESTLE and Digital ecosystem) for investigating the case studies. Among five of these cases, three of the companies are based on developing countries and the rest are on developed regions. All cases will be compared with each other to gain a greater understanding about the differences between developed and developing nations; how developing countries can solve their challenges inspired by developed countries.

2.3 Expert interviews

The case study research is being followed up by the interviews with the experts in the field. The aim of the interview is to gain a greater understanding about the technology, the external factors that have impact on this particular system as well as legal and privacy issues. It is important to understand what the experts believe about the implication of Artificial Intelligence and Deep Learning to promote Intelligent Transportation System. Another focus of the interview is to find out the geographical impact on their businesses as well as their personal experience regarding the drivers and barriers in the field of traffic management. Nevertheless, Linkedin and gmail will be used to communicate with the interviewees and the interviews will take place on a computer which will also be used to record the interview with the software program QuickTime player. The transcribed interview will be presented in Appendix.

However, for the initial research phase, relevant literature has been obtained and reviewed to provide the foundation of this thesis and for that, the databases of IEEE, ACM Digital Library, SpringerLink, Google, and Google Scholar were used.

Chapter 3: Analytical Framework

For investigating the case studies as well as analysis purposes, the project will use the perceived attributes of PESTLE and Digital Ecosystem framework which will be discussed in this chapter briefly. PESTLE analysis will help us to understand how ITS system is affected by external factors/barriers where with Digital Ecosystem we can find out how a company can create value in terms of safe and efficient traffic management.

3.1 PESTLE Technique:

Businesses exist in an environment that is subject to a range of internal and external uncertainties. The ability to ascertain and analyse the extent to which these risks can affect business outcome is largely significant in today's competitive market environment. Businesses that are proactive in identifying and engaging to possible risks are usually the most adaptable and have a high chance of survival.

Almost all elements of risk can be placed under two broad categories: internal and external risk. Internal risks are those that are within the control of the company, and are generally specific to the nature of work, project, etc. External Risks are more centered around risk factors that the company does not have the ability to control. However, these factors often influence the ability of companies to survive or succeed in a competitive market. Given the extent to which External Risks can affect a company's fate, there has been significant effort towards trying to establish a generally accepted norm for analyzing that risk. PESTLE Technique is one such tool, derived from Strategic Management Techniques of Business Management.

The acronym PESTLE signifies the following external aspects: political, economic, social, technological, legal and environmental. The PESTLE technique uses each of these aspects to anticipate the extent to which external factors will manipulate business outcomes. This is especially important in ensuring that projects are successful since they operate in a dynamic external environment (Rastogi, 2016).

The Political factors are often governmental policy that dictates the terms for regulation of a particular company or industry. These can range from international trade policies such as import quota and tariff to broader fiscal, monetary and supply side policies (Rastogi, 2016). To implement an Intelligent Transportation System the political factors are quite important. For constructing a

smart transportation system, it requires governmental support such as funding and favorable policies.

The Economic factors are those risks that are driven by the economic reality in which the business operates. Macroeconomic instruments such as inflation rate and GDP growth alter how a company can price their product and determine how willing consumers would be to spend money on the good or service the company is offering to provide (Rastogi, 2016). The economical growth of a country has a huge impact on ITS which will be discussed in the case study section.

Businesses do not operate in a void; instead they work as a societal function that constantly interacts with societal actors. **Social factors** in PESTLE aim to encompass the nature of those interactions. All business projects need to be cognizant of these elements such as the cultural norms, demographic composition, religious views and attitudes (Rastogi, 2016). This factor is also important as successful implementation of a smart traffic system depends on the attitude and behavior of the citizens.

With our gradual transition to a more innovation-based society, **technological factors** have also become an important influence in the business scene. With more and more automation and our constant quest for data centric information gathering and processing, the progress of technology has the power to determine how an industry will be shaped, which in turn shapes businesses and project decisions (Rastogi, 2016). Using the new and advanced technology for ITS can change the whole transportation system of a country.

Legal aspects of a business's external environment pertain to the laws of the land that create a parameter for the projects to operate within. This includes employment laws, tax laws, export and import regulations, quality standard, etc. These are most non-negotiable statutes or government policies that are enforced to the letter of the law. Legal analysis is important to identify the extent to which each of the relevant policies would affect the project's profitability or sustenance (Rastogi, 2016). As we will discuss the privacy and legal issue related to ITS in a separate chapter, this factor will not be taken into account while conducting the case study.

The last category has gained significant traction of late. Analysing **environmental factors** such as climate, weather, geographical locations, climate change are integral to understand the way a project is going to affect the community and the environment. It is important to identify different environmental phenomena such as seasonal weather pattern changes or natural calamities. (Rastogi, 2016). One of the major advantages of the Intelligent Transportation System is it can help to reduce

CO2 emission. However, we will see in the case study how different countries are using this system for a sustainable environment.

While it is admittedly impossible to predict all external elements that can affect a project, PESTLE significantly reduces the unpredictability and encourages decision makers to have a structured way to respond to issues as they arise.

3.2 Digital Ecosystem:

Ever since the industrial revolution, our society has pushed for a more efficient way of conducting business. By decreasing dependencies or establishing a competitive advantage, businesses are trying to make their systems and processes more conducive to the business environment it operates in. Business ecosystem, a term first coined by Moore, was a way to focus on a few components that directly pertain to a business' basic functionality. Moore's suggested concept of business ecosystem included customers, lead producers, competitors, etc. (Moore, 1996). This concept revolutionised how we viewed stakeholders of a business. There was however one major criticism of the Business Ecosystem concept, as it does not consider the influence of modern day technological advancement on business. It is plausible that Moore had understandably failed at foreseeing how big the internet and our modern computer system will turn out to be, which resulted in a need for an alternate concept to further build on Moore's initial Business Ecosystem notion (Peltoniemi, & Vuori, 2004).

The inclusion of a digital component first came about in 2002, and a new term 'Digital Business Ecosystem' was introduced. This umbrella concept was designed to explain the catalytic effect of the technological advancements in the business ecosystem (Hoyer, & Stanoevska-Slabeva, 2009). According to Hoyer and Stanoevska-Slabeva, there are six key elements in the Digital Business Ecosystem. To effectively analyse an ecosystem, a comprehensive understanding of the following elements is crucial.

Features of the specific product or service: It is important for the Digital Ecosystem to constantly keep in mind how important the features of a specific product or service are to the end consumer. So if a company's service is ride sharing, they need to have an ecosystem that allows for riders to pick up passengers from their current location, if that is what the consumers are looking to get out of this. Knowing this would enable the decision makers to prioritise the sanctity of any component that directly affects this particular expectation of ride sharing (Hoyer, & Stanoevska-Slabeva, 2009). In

the case of Intelligent transportation systems, the scope of services and companies' ability to address the needs of various services to make the traffic management system better will be the main point of focus.

Features of the specific medium (technology): While the features of the actual product or service is important, Digital Ecosystem uniquely focuses on the importance of having a technological medium through which customers interact with the service or offer. This might look like a mobile application, or a desktop software, or any amount of customisation that is done to give a smoother experience to the customers. In this age of information collection and analysis, this is especially important since companies invest a lot of resources to identify what medium maximises user convenience, and actively discourages any technological medium that is unintuitive or complex (Hoyer, & Stanoevska-Slabeva, 2009). Different technologies will be taken into consideration to evaluate their efficiency while they have been used for intelligent transportation systems.

Value Chain: The market is becoming more and more dynamic and businesses have to be more adaptive to cope up with that. The extent to which this dynamism affects the value chain of a business, depends on customer expectations, how adaptive competitors and supply chain are. Incorporating digital means to make that value chain more potent and responsive might as well be the distinguishing factor between two competing businesses. While all factors within the value chain are interdependent, a concentrated push to improve one aspect of the chain will likely have a lasting effect on the subsequent components within the digital ecosystem. This component also shed light on the automation of the process (Hoyer, & Stanoevska-Slabeva, 2009). For the purpose of this research, the scale of operations of Artificial Intelligence and Deep Learning will be taken into consideration as these technologies are responsible to automate the whole transportation system.

Financial Flow: Most businesses exist to make money in excess of the amount of money they spend in making the good or service a success. Digital ecosystems have the probability to make the process automated and with maximum cost reduction (Hoyer, & Stanoevska-Slabeva, 2009). However this factor will not be taken into consideration while conducting the case study.

Societal Environment: This entails different factors such as barriers or legal aspects that might have influence on the business model. (Hoyer, & Stanoevska-Slabeva, 2009). Assessing the societal

environment will enable us to find out the drivers and barriers a company has to face in the field of Intelligent Transportation System.

For a business to operate effectively and efficiently, especially in a competitive market, there is little alternative to digitizing. The Digital Ecosystem has been a revolutionary next step in our understanding of how businesses around society would adapt to advancement in technology.

Chapter 4: Literature Review

This chapter will give a broad overview of ITS system along with different technologies which are being used in this sector and some scenario of the current situation of ITS in both developed and developing countries. .

4.1 Intelligent Transportation System:

Day by day traffic management has turned into one of the major concerns for any urban city with the increasing number of vehicles. One solution can be an increase in the growth of infrastructure but it is ineffective in terms of cost, effort and time. Therefore, countries around the world are looking towards using ICT technologies to develop efficient traffic management systems. The recent advancements in Wireless Sensor Networks(WSN) and low power consuming sensors which are cost effective have made it easier to create an intelligent transportation system. The tiny sensors which already showed impressive results across different fields starting from the health sector to surveillance and home automation to industrial practices, can be used to map entire cities in order to collect important data. With the popularity of IPv6, it is now possible to allocate a sensor node along with an IP address for tracking and also for gathering real-time information regarding traffic flow, traffic congestion, etc. Not only that, but also for vehicle classification, speed calculation and vehicle count these sensors can be used. However the collected data are diverse in nature; thanks to machine learning algorithms which are able to extract meaningful information form these huge chunks of collected data using efficient data analytics. Using Deep learning and Machine learning algorithms, the levels of traffic congestion can be predicted for a particular area of a city (Khanna et al., 2018).

By Intelligent Traffic System, we refer to a system that integrates a variety of tools such as traffic engineering concepts, software, hardware and communication technologies to improve a city's efficiency and safety. Among the various countries around the world that work on providing infrastructure and the required set-up for ITS, the United States and some of the European nations have already started developing and implementing ITS starting from a ground level (Dubey et al.,2017). In this section, we will describe how different technologies such as short term traffic prediction methods (parametric, non-parametric and artificial intelligence), data mining, deep learning, swarm intelligence and agent based techniques can be used to make a smart traffic system

by traffic analysis, prediction, scheduling and management (Chavhan, & Venkataram, 2019). We will also look into different ITS models, their advantages and world wide scenario of this smart system.

4.2 Technologies in ITS:

The Intelligent Transportation System integrates current and growing technologies in order to improve transportation conditions, safety and services. Here we will discuss the most used technologies in this sector.

4.2.1 Wireless communications: Wireless networks use radio waves or microwaves for transferring and sharing the data between nodes after connecting them (Qureshi, & Abdullah, 2013). Advances in wireless communication have made it possible for wireless sensor networks (WSN) to have a wide range of potential applications including national defiance, environment monitoring, medical systems, target tracking, habitat sensing and fire detection. The significant advantages of WSN in ITS are given below:

1) Using the sensors the driver can exchange real-time information about wider range of traffic conditions and can respond to emergency situations in advance;

2) The structure of the sensor node is pretty simple and does not cost much which makes it convenient for a large number of deployments.

3) The sensor nodes can monitor the real-time traffic and send the information in the center timely which speeds up the process of decision-making.

4) By collaborating with the multi-sensor, it is possible to improve the detection accuracy and reliability;

5) Traffic information shared using a medium of radio waves, are not affected by time and weather (Guo et al., 2010).

Wireless communication can be 17ategorized into various sub domains such as ad hoc networks, sensor networks, mesh networks, cellular networks and they are different from each other in terms of packet types, resources and infrastructure. Here we discuss some of the technologies:

Radio Modem Communications: This type of communication uses FM radio bands to broadcast information about traffic congestion and in emergencies to warn drivers. Typically Radio Modem

Communication is used for Fleet Management, Automated Meter Reading (AMR), Telemetry Applications etc (Qureshi, & Abdullah, 2013).

Short Range Communications: The standards of short-range communication, specifically WAVE (Wireless Access for Vehicular Environment) or the DSRC (Dedicated Short Range Communication) are promoted by Intelligent Transportation Society of America and the US Department of Transportation by using IEEE 802.11 protocols. Dedicated Short Range Communication allocated 75MHz of spectrum at 5.9 GHz which is entirely used for Vehicle-to-Vehicle and infrastructure-to-vehicle communication in order to improve traffic flow and save lives (Qureshi, & Abdullah, 2013).

Long Range Communications: Long Range Communication uses different networks like WiMAX (Worldwide Interoperability for Microwave Access), 3G, GSM (Global System for Mobile Communication) for providing wireless access over long distance in the transportation sector (Qureshi, & Abdullah, 2013).

4.2.2 Inductive loop detection: An inductive loop vehicle detector uses the magnet to induce an electrical current in a wire in order to detect vehicles. This system is quite cost-effective and consistently being used in today's traffic and parking applications (Qureshi, & Abdullah, 2013).
The working principle of Inductive loop detection is that there is one or more turns of insulated wire which are placed in a shallow cutout in the roadway. The system consists of an electronic unit in a controller cabinet. Due to the pass of a vehicle over the loop, the induction of the wire is changed which causes the change in the frequency. Changing in the frequency makes the electronic unit send a signal to the controller which indicates the presence of the vehicle. Inductive loop detection is used for knowing the vehicle presence, passage, occupancy etc. We can also know the number of vehicles passing through a particular area by using this system. But there are some drawbacks too. The improper connections made in the pull boxes might result in poor reliability. The problem of reliability can be more serious if this system is implemented in poor pavement or where digging of the roads is frequent (Lanke, & Koul, 2013).

4.2.3 Sensing Technology: Sensing Technology in the transportation system is becoming popular day by day. Wireless sensor nodes are normally low-cost and take low power for data processing. Sensor technologies designed for instant car communication with each other. As such applications

run on real time; therefore, end-to-end delay and synchronization is critical for such systems. These sensors gather data and one or more sink nodes connected to each other through different long range connections i.e. satellite, WiFi, WiMAX, etc. A sensor node consists of the main four components which are power unit, transceiver, sensing and processing unit. In order to find locations, the sensor node has an additional unit. However, the sensors are very small like a matchbox (Qureshi, & Abdullah, 2013).

There are different types of Sensor networks such as seismic, thermal, infrared, acoustic, magnetic which are capable of monitoring the different conditions like temperature, humidity, movement of vehicle, pressure, noise, speed, direction etc. (Qureshi, & Abdullah, 2013). Infrared sensors are the most used sensing technology in the field of intelligent transportation systems which can detect energy emitted from vehicles, road surfaces and other objects. In the next step, the energy converts into the electric signals by focusing it onto an infrared sensitive material using an optical system which can help to view the traffic. The main purpose of using Infrared sensors are for signal control, detection of pedestrians in crosswalks and transmission of traffic information. The basic cons of infrared sensors are that the operation of the system can be affected by fog where the installation and maintenance of the system is also tedious (Lanke, Koul, 2013).

4.2.4 Video analysis: Video analysis system needs a smart camera along with a processing unit and a communication unit. Using video cameras the traffic is constantly monitored and the captured video is compressed for reducing the transmission bandwidth. In order to compute traffic statistics the video analysis abstracts scene description from the raw video data. From this statistic it is possible to know the frequency of the vehicles, average speed of the vehicles as well as the lane occupancy. But this system also faces some difficulties which are:

(a) The system is quite costly

(b)When there is heavy fog or rains the system can get affected.

©Proper street lighting is mandatory for night time surveillance (Lanke, Koul, 2013).

However there are some advantages of this system as it reduces costs for the data collection, the analysis is better here which results in better accuracy and enhanced safety (Qureshi, & Abdullah, 2013).

4.2.5 Computational Technologies: With technological development, computational science is becoming popular to be used in different fields. These technologies include model-based process

control, ubiquitous computing and artificial intelligence. In intelligent transportation systems the computational technologies provide different architecture and software for real-time applications which require real time operating systems, rich microprocessors, memories and hardware. Many algorithms and computational programs have been developed to resolve different problems in the transportation sector (Qureshi, & Abdullah, 2013).

Different models such as KNN (K Nearest Neighbors), ANN (Artificial Neural Network), TSA (Time Series Analysis) and SVR(Support Vector Regression) models can be used for traffic prediction and management. The TSA model can be used for accurate prediction and efficient computation as it has shown high performance during highly congested periods of time to predict traffic flow. Another model is SVR which is suitable for predicting traffic flow for short term under the typical and atypical traffic conditions. To predict the traffic congestion based on speed, traffic flow and density, a non-parametric KNN model can be used. Again in urban areas' traffic flow prediction, ANN models are useful. However these models face difficulties when it comes to managing immediate changes in the road conditions and new road structure. Low computing speed and high processing time requirements are other drawbacks of these models. As Neural networks can deal with noisy data, it can be used to predict the travel time. A study said that to train the neural network in this purpose Bayesian techniques are preferable which results in lesser error and predicts accurate confidence bounds. Another technique is data mining where KNN and ANN models can be used as tools in order to traffic analysis, density estimation, prediction and traffic management. When there are special events such as extreme snowstorms or rainfall; deep learning techniques which use NN as the tool can predict the traffic flows. Multiagent system (MAS) is another approach which can be used in different conditions and scenarios. Swarm intelligence (SI), such as ant colony and hierarchical fuzzy system can be used in an adaptive MAS to manage road traffic. (Chavhan, & Venkataram, 2019).

Nevertheless, to have a broad overview of this computational technology we have chapter 4 which will include different structures and applications of Artificial Intelligence and Deep Learning in the field of Intelligent Transportation system.

4.3 Areas of ITS:

In this section we will discuss how different technologies discussed in earlier can be used to the following areas of ITS Metropolitan deployments:

-Arterial and Freeway Management Systems

-Transit Management Systems (TMS)

-Incident Management Systems
-Parking Management
-Electronic Toll Collection System

4.3.1 Arterial and Freeway Management Systems: Inside the urban center, the arterial road carries the major flow while the freeways are fed by these arterial roads located within each town. In order to avoid any traffic congestion, the arterial roads need to be run up to their own capacity of flow (Chegg Study, 2020). That's why the Arterial and freeway Management System has become popular in many developed countries. Different emerging technologies and hardware like Variable message Sign (VMS), ramp meter, circuit television (CCTV) and traffic signal control systems are being used for this purpose. Ramp metering techniques are the most common techniques to measure and regulate how much traffic is entering and leaving major freeways to ensure that demand remains below capacity, in order to reduce congestion. Cities using Freeway Management Systems reported that they are able to handle more traffic as well as maintain the increased travel speeds. One example of this system is the California freeway management system where 2 Gb/day data processes in real time. In these systems, millions of unprocessed data such as speed record, traffic flow, etc are collected and stored (Qureshi, & Abdullah, 2013; Genesee Country, n.d.).

Various studies have discussed the arterial and freeway system. Traditionally freeway systems provide the navigation services, for which fixed sensors such as loop detectors and television cameras are being used. But there are some drawbacks as these systems result in high cost, maintenance and limited coverage. Currently, mobile sensors and GPS (Global Positioning System) are increasingly applied in this sector. Many studies show that mobile-based sensors are more efficient than GPS-based sensors because of their ready-to-use infrastructure and the wide coverage (Qureshi, & Abdullah, 2013).

4.3.2 Transit Management Systems (TMS): Transit Management System helps to enhance operating efficiency, service reliability, and removal of service disruptions. Via the system, the user can get general information, maps, schedule Information, operational Information while traveling or even being at home. An example of the Transit Management system is an Automatic Vehicle Location (AVL) technology that allows us to track vehicles. AVL provides information about the real-time position of a vehicle that helps the travelers to know the location of transit vehicles. Besides AVL, other various software like BRT (Bus Rapid Transit), TAD (Travel assistant device) are working for

the betterment in location and transit time and also for safety operations (Qureshi, & Abdullah, 2013).

4.3.3 Incident Management Systems: One of the significant areas in the intelligent transportation system is Incident Management System. Different types of incidents, such as SARS epidemic, 2008 Sichuan earthquake, or everyday road accidents make this system more necessary. The main objective of the Incident Management System is to track safe passages for fire vehicles and ambulances to safely and quickly reach their intended destinations during an emergency response incident According to World Health Organization data, one of the major public health issues in Europe is to get injured because of road accidents and the death rate is about 31 thousand per year. Over 1.2 million citizens die on the roads worldwide. Moreover WHO forecast that by 2030 the transportation injuries will go up to become the fifth foremost reason of death. Incident Management System can be categorized into many subsystems such as roadway incident management, emergency response management, incident detection, traffic management. There are different models and systems that have been proposed for incident management systems such as CIMS (critical incident management system), CPs (cyber physical system), decision support systems to collect real time data and manage traffic management according to that whenever any incident occurs (Qureshi, & Abdullah, 2013). However, Incident Management Systems send dynamic messages to alert travelers about accidents or stalled vehicles on the road ahead. In order to detect and locate incidents quickly video cameras and road sensors can be used and computer-aided dispatch can speed emergency services to the scene (Genesee Country, n.d.).

4.3.4 Parking management: City streets become crowded because of Illegal parking. Not only that; illegal parking also creates problems for disabled drivers, city vehicles and others who need access to reserved parking spaces. As some drivers are overstaying, some visitors are unable to park which disrupt the normal traffic flow. Using traditional parking enforcement systems seems costly and inefficient; they may even add to crowding themselves. With the smart parking violation detection system parked vehicles will be scanned and then communicate with parking meters and drivers will automatically be cited for illegal or extended parking. Traffic flow will be improved by using these automatic systems as they increase driver compliance and smooth turnover of parking spaces (Advance Access, n.d.).

4.3.5 Electronic Toll Collection system (ETCS): One of the most popular applications of intelligent transportation systems is Electronic toll collection. It enhances the mechanism of collecting toll and

eliminates the delay. ETS systems can be classified as DSRC (dedicated short-range communication), where an on board unit (OBU) is placed in the vehicle and RSU (Roadside unit) is installed on the road and they can communicate with each other in the range of 30 meter. Electronic toll Collections applications are becoming popular in many developed countries and are being used by the Intelligent Transportation Society of America, ERTICO , ITS Japan and so on (Qureshi, & Abdullah, 2013).

4.4 Key Benefits of using ITS:

Most of the developed countries are using ITS to assist their transportation system. The main goal of the ITS is to deal with public safety, environmental feeds and many more. Some of the advantages of using ITS will be discussed here:

Increasing Safety: With the help of ITS it is possible to ensure public safety on the roads. Unsafe speeds, new trend of driving, heavy traffic; all are the causes behind increased road accidents. Real-time traffic monitoring systems collect information on visibility, road conditions and more and send it to the traffic controllers. According to the needs, this information can be used to update warning signs and even speed limits to alert drivers to the conditions around them. Again ITS helps to prevent traffic jams as well as reduce the risk of collisions by guiding the user through voice command and also gives an alert to the user about the traffic or congestion ahead. Thus ITS traffic control helps in diverting traffic away from busy or dangerous areas (Singh, Bansal, & Sofat, 2014; Advance Access, n.d.).

Delivering environmental benefits: ITS can also deliver the environment alerts if there is any. In order to record the temperature, humidity and other environmental factors sensors can be used which are being placed along the road side. In the next step all the factors will be calculated to get the values which will be sent to the central server. Here the values are stored in the database for further actions. If any user is subscribed to the system, he may get an alert about the environment as well as about the forecast and precast weather report (Singh, Bansal, & Sofat, 2014).

Traffic control: By getting the number of vehicles on each and every lane ITS can keep a track on the congestion before it takes place. Based on the number of vehicles on a single lane, ITS makes decisions whether to route the traffic onto another lane or not which decreases the risk of congestion of a particular lane. It can also keep track of the number of the vehicles running at a particular time

on a particular lane. And based on that information It will send an alert notification to the user that the congestion will be high on some particular lane at some particular time (Singh, Bansal, & Sofat, 2014). Moreover, Intelligent transportation systems allow traffic lights to change by themselves. Such a system of adaptive traffic lights are able to create smart road intersections that can control the traffic intelligently by responding to the patterns they observe in the vehicles passing by. In this system traffic lights change in response to traffic patterns rather than on a fixed schedule, so that traffic can move smoothly and waiting time will reduce. Based on the situation they can also prioritise specific forms of traffic, like emergency vehicles or public transit (Advance Access, n.d.).

Enhancing mobility and convenience: Intelligent transportation systems allow us not only to measure the number and type of vehicles on a particular road but also deliver the real time traffic information such as, peak traffic times, journey length and other data. That means before departing from their homes users can check the status of the traffic and other related information where they are heading to (Singh, Bansal, & Sofat, 2014; Advance Access, n.d.).

Reducing infrastructure damage: Heavy vehicles especially when they are overloaded can put a lot of strain on the road network. There are some weight stations and other older forms of weight control that can reduce the risk of overloading but it takes a lot of time hence can result in delayed traffic. With the help of a Weigh-in-motion system we can measure the type, size and weight of vehicles as they move, and then send the collected data back to a central server. Thus it is now possible to identify overloaded vehicles automatically and appropriate measures can reduce damage to roadways. Not only these systems make enforcement simpler, but also they reduce expenditure on road repair (Advance Access, n.d.).

4.5 World wide leaders of ITS:

Some of the countries that are leading the way in the deployment of Intelligent Transportation System are discussed below:

4.5.1 Japan: Japan leads the world in Intelligent Transportation Systems. Before implementing the ITS in Japan, 20% of all Carbon dioxide emissions was in the transport section; 5 billion hours annually was used to lose because of traffic congestion and 730,000 accidents occurred resulting in 4,863 fatalities (FY2010) (Ministry of Land, Infrastructure, Transport and Tourism, n.d.). The main

reasons behind the implementation of ITS in japan were it's congested roadways and general concern for the environment. It was expected that ITS will resolve these problems by saving people's time that they waste in traffic jams and by reducing produced exhaust gases. Basically the goal of the Intelligent transportation system in japan was the reduction of traffic accidents, the realization of automatic driving, the relief of traffic congestion and the improvement of the environment. "There are nine areas of ITS which have been developed in Japan: 1. Advances in Navigation Systems 2. Electronic Toll Collection 3. Assistance for Safe Driving 4. Optimization of Traffic Management 5. Increasing Efficiency in Road Management 6. Support for Public Transport 7. Increasing Efficiency in Commercial 8. Support for Pedestrians 9. Support for Emergency Operations." (Hollborn, 2002).

4.5.2 South Korea: South Korea started to take ITS into account in the early 90s with the development of advanced traffic light control systems and the FTMS pilot project of expressway traffic control systems. The "National Transport System Efficiency Act," is the foundation of the ITS project, which was enacted in 1999 though the ITS master plan was drawn up in 2000. At first as a part of ITS, drivers were able to make the expressway toll payment automatically without stopping their cars, users could get real-time bus information and it was possible to pay transportation fares without cash using a transportation card system (Lim, & Ryu, 2012).

South Korea, specifically Seoul city, is one of the most highly dense cities in the Asian Region. One of the main issues here is the traffic problem. To deal with the traffic problem, South Korea puts in an annual investment of 234.5 billion Won into developing and running its intelligent transportation systems. From 2001 through 2009, 2.1 billion Won has been invested in this regard, which has helped to develop an intelligent transportation systems across a distance of 7,384 km including 3,794 km(100%) of national expressways, 2,552 km(19.9%) of national roads and 1,038 km(2%) of other roads (Lim, & Ryu, 2012).

To manage the traffic situation in Seoul city Seoul TOPIS (Seoul Transport Operation & Information Service) is working and collecting traffic information from traffic-related organizations such as; bus management system, traffic card system, unmanned enforcement systems and traffic broadcasting, the National Policy Agency, and the Korea Expressway Corporation. After evolving for the last 15 years, Seoul TOPIS launched a new platform which includes the functions of six platforms such as center platform (the traffic information control room), the bus platform (BIS/BS), the unmanned

enforcement platform, the freeway traffic management system (FTMS), the advanced traffic management system (ATMS), and the big data platform (traffic predictions, information support) (Ko, & Lee, 2018).

However, to collect traffic information the South Korean's Expressway Management Systems use Vehicle Detection Systems, which is installed on the roadside at 1km of intervals. They also deployed Closed Circuit Camera every 2-3 km. and probe vehicles. The data collected through these systems are stored at South Korean's National Transport Information Center, where the data can be distributed to other users via various communication means (Singh, Bansal, & Sofat, 2014).

4.5.3 United States: In order to cope up with advance climate change and achieve the energy conservation goals, the United States started using Intelligent Transportation Systems (ITS) which also improved vehicle mobility, safety and efficiency. According to the Texas Transportation Institute, in the year of 2012, people lost around 5.5 billion hours of extra travel time because of traffic congestion which also results in an extra 2.9 billion gallons of fuel burned. Compared to the total cost of crashes and congestion, which drain the economy of more than $400 billion per year, ITS R&D funding is minuscule. The main focus area for US-ITS is Telephonic Data Dissemination, IntelliDrive, Next Generation 9-1-1, Cooperative Intersection Collision Avoidance Systems, Congestion Initiative, Integrated Corridor Management Systems, Clarus Initiative, Emergency Transportation Operations, Mobility Services for All Americans and Electronic Freight Management (IEEE-USA, 2014).

ITS America (The Intelligent Transportation Society of America) is working to advance the research and deployment of intelligent transportation technologies for saving lives, improve mobility, promote sustainability, and increase efficiency and productivity. ITS America brings all the relevant sectors; such as state departments of transportation (DOTs); regional and local transportation and planning agencies; private companies providing ITS products, services and technology; auto manufacturers and suppliers; research organizations; academic institutions, transportation associations together to make the system efficient. ITS America is using the new and developing vehicle to everything (V2X) technology, which sends hazard alerts to vehicles, bicyclists, and pedestrians. Not only that, to decrease congestion and fuel consumption, these technologies can be used to enhance automated driving systems. Automated vehicle technology can also eliminate the 94 percent of crashes which are caused because of human error. ITS America also created the Mobility On Demand (MOD)

Alliance in 2018 to help the consumers to identify and use the transportation options that best meet their mobility needs at any time. One of the problems of Intelligent transportation systems is cybersecurity risks as vehicles and infrastructure become more connected. To address these concerns, ITS America is trying to adopt the best practices and standards to deal with the cybersecurity threats. They also advocate public policies regarding this issue (ITS AMERICA, n.d).

4.5.4 Europe: European Union has adopted Intelligent Transport Systems (ITS) a long time ago to tackle Europe's growing emission and congestion problems. As ITS can make transport safer, more efficient and more sustainable, different information and communication technologies are being applied in Europe. Nevertheless, in order to make ITS be coherent and properly coordinated across the EU, The European Commission is working with Member States, industry and public authorities, so that they can find common solutions to the various bottlenecks that are being faced during deployment. Various innovative projects in ITS get financial support from the European Commission while taking care of the legislative instruments. With the digitalization in the transport sector, ITS are expected to take a leap forward in the coming years. For efficient management of the transport network, improving journeys and operations on specific and combined modes of transport, the European Commission aims to make more use of ITS solutions. For the next generation of ITS solutions, they are deploying automation technology in the transport sector, so that vehicles can connect with each other and exchange data effectively through wireless technologies (European Commission, 2020).

In order to promote research and define ITS industry standards, ERTICO - ITS Europe is working which is a public-private partnership of 120 companies and organizations representing service providers, public authorities, traffic and transport industry, vehicle manufacturers etc. ERTICO brings the interests of public and private stakeholders across Europe, to strengthen the competitiveness of the industry and improve services for the user to achieve societal and political goals. ERTICO’s final goal is to create safer (zero accidents), smarter (zero delays) and cleaner (reduced impact on the environment) mobility services using intelligence for the better lifestyle of all citizens. The main focus of ERTICO is Connected & Automated Driving, Urban Mobility, Clean Mobility, and Transport & Logistics (ERTICO, ITS EUROPE, 2020).

For achieving its vision and to fulfill its mission, ERTICO is engaging relevant stakeholders to make the smart mobility agenda advance. ERTICO creates Innovation Platforms for the deployment of intelligent transport solutions which are self-funded and both ERTICO and non-ERTICO Partners can access them. Though the target of these Innovation platforms are mostly European markets, they are ready for possible global scaling too. Currently over twenty research, pilot and deployment projects are managed by ERTTICO, which are carefully selected and are working on based on the knowledge of earlier projects and activities (ERTICO, ITS EUROPE, 2020).

4.6 ITS in Developing Countries:

Though Intelligent Transportation Systems (ITS) application is quite common in the industrialized nations, many large cities in the developing world need to work more to develop a basic architecture for ITS deployment. Nevertheless, the situation is getting better there and many developing countries already adopted various technologies to make their traffic management system better and safer. The same arguments that have influenced the developed countries to plan and implement ITS are also applicable for developing countries (Khan et el., 2014).

For the research purpose we will only consider the situation of developing countries in Asia. to help the developing countries in Asia, ITS Asia-Pacific is working to facilitate Intelligent Transport Systems (ITS). Indonesia, India, Nepal, Bangladesh, Thailand, Malesiya are some of the Asia-Pacific developing countries who have started their journey to implement Intelligent Transportation System (ITS Asia-Pacific, 2015). However in this section we will discuss the current situation of ITS in India and Indonesia, as our case studies are also based on these regions.

4.6.1 India: With the population and economic growth in India, the rapid outgrowth of vehicles on the street of the urban areas became a common issue. Day by day the number is increasing and the indian urban areas are failing to cope up with this upsurge of vehicular growth which resulted into higher traffic congestion in almost all cities (Rawal, & Devadas, 2015).

While comparing the ITS applications used in developed nations with Indian scenarios, we can see India is facing a number of challenges in this field. The available infrastructure in India is unable to adapt the available ITS technologies directly. So according to the necessity either the infrastructure needs to be changed or the ITS technologies. Indian road transport is quite different from other developed countries based on their types of vehicles, road infrastructure, and also people understanding about traffic rules, societal aspects, and traffic management systems. It is quite

challenging too because of high population density and old road infrastructure. However the country is modernizing in the traffic management system using sensor techniques like GPS, WIFI, Camera, and Microphone in smartphones, which can estimate traffic conditions to avoid congestion. Before using these technologies, traditional modes of techniques were being used which caused various crucial issues like missing of the vehicle to vehicle coordination, lack of homeland security systems and vehicle operations, failure of traffic management etc. (Singh, Bansal, & Sofat, 2014; Raman, Pradesh, & Rodda, 2018).

Though a small scale of ITS projects had been already introduced in various cities in India for toll collection, parking information, web based traveler information etc.; there are more ITS concepts like emergency management, congestion management, advanced traffic management systems, advanced traveler information system, commercial vehicle operations, advanced vehicle control systems etc. which are mandatory for Indian scenarios. However as mentioned before , India is facing some challenges in the field of ITS and to mitigate those issues some of the actions needed to be taken. It is very important for the country to set up the fully functional Traffic Management Centre with a national ITS data archive. It is also important to develop models and algorithms for ITS while taking care of national ITS standards for different ITS applications. Finally, the interaction between academia, industries and governmental agencies is also necessary to achieve the improvement of technology, infrastructure and social schemes (Singh, Bansal, & Sofat, 2014).

4.6.2 Indonesia: With the growing population and economy, Jakarta metropolitan area in Republic of Indonesia has seen an extended number of vehicle registration; 5 times to about 14 million units in 2012 from about 3 million units in 2000. The rapid increment of vehicles causes congestion problems as the road infrastructure is failing to keep up with that (Japan International Cooperation Agency : Mitsubishi Heavy Industries, Ltd. : Mitsubishi Research Institute, Inc., 2015). So to control and monitor the traffic, the Department of Transportation of Jakarta, Indonesia, has launched an intelligent transport system (ITS) which has three sub-systems: a bus tracking system which can track city buses, an traffic control system to set traffic lights based on traffic congestion and a traffic information system for providing electronic information to make the journey easy for road users. Cameras are being used for monitoring heavy traffic, and the intelligent system can change traffic lights at intersections based on priority. GPS technology is also integrated with the ITS for monitoring the Busway system in order to cut travel and waiting times. Again people will get the notification

about traffic congestion, accidents, alternate routes, estimated delays etc. through the system (Road Traffic Technology, 2011).

The development of intelligent transport systems in Indonesian cities has been started with a vision of

- providing comfortable and efficient transport services.
- increasing the road safety for users.
- reducing the impact of pollution and saving the environment.
- improving the overall road transportation system .

ITS architecture and planning have been adopted in Indonesia with the capacity of the availability of technology and infrastructure (Munawar, & Sutanta, 2015).

However, ITS Indonesia is a member of ITS Asia Pacific Forum and ITS World Community. This organization is working to bring industry, academia, government agencies and communities together for the development of intelligent transport systems which can provide a safe and convenient transportation ecosystem (ITS INDONESIA, 2019).

Chapter 5: Artificial Intelligence and Deep Learning

In the previous chapter we discussed different technologies that can be used in the field of Intelligent Transportation System. For this thesis purpose we will dive more deeply into computation technologies specially Artificial Intelligence and Deep Learning as these technologies become more popular to automate the traffic management system and make the road safer.

5.1 Artificial Intelligence:

Artificial Intelligence is a branch of Computer Science that is designed to perform tasks which require human intelligence. At first the term 'Artificial Intelligence' was coined by John McCarthy in Dartmouth Conference 1956. There are four types of approaches of AI and they are 'Thinking humanly', 'Thinking Rationally', 'Acting Humanly' and 'Acting Rationally'. A computer answers the questions of an interrogator, if the interrogator cannot differentiate that the answer was from a device then the computer passes the test of acting humanly. By analyzing the human brain precisely, we can come up with some theory of how humans think and match the input output behavior of a computer program. Logicians are developing notation to create intelligent systems that can think rationally. An agent is rational when it can produce the best outcome in any uncertain condition. So, for problem solving, artificially intelligent agents are becoming successful day-by-day (Ray, 2018; Russell, & Norvig, 2010).

5.1.1 Artificial Intelligence-based techniques mainly used in ITS:

Artificial Intelligence mainly focuses on creating intelligent computer programs. AI has now reached our everyday life for security checking, fraud detection, transportation systems etc. It has been studied that people all over the world spent at least one hour on the road. So, the transportation system needs to be developed and for that purpose Intelligent Transport Systems (ITS) have been introduced which takes different types of AI techniques and processes a lot of data taken from the vehicles and drivers to provide real time decisions. The most used techniques for ITS are Artificial Neural Networks (ANN), Genetic Algorithms (GA), Fuzzy Logic (FL) and Expert Systems (ES) (Hawi et al., 2015; Machin et al., 2018). Now we will discuss about these techniques in details:

Artificial Neural Networks (ANN): Artificial Neural Networks (ANN) are based on the concept of the human brain. The study of ANN was first bought by Walter Pitts and Warren McCullough in

1943. A Neural Network is created with a group of networks of neurons. The popular categories of neural networks are feed forward networks. It can consist of an input layer, one or many hidden layers and the output layer. Perceptions, Multi-layer perceptions and radial basis networks are the most common feed forward network (Agarwal et al., 2013; Hawi et al., 2015).

In the ITS system, ANN plays an important role to control the traffic. Different types of approaches can be taken using ANN in which data were collected from the vehicles which then are fed to ANN model. After receiving the data, the model finds out the most suitable situation for traffic control. ANN can control traffic light in the urban area which is commonly known as Environmental Observation Method (EOM). This approach is different from others because they used a mathematical plan for generating the signals. However, EOM is not actually helpful in the real time traffic nature. Later to solve this problem actual data was taken using an ANN and then the green light timing was set by analyzing the actual data from the traffic (Hawi et al., 2015).

Genetic Algorithms: Genetic Algorithms are based on Darwin's Natural selection which use the techniques of search and optimization. GA takes all the possible solutions of any given problem and then the solutions are handled properly using the fitness function. Fitness function helps GA to find the random solutions of the given problem and select which one is the best suited solution. Then for the reproduction, GA uses the crossover and mutation techniques. Total GA procedure leads us to the local maxima but for reaching global maxima we use the mutation technique. Figure 1 shows a schematic view of GA. We can find the best solution of a problem within a very short time using the GA techniques. This technique is used in game theory, recognizing a pattern, neural network, fuzzy logic etc. (Lin et al., 2009).

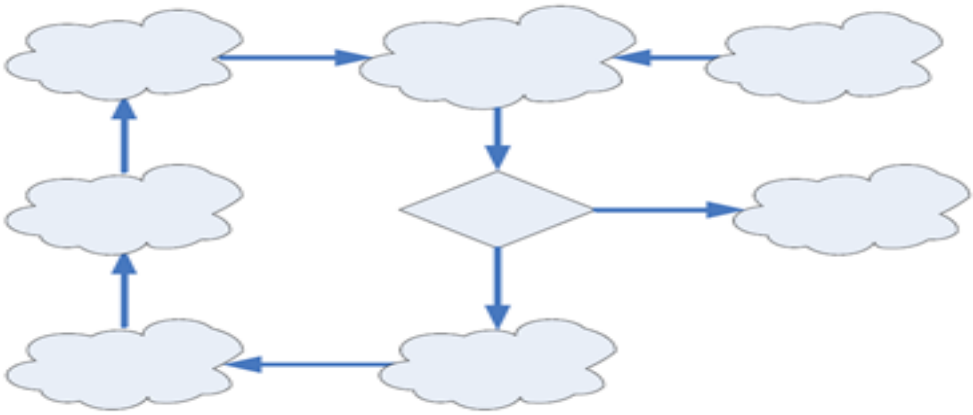

Figure 2: Schematic Genetic Algorithm (Lin et al., 2009).

Finding the shortest path is an important issue in ITS as we want to reduce the road time. Shortest driving time can be generated using GA for which we need to follow some steps. All the possible routes are considered as chromosomes and they are the population of the given problem. Fitness checking is done by using a fitness function which takes the distance and velocity and calculates the best solution. This process continues until the optimal solution is found or the termination condition is fulfilled (Lin et al., 2009).

Fuzzy Logic: Fuzzy logic techniques have the capability of making decisions like humans in any uncertain environment. Fuzzy logic gives us the value of a statement between 0 to 1 instead of just 0 or 1. Fuzzy expert system attempts to think like humans, try to describe a situation and then make decisions using common sense. Sensors collect data from the environment and then they are used for processing in the Fuzzy Logic Controller (FLC). FLC works like the traffic officer handles traffic data and that is why it is considered suitable for traffic light control. It assigns traffic light based on the urgency or according to the fluctuation of the traffic. The best decision is made by considering the traffic which reduces congestions (Hawi et al., 2015).

Expert System: Expert system works with the predefined knowledge which takes the rule and applies to make decisions. ES makes decisions like human beings such as for a given problem apply logical summarization that could be the possible logical answer for the given problem. Actually, ES stores data for any problem which is called the knowledge and then by using this knowledge can solve a problem which is related to the given data like an expert. ES has different types of application in which transportation is one of them. So, for ITS we can use expert system and can mimic decisions (Machin et al., 2018).

5.1.2 Application of AI in ITS:

Artificial Intelligence techniques can be used to reduce the problem related to the transportation system. Most of the discussed techniques are now used to ease the traffic problem. The advantages of AI in transport systems are a lot; for example replacing traffic sensors with smart agents can lead us to detect accidents automatically and the traffic condition for future. Vehicle control is an important issue for controlling traffic in the road which focuses on safety and comfort of both the passengers and drivers. Genetic Algorithm is used mostly for vehicle control systems which deals with reducing the fuel consumption, autonomous driving and modified braking systems. ANN is used

to control the routes for Remotely Operated Vehicles (ROV) (Abduljabbar et al., 2019; Machin el al., 2018).

A lot of traffic data was stored for traffic control and prediction systems where many techniques are used for automatic traffic condition prediction. For controlling traffic and predicting versatility patterns a lot of AI techniques were used by the experts but most suitable was the ANN technique. To reach the destination within short time and maximum speed level, a new approach was taken which at first sent the vehicle the time range for arriving at the intersection and the time that vehicle must delay to reach the intersection point. Fuzzy Logic can also be used to control traffic congestion where vehicle to vehicle communications were made to know the condition in the intersection point and optimize the vehicle speed in the metropolitan area (Machin el al., 2018).

Road safety and accident prediction is a burning issue now-a-day. The aim is to prevent accidents, finding the causes of accidents or increase the chance of survival of both the passengers and drivers. By analyzing and collecting the necessary data from the previous incidents, some information can be collected to avoid or predict the accident. Fuzzy logic and ANN used a lot to predict accidents. GA (Genetic Algorithm) was used to find out the necessary resources once the accident has occurred in addition to lessen the severity of the injuries. FLC (Fuzzy Logic Controller) helps to use the brake as soon as an obstacle is found and avoids a crash. ES (Expert System) was used to reduce the risk of collision between the transports and pedestrians (Machin el al., 2018).

Uber, using the new techniques of AI, can share the mobility and identify the illegal drivers with their activities. In future there will be cars without drives using AI and sensors which can be profitable. Vehicle tracking is another important issue in ITS. An Automated Vehicle Locator (AVL) helps to increase the efficiency of public transport and increase the quality of the public transport system. AVL can track vehicles using GPS signals, can change the route if detects any kind of difficulty and also send information to the travelers. A lot of implementation of AVL systems such as iBus system, planning bus schedules for public transport, estimating future passenger demand (Abduljabbar et al., 2019).

5.2 Deep Learning:

Machine learning algorithms can make data-driven predictions on unknown test data by learning from example inputs. Such algorithms can be categorized into: supervised learning (where labeled input and output pairs are given and based on that the algorithm needs to predict outputs of unknown inputs)

and unsupervised learning (whose aim is to explore intrinsic characteristics of inputs). One of the subfields of machine learning is deep learning which is a powerful approach for function approximation, classification, and prediction capabilities. Deep learning architectures have different variants such as Convolutional Neural Networks (CNN), Deep Reinforcement Learning, Auto Encoder, Recurrent Neural Networks (RNNs) etc. which can be used in the field of Intelligent Transportation system. We will discuss these architectures broadly with some deep learning applications in ITS **(** Wang, & Sng, 2015 ; Mohammadi et al., 2017).

5.2.1 Deep Learning Architecture:

Here we will discuss different deep learning architectures that can be used in ITS.

The Convolutional Neural Networks (CNN): Video surveillance is a great medium to collect information about traffic. The procedure to get dsire data from video surveillance involves vehicle tracking and vehicle counting combined with motion detection as well as trajectory. However, tracking a vehicle is not easy for high occlusion rates. To increase the detection rate Convolutional Neural Network can be used. In this approach multiple layers are trained in a robust manner to get impressive results for object classification and recognition (Cui et al., 2020).

Generally to deal with any complex input, the architecture of a deep CNN consists of three main neural layers, which are convolutional layers, pooling layers, and fully connected layers. Each layer plays different roles and applies different filters (in the order of hundreds to thousands). A CNN automatically learns the values of its filters during the training period, according to the given task. For example, to classify the image of a cat as shown in Fig. 3, we can feed the raw pixels as input of a CNN. The CNN may learn to detect the edges from these raw pixels in the first layer. Then, in the second layer, it can detect simple shapes using these edges. In this way, it is possible for the CNN to be able to learn higher-level features like facial shapes and so forth in the subsequent (i.e., higher) layers. To exploit these high-level features, a classifier will be used in the final layer (Fadlullah et al., 2017).

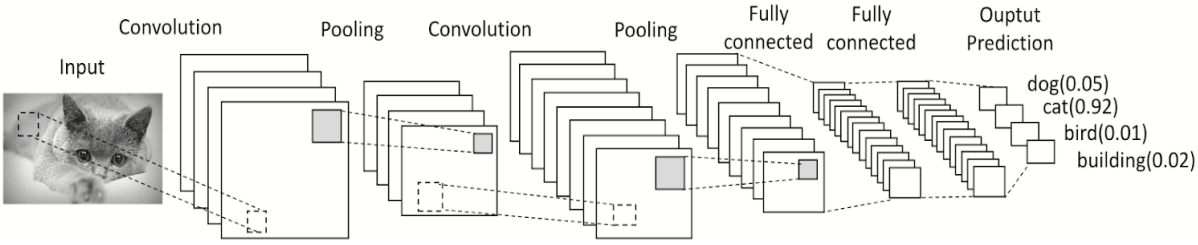

Fig 3: CNN architecture (Fadlullah et al., 2017).

Deep Reinforcement Learning: The Intelligence Transportation System plays a vital role to control the traffic flow as well as the traffic light. Reinforcement Learning (RL) techniques, such as Q-learning can be used for these purposes (Liu et al., 2018). Reinforcement learning is a combination of both supervised and unsupervised learning methods. In this method, the agent needs to learn by interacting with its environment. Q-learning is the most well- known reinforcement learning technique which is able to optimize real-time traffic light control for large-scale transportation systems (Fadlullah et al., 2017).

Recurrent Neural Networks (RNNs): Another important feature of ITS is traffic forecast. But getting the accurate prediction is tough due to the large number of vehicles and travelers as well as noisy traffic data. There are some additional factors which also need to be considered while forecasting the traffic; such as: weather, construction, and accidents, etc. The Recurrent Neural Network (RNN) can be used for predicting the traffic (Guo et al., 2020).

Auto encoder: In order to predict traffic conditions, data are gathered from sensors, induction loops as well as video cameras. Sometimes it is hard to process these data as using these data requires permission from authority or sometimes these data are just outdated. Due to this scarcity some models failed previously to predict the traffic in a large scale road network. However, Deep Autoencoders showed better results in this purpose (Zhang et al., 2019). Autoencoder became popular as an early tool for pretraining supervised deep learning models. In this model it is not necessary to predict some target value Y based on given inputs X to train the network, instead of that an auto-encoder can reconstruct its own inputs X.

Normally to accomplish the task, a deep autoencoder forwards the code learnt from the previous autoencoder to the next. However, to get the discriminative and representative features of raw data

multiple layers are needed. But if errors are present in the first few layers, the model can show ineffective results. As a result, the network needs to learn to reconstruct the average of the training data. To get over this problem, one approach could be to pre-train the network with initial weights that can approximate the final solution (Guo et al, 2016; Shickel et al., 2017).

5.2.2 Deep learning application:

One of the popular use cases of Deep Learning is to predict the traffic flow. It is possible to make the predictions at fixed intervals into the future (e.g. 15, 30, 45, or 60 minutes) by training the deep neural network. Again most of the public transports (public bus and subway) follow a fixed route, deep learning models can learn mobility patterns between nodes in subway and bus networks to predict the everyday traffic flow. DL can also be applied to model traffic flow after any accident has occurred (Veres, & Moussa, 2019).

A particularly challenging problem in the field of transportation is navigation. While providing the solution that will satisfy personal preference is quite difficult as there are often many routes that can be taken to reach a destination. Deep Learning can be a useful tool in this situation (Veres, & Moussa, 2019).

One of the major parts of an Intelligent Transportation System is classifying vehicles. Deep learning algorithms are good techniques for this purpose and the procedure requires to collect data, extract the feature and train the model (Sarikan et al., 2017). Vehicle detection and tracking via automatic licence plate recognition are other mandatory options for safety purposes where deep learning can outperform other traditional models as it can handle large amounts of video data. Again CNN can be used for automatic toll collection (Awang, & Azmi, 2018).

Chapter 6: Privacy and Security issues related to ITS

Intelligent Transportation Systems use different technologies such as; photo enforcement, weigh-in-motion, video surveillance etc. and via these technologies huge amounts of personal information have been collected. Though gathering information is required for proper traffic management, the general public are becoming concerned about their rights of privacy. In order to safeguard private information, technologies are playing a pivotal role along with legislation and policy (Cheung et al., 2009; Fries et al., 2012).

There is a reciprocal relationship between privacy and ITS. The improvement in the Intelligent Transportation System requires a tremendous amount of data which will undoubtedly affect Privacy; while implementation of ITS will also be affected by the fact of privacy concerns. Intelligent transportation technologies can affect individual privacy in many ways. Being deployed by government agencies, or private corporations, ITS technologies can be used for real-time surveillance of a specific person. It is also possible to collect, aggregate and manipulate one's travel and other personal data with these technologies (Glancy, 1995). So it is quite conflicting for both the operators and enforcement authorities to manage efficiency, public safety and individual privacy at the same time. Though people demand privacy within their daily lives, global concerns for the safety and security in the roads outweigh their desire for maintaining that autonomy and separation (Fries et al., 2012).

Nowadays getting real-time information about traffic congestion and adverse weather conditions has become a popular feature of ITS. In order to provide this service, the driver's location, speed and destination, and maybe other information will be collected which can be very useful to third party trackers including law enforcement agents, private investigators, advertisers or stalkers (Glancy, 1995).

6.1 Collecting Data via ITS:

In recent years, ITS technologies have been rapidly deployed for safety and security purposes. Here we will discuss how personal data can be collected by using a number of technologies in the transportation system, such as photo enforcement, GPS tracking, Electronic credentialing, Electronic tolling, video surveillance etc. in details:

6.1.1 Photo enforcement:

A traffic enforcement camera which is also known as a red light camera or road safety camera, can be installed beside or over a road for detecting motoring offenses, such as; speeding, vehicles going through a red traffic light, vehicles going through a toll booth without paying, unauthorized use of a bus lane etc. It can also be linked to an automated ticketing system to generate fine if any violation occurs (Wikipedia, 2020). However this automated photo speed enforcement is used by law enforcement to influence driving behavior of citizens which can also track and store data about driver's behavior as well as his personal information (Fries et al., 2012).

6.1.2 GPS tracking:

For vehicle navigation and fleet tracking, Global Positioning Systems (GPS) have been widely used for several years. By using GPS, tracking carriers or authorities can get notification if a vehicle has deviated from an intended route or entered a restricted area. Though the purpose of using such a system is to ensure the movement of freight shipments remain on their allowed route, they can also be used to monitor the location of the driver and the truck, which raises privacy concerns for both the driver and the carrier (Fries et al., 2012).

6.1.3 Electronic credentialing:

Electronic identity credentials can be referred to as an e-ID, electronic voter ID card, biometric passports, bank cards, etc. (Wikipedia, 2020). With current technologies the government might be able to track any vehicles and possibly revealing proprietary information including electronic credentials of a driver. In many countries this caution has resulted in the restriction of the data exchanged or collected (Fries et al., 2012).

6.1.4 Electronic tolling:

Electronic tolling has become so popular nowadays to solve the problem of recurring delays on toll roads. It has also raised many challenges regarding the privacy protection of motorists as automated tolling systems can supply personal information to the authority (Fries et al., 2012).

6.1.5 Video Surveillance:

Nowadays the most commonly used imagery system is Video surveillance systems. With such a system it is possible to monitor sensitive information including identities of individuals, their

activities, routes etc. Though it is important to have such information for security purposes; misuse of private information can lead to unnecessary litigation. That's why it is very important for a company as well as authority to develop privacy protection schemes in order to protect personal information without degrading the visual quality that is necessary for security. However to protect privacy information, data encryption or scrambling schemes are not appropriate as using these techniques make the protected video no longer viewable. Again using image blurring techniques for protecting individuals' identities can modify the surveillance videos, making them unsuitable for use as evidence in the court of law (Cheung et al., 2009).

6.2 Security and privacy challenges:

While in the previous section we discussed how personal information can be collected through various ITS technology, in this section we will discuss how these collected data can raise privacy challenges. However there are also some security issues related to the ITS which we will discuss here as well.

6.2.1 Privacy Issues:

The use of ITS can open a massive opportunity for invasion of individuals' privacy, as various data related to an individual's location, habits etc. are collected and stored through an ITS system (Hahn, Munir, & Behzadan, 2019). Also Location information that is collected to provide location-aware services can be detailed enough to pinpoint the buildings that drivers visited. Not only that, data about recurring visits to a medical clinic can indicate illness; visits to activist organizations can hint at political opinions and so on (Hoh et al., 2006). However, customer data generated by Intelligent Transportation System is a valuable commodity as many third parties such as marketers, merchants, insurance companies, data brokers as well as application developers, governments, and law enforcement agencies are interested to purchase for analysing to get valuable insights (Jaisingh, El-Khatib, & Akalu, 2016).

Various entities that can compromise privacy:

Service Providers: Location-based service providers, Internet service providers, cloud computing service providers can directly access the data which they have collected through their services. They may have the motive to repurpose these collected data.

Involved Parties: Involved parties including device manufacturers (smart cards, vehicles, or CCTV cameras manufacturers) to software developers can gain access to sensitive data.

Third Parties: All the entities who are neither a service provider nor involved with the infrastructure and devices can be referred as third parties. They do not have the authentication to access the system but can acquire data through other channels (Eckhoff, & Wagner, 2017).

6.2.2 Security Issues:

Collecting and storing data not only raises privacy concerns but also security concerns as well which will discuss below:

Data integrity: For the correct functionality of ITS, it is very important to maintain data integrity. Data integrity can be compromised at every point in ITS by any malicious or man-in-the-middle attack. Using the incorrect information for various calculations and decision making will result in catastrophic scenarios. Another attack against integrity is Global Positioning System (GPS) spoofing where attackers broadcast false GPS signals. Based on the corrupted data, travelers change their routes. Sybil attack is another one where a malicious actor can act like multiple parties and injects false broadcast messages to degrade traffic monitoring systems (Hahn, Munir, & Behzadan, 2019).

Availability: In order to maintain safety and make the journey easy for travelers, their devices need to be available to communicate with other components of ITS. But this availability of ITS components can cause Denial-of-service attacks. Attacks on availability are quite dangerous for ITS as many ITS components operate in real times (Hahn, Munir, & Behzadan, 2019).

Confidentiality: As discussed earlier, the Intelligent Transportation System deals with sensitive information and protecting the confidentiality of those information is crucial. Confidentiality enables devices and parties within ITS to send their data through a secure channel which will prevent any eavesdropping or disclosure of information to uninvolved parties. It is very challenging to incorporate confidentiality in ITS as it involves a wide variety of devices.(Hahn, Munir, & Behzadan, 2019).

6.3 Methods for preserving privacy and ensure security:

It is requisite for the authority to solve privacy and security related issues and for that purpose they can use different techniques as well as policies. In this section we will discuss some current practices for protecting privacy that relate to ITS shortly (Fries et al., 2012).

6.3.1 Technological Approaches for privacy preservation:

The following section gives an overview of the potential technological solutions to preserve privacy as well as enhance security.

Secure ECU Architecture: As many of the ITS devices are resource constrained, it is hard to incorporate stronger security protocols. So the architecture of the system should be in a way which can control security and privacy issues. Different hardware security modules (HSMs) and Trusted Platform Modules (TPMs) can be used for this purpose (Hahn, Munir, & Behzadan, 2019).

Intrusion Detection Systems: For computer and network security, Rule-based and signature-based intrusion detection systems are quite effective. Intrusion Detection System can be interrogated with ITS system to fight against attacks and malicious actors to secure the privacy of citizens. It can be a valuable defense factor by configuring the rules correctly. Again there are some adaptive intrusion detection systems which are based on machine learning, can statistically detect anomalies and attack indicators to make the system more secure (Hahn, Munir, & Behzadan, 2019).

Privacy-Preserving Computing: In order to analyse traffic patterns, huge data collection is required, where privacy of these data needs to be maintained. One of the solutions that can preserve privacy while analysing massive amounts of data can be Privacy-preserving computing (Hahn, Munir, & Behzadan, 2019). Data aggregation can be used as well which reduces the possibilities of identifying individual vehicles (Cottrill, 2009).

Utilization of Trusted Third Parties: For managing the collection, encryption, and aggregation of user data, trusted third parties can be used. A trusted third party can validate the authenticity while not collecting information of the user that can identify him. Using pseudonyms the trusted third party can protect the identity of participating vehicles (Fries et al., 2012; Cottrill, 2009).

Separation of Communication and Authentication: Another way to protect privacy is to store location and speed data and vehicle identification data separately. That is how real-time location and speed data will not be associated with an identifiable vehicle. However there is potential risk on modifications of speed or location data (Cottrill, 2009).

6.3.2 Policy Approaches for privacy preservation:

Technology alone is not enough to deal with privacy and security issues. A country needs to come up with several legislation to solve these issues. As an example we can look at European commission which is working hard to implement GDPR for preserving one's privacy in Europe. Even in the ITS action plan for Europe this issue has been covered in Action Area 5: "Data security and protection, and liability issues" under:

"Action 5.1: Assess the security and personal data protection aspects related to the handling of data in ITS applications and services and propose measures in full compliance with Community legislation." (European Commission, n.d.).

Chapter 7: Case Study

In this section we will conduct five case studies where three of them are based on Developing countries and the rest are based on Developed countries. Case studies will be presented here using the digital ecosystem framework to understand how different organisations are implementing artificial intelligence and deep learning in the field of ITS to get the best result for satisfying the government as well as the citizens. However to make a comparison study between Developed and Developing nations we will also look into the external factors that an organisation has to face while deploying a smart traffic system and for that purpose we will use PESTLE framework.

7.1 Case study of Denmark (ITS TEKNIK):

Denmark is a prosperous Scandinavian country with a population of 5.5 million. Denmark's political system is based on constitutional monarchy, where there is a high social trust among the citizens. This small country is continuously coming up with revolutionary approaches to integrate different new technologies to deal with all the social and environmental challenges (Denmark in Ukraine, n.d.; denmark.dk, n.d.).

7.1.1 PESTLE Analysis for ITS in Denmark:

In this section we will discuss what are the impact of politics, economics, social norms, technologies as well as environmental issues on deployment of the Intelligent Transportation System in Denmark using the PESTLE framework.

Political: Political environment can play a key role in solving some of the current and future traffic challenges for a sustainable traffic system. In Denmark, traffic planning takes place on national, regional and municipal levels to improve the quality of life. The political goal is to achieve the long term plans fitted for an efficient and safe traffic management. However the politicians have a unique interaction with urban planners and public stakeholders in the transport sector which can contribute to the ongoing development of an intelligent transport system all over Denmark (State of Green, 2016). For implementing intelligent transport systems (ITS) in the capital which will control the traffic digitally based on weather and real-time traffic conditions, Copenhagen City Council has approved a budget of 60 million kroner ($9.1 million) (“Copenhagen to roll out new smart traffic system,” 2015).

Economical: Nowadays commuters are choosing the most efficient transportation mode to arrive at their destination in the most efficient way as saving time has a significant socio-economic impact on everyone's life. In Denmark, in order to identify the socio-economic value, the benefits of all transport infrastructure projects are being assessed based on construction and maintenance costs, travel time, accidents, public health, and also environmental effects (air quality and CO2 emissions). However, the socio-economic effect of the ITS initiatives can improve productivity as less time is spent on the daily commute (State of Green, 2016). Each year, about 160 million people use buses in the metropolitan area. The 10 City of Copenhagen has been working continuously so the buses can travel faster and more promptly. Some initiatives have taken place including the uniquely dedicated bus lanes which get green lights before the other traffic as a part of a smart traffic system and buses can reach their destinations more easily as well as on time (Københavns Kommune, 2014).

Social: When it is about using digital infrastructure, the population needs to be educated on digital technology. A high percentage of the Danish population have access to the internet (85%) and can get updates of their daily journey. In Spite of a well developed digital infrastructure, Denmark also has funds for advanced educational programs on digital technology for general people (ARUP, 2016). As ITS can improve safety and reduce the risk of accidents, people are accepting this technology very broadly.

Technological: New technological solutions are crucial for developing a smart transport system which can ensure high mobility in a sustainable way. For developing an ITS system, it is not possible to focus on only one technology. Several solutions need to be assessed to find out their strengths and weaknesses. However, Denmark takes an active approach to facilitate a combination of different technological solutions in the field of smart traffic management (Ministry of Transport, n.d.). Artificial Intelligence and Deep learning can promote different features to make citizen's lives better.

Environmental: in spite of having an environmentally friendly transport system, Denmark is continuously trying to reduce the impact of the transport sector on the environment. Deployment of different ITS features is a part of it.

Now to understand how an ITS company works in the context of Denmark this research paper has chosen ITS Teknik as a company which has a great impact on Denmark's Transportation system.

7.1.2 ITS Teknik:

ITS Teknik is working to maintain mobility in cities and prioritize traffic safety in Denmark. They are also taking into account the surrounding environment while settling the traffic on congested roads. ITS Teknik offers advanced ITS systems which are able to control traffic signals using simple counting machines and speedometers. However, in order to deliver the best service, it has been collaborated with the world's leading suppliers of traffic equipment,

ITS Teknik is a merger of Dansk Trafik Teknik and Olsen Engineering, which arose in 2013 and became one of the market-leading companies in today's industry. They also have competency in road traffic consultancy besides development, production, installation and service. That means the company is responsible to supply all necessary equipment, install them, put the system into operation and service the systems and also provide traffic technical advice (ITS Teknik, 2020).

Features of the specific service:

ITS Teknik provides different services and solutions to ensure road safety and better traffic management. It will be broadly described here:

Parking: In order to optimize the expensive parking spaces and reduce parking-seeking traffic, ITS Teknik provides the solution for the motorists to find the nearest available parking space using the shortest route. As parking-seeking motorists cause Up to 40% of inner-city traffic, information about free parking spaces can significantly reduce parking-seeking traffic. Again this search traffic can cause environmental problems for both outdoors and in parking garages. Reducing the search traffic will limit noise and emissions from cars. ITS Teknik takes these problems into account and with their parking guidance systems, traffic management and operating systems, they ensure the optimal interaction.

They also offer access control for the parking spaces to ensure that there are available parking spaces for the residents or employees for whom the parking spaces are intended. It will help the individual employee to spend less time to find a vacant parking space. Again the number of lorries are increasing in Denmark which requires extra parking spaces. With ITS Teknik's equipment it is possible to optimize the capacity of truck parking spaces, e.g. along the highways. The system can inform the truck drivers about the number of available spaces via electronic motorway signs (ITS Teknik, 2020).

Cyclists: ITS Teknik offers various solutions for cyclists and achieving bicycle green wave is one of them. The idea of the green wave is to coordinate the traffic lights for cyclists so that they will know what speed they should ride to hit green lights in the morning rush hour (Copenhagenize.com, 2014) and ITS Teknik's solution can inform the cyclists about what speed they need to keep to reach safely over the intersection. Their solution can also count bikes and the statistics can be used for comparison study of different cities.

Another service provided by ITS Teknik is right-turn solutions which can reduce the risk of accidents between cyclists and right-turn trucks at signal-regulated intersections. It may cause serious accidents with right-turning trucks and straight-ahead cyclists. They have integrated LED light along the outside of the bike path. These lights will flash when cyclists are on their way out to the intersection on the cycle path and right turning motorists can notice the flushing lights in their side-view mirrors which will avoid accidents. However if there are no cyclists near the intersection, the lights go out automatically (ITS Teknik, 2020).

Traffic Detection: To manage the traffic and ensure the traffic safety it is essential to have good knowledge of the traffic size and distribution. In order to conduct this counting ITS Teknik offers different types of equipment including milled coils in the roadway that are laid out on the roadway to register vehicles. Besides counting vehicles, the system can classify the vehicles into groups and record the vehicle's speed. Traffic counts are made at key locations every year to find out if there is any need for new measures to make the road more safe.

Another feature of their system is to show road users their expected travel time, for which a measurement and calculation system have been developed. The system provides information about travel time, delay and speed (ITS Teknik, 2020).

Automatic Incident Detection: The system can detect any slow-moving and stopped vehicles due to puncture or lack of fuel. To detect any incident automatically they use a video detection system, and send notification to the police. The system is also able to monitor the emergency lane and allow users to use it during rush hour using electronic light boards. However, cameras and detectors make sure that the emergency lane is not clogged when necessary (ITS Teknik, 2020).

Bus Priority: People often want to give priority to public transport in relation to other road users. Setting up the signal systems can help to achieve that. Coils can be established in the road to detect

buses and when the bus is detected, the traffic light will give priority to that by either staying green or changing to green as soon as possible. This is maintained for either as long as the bus departs the intersection or the predefined time interval has elapsed (ITS Teknik, 2020).

Features of the specific medium (technology):

In this section we will discuss different technologies that ITS Teknik is using to provide their services in the area of parking, cycling, road safety and traffic detection.

Single Space Detection for parking: As discussed earlier ITS Teknik offers efficient solutions to motorists to find the nearest parking lot quickly and for that they install single space detectors (SSDs) in the parking space to increase user satisfaction. SSD can be integrated with LEDs to indicate whether the space is free, occupied, reserved or a handicap space.

The parking guidance systems are based on installation of coils in the entrances and exits of the parking spaces. Whenever a car drives over these coilos, the coils sends a signal to a computer that constantly calculates the number of available slots. The finished data then shown in ITS Teknik's own developed parking pylon to inform motorists about the number of available spaces (ITS Teknik, 2020).

Bicycle Barometers: Since 2005, ITS Teknik A / S has been producing bicycle barometers which is a counting machine for cyclists, and also has a display to show how many cyclists pass by on site. Both the day's figures and the year's traffic for today's date is visible in this display. Moreover, cyclists can get information about rainfall, pollution, and their speed as well from these barometers. However, to count the cyclists, the system uses fiber optic sensors or inductive coils. This intelligent traffic management product also helps local authorities to plan efficient cycle routes (ITS Teknik, 2020).

Detectors and ANPR: For any kind of traffic management the first step is to collect traffic data. ITS Teknik therefore uses coils in the roadway to detect road users reliably. They also use video or infrared detection for this purpose. Another technology is ANPR (Automatic Number Plate Recognition) to read the number plates clearly even when the vehicle is in motion. The camera used by ITS Teknik is able to read the number plates in low light and bad weather conditions. The information being collected then forwarded to the Server online for further processing e.g, traffic monitoring, security, speed control etc. (ITS Teknik, 2020).

Advanced Smartmicro Radar: ITS Teknik also uses Advanced Smartmicro radar for the purpose of traffic detection. The radar is a 2.4 GHz sensor which is able to measure exact position and speed for each type of road user. It can also measure a distance of up to 300 m and able to track up to 64 road users at the same time (ITS Teknik, 2020).

Adaptive signal control: ITS Teknik supplies an adaptive signal control system 'MOTION' which is the real intelligence in the traffic management system. Using the coils in the carriageway MOTION can collect traffic data continuously and processes these to calculate new signal plans. MOTION made it possible to achieve a much smoother flow of traffic by reducing the number of stops and the total waiting time for road users, which results in the reduction of fuel consumption (ITS Teknik, 2020).

Value chain:

To automate the whole system ITS Teknik has a Central Internet Based Monitoring System(CIBOS). CIBOS is integrated with an Internet-based operating surface and is responsible for monitoring signaling systems. For increasing the safety on the road and reducing the impact of traffic on the environment the systems are functioning optimally with easily accessible monitoring (ITS Teknik, 2020).

However from the interview we get to know that ITS Teknik is also using Artificial Intelligence for some of their services though the CEO did not mention which services exactly (Hedelund, 2020).

Societal Environment:

In order to ensure better traffic management ITS Teknik has expertise for road traffic consultancy who offer traffic technical advice. Through different projects they are collecting the latest knowledge to utilize it for consultancy purposes. For trouble-free service of all of their products they also offer installation and spare parts. Furthermore, they are also working with privacy and security issues of Danes. As in the european context it is very important to comply with GDPR, this company has their own legal department to handle that. Again they do not store any data to avoid any security breach or privacy issues. This company has shown their competence in the field of development, production, installation and service to make people's daily life better in Denmark (ITS Teknik, 2020).

7.2 Case study of Austria (Kapsch Trafficcom):

Austria is a landlocked country of 83,878 square kilometres with 8.7 million inhabitants. Being one of the wealthiest countries in the world, the nominal per capita GDP is $46,972 (2018 est.). Austria follows parliamentary representative democracy and has developed a high living standard for its citizens. To ensure efficient traffic management, Austria has adopted the intelligent transportation system and day by day the system is getting better (Austrian Embassy, Washington, n.d.).

7.2.1 PESTLE analysis of ITS in Austria:

How different external factors are supporting the implementation of ITS in Austria will be discussed here:

Political: The rising number of vehicles in Austria is leading to congestion, increasing injuries as well as incidents of criminal conductance. To mitigate these problems political decision-makers along with transport operators and vehicle manufacturers are making their own contribution for the "Vision Zero" movement. The goal of Vision Zero is ensuring efficient traffic management by reducing the number of fatalities and traffic congestion to zero. In the last ten years the Government has invested over 100 million euros for the research and development of a strong ITS industry in the country (Federal Ministry for Transport, Innovation and Technology, 2016).

Economical: Austria's economy is thriving and generates a wealth of innovations in the area of energy, mobility, sustainability, healthcare and many other segments. By using different cutting-edge information and communication technologies, Austria as a nation is contributing to form a strong economy. To achieve the vision for a smart traffic system, their main focus is strengthening CO2-free modes as well as decreasing the motorised individual traffic (MIT) in the city to 20% by 2025 (Smart city Wien, n.d.).

Social: The smart traffic system involves technological novelties and social innovations which requires the interaction of different individuals and organisations (Smart city Wien, n.d.). Austria offers awareness-raising activities along with education and training programmes to its citizens to make the ITS platform more flexible to them (Federal Ministry for Transport, Innovation and Technology, 2016).

Technical: The main purpose of an intelligent transport system is to increase the individual mobility benefits, to overcome social challenges such as climate change and to safeguard Austria's competitiveness. The achievement of these targets depends on the technologies used in the transport system ranging from information processing for better traffic management to exact routing. However, the technologies for the smart transport system in Austria are already at a very advanced stage due to the early entry (Federal Ministry for Transport, Innovation and Technology, 2016).

EnvironmentaL: As a part of the EU, Austria is aware of reducing the CO2 emission due to road traffic and they are developing the intelligent transportation system in a way to achieve that.

Now we will look into **Kapsch Trafficcom** to understand how an intelligent transportation system works in the context of Austria for better and safer traffic management.

7.2.2 Kapsch Trafficcom:

Kapsch TrafficCom is working internationally in the field of intelligent transportation systems and has success stories in more than 50 countries around the globe. Kapsch TrafficCom is a part of the Kapsch Group, 1has the motive to provide intelligent mobility solutions for the citizens to make their journey comfortable, safe, and efficient.

Using the right technologies, this company is working to optimize the highly complex traffic system. Currently, they are providing their services for smart tolling, traffic safety and security, traffic management and smart urban mobility both in urban areas and on highways. They are creating value for both the drivers and infrastructure providers by offering their components, implementing the solution as well as maintaining the operation of the system. They are also working to reduce the pollution beside a better traffic management system (Kapsch TrafficCom, 2020).

Features of the specific service:

Using different technologies Kapsch is providing different services which will be discussed in this section:

Tolling: To control the road traffic and offset the cost of environmental pollution, one of the efficient ways to charge tolls based on use. With this system drivers can pay tolls quickly and easily. In order

to deal with Increasing urbanization this company provides the service of electronic tolling, city tolling and plaza tolling for better traffic control. The system uses various parameters for road pricing models; for instance: time, vehicle class, emission class, distance that the car traveled, fees are collected (Kapsch TrafficCom, 2020).

Traffic Management: In densely populated areas congestion is a major problem. Kapsch Trafficcom have started using the concept of managed lanes which can avoid congestion and lower CO2 levels. These managed lanes can be monitored by traffic management solutions and can control the entry and exit of vehicles based on current traffic conditions (Kapsch TrafficCom, 2020).

Safety and Security: In order to ensure traffic safety and security this company is combining sensor technology, software, and transmission technologies (radio or cable) to provide Automated traffic surveillance solutions to the authority for improving traffic safety and saving lives. However the system is also capable of traffic signal monitoring and vehicle speed monitoring and provides more detailed information to drivers about traffic congestion, can suggest alternate routes, or advise them to adjust the speed limits (Kapsch TrafficCom, 2020).

Smart parking: Around 30–40% of traffic is generated while road users are searching for a parking space. Kapsch Trafficcom provides Intelligent solutions which can guide road users to the nearest available parking space for lowering the traffic volumes as well as reducing CO2 emissions (Kapsch TrafficCom, 2020).

Features of the specific medium (technology):

Here we will talk about the technologies that have been implemented to provide the services; such as traffic management, preventing traffic violation, toll collection and so on.

Automatic Number Plate Reader (ANPR): Using the ANPR, the system can handle both front and rear images. The system supplies a digital image and uses optical character recognition to evaluate the number plate in that image. For security purposes they use different authentication and encryption (Kapsch TrafficCom, 2020).

Vehicle detections and classification (VDC): The VDC system uses video-camera for vehicle enforcement in stop/start traffic conditions. This company also uses Laser-based vehicle detection and classification (LVDC) where patented arrangements of infrared laser scanners are used for vehicle detection and classification (Kapsch TrafficCom, 2020).

Weigh-in-Motion (WiM): The Kapsch TrafficCom WiM system has a controller unit, sensors and a specially designed software. The sensors collect the signals and transfer them to the control unit where wheel-based weight information is processed. This system can determine axle weights, gross weight and trailer weight (Kapsch TrafficCom, 2020).

Value chain:

For providing their various services Kapsch TrafficCom needs to gather vast amounts of data being generated by traffic systems. These relevant data can generate useful insights for intelligent decisions. However they use machine learning to identify patterns, detect unplanned incidents, make predictions, as well as validate the impact of measures and suggest optimizations based on gathered data (Kapsch TrafficCom, 2020).

Societal Environment:

This global organization is working hard to make an intelligent system which will help the users to arrive at their destination comfortably, on time, safely, and efficiently. They are not only dealing with congestion problems but also fighting with poor air quality as a result of traffic. When it is about users' privacy, they are fully transparent to deal with user information (Kapsch TrafficCom, 2020).

7.3 Case study of India (Videonetics):

India occupies the greater part of South Asia with 1,352,642,280 inhabitants and 3,287,263 km^2 of land (Wikipedia, 2020). This second most populous country in the world is seeing terrible road congestion in every single day which requires the implementation of an ITS system in every single city (Sen, & Raman, 2012).

7.3.1 PESTLE Analysis for ITS in India:

As a developing country India is facing a lot of challenges when it is about the development of smart traffic systems. Here we will discuss the factors that affect the ITS system directly and indirectly.

Political: The growing economy and rapid urbanisation requires a robust urban infrastructure and for that purpose the Government of India has announced the Smart Cities Mission. Towards this initiative, the government has provided a funding of INR 50,802 crore (US$ 7.6 bn) over a five years period (2015-16 to 2019-20). The major component of a smart city is its transportation system and Indian government has approved several projects for unbun infrastructure and transportation development. Under these projects, some intelligent traffic management models have already been initiated. With increasing opportunities, more initiatives have been taken to implement smart technology for different purposes such as; smart cards (to pay for transportation automatically), electronic toll collection, real time parking management, etc. (Grant Thornton, 2016).

Economical: The rapidly advancing economy of India is responsible for the constant influx of rural population into urban areas results in huge traffic congestion. The average traffic speed in most of the Indian cities is just 17-23km/h which means people lost their precious time on the road every single day and it has a great impact on the economy. Again Road accidents are very common in India which causes a loss of around 3% of GDP. These above reasons are creating enormous demands of intelligent transportation systems (Singh, 2016; Vanajakshi, Ramadurai, & Anand, 2010).

Social: The main social issues affecting the deployment of ITS in India are: lack of user awareness, less demand for automation and also lack of interest among policy decision makers (Vanajakshi, Ramadurai, & Anand, 2010). The demographic composition of India also makes it difficult to deploy the smart system. Another problem is citizens' behaviour. They are not respectful to the traffic rules which can hamper the development of an intelligent system.

Technological: Though India has already introduced different intelligent transportation programs, still the integration of advanced technology into mainstream traffic management is crucial. Right now the main focus is on single-city based isolated deployments such as; parking management, area-wide signal control, and advanced toll collection (Vanajakshi, Ramadurai, & Anand, 2010).
Again with the current position, India is facing a few inherent challenges (inefficient infrastructure and slow pace of development) which will make it difficult for this country to keep pace with other countries on technological advancements (Grant Thornton, 2016).

Environmental: The severe congestion is deteriorating air quality as well increasing greenhouse gas (GHG) emissions. Before the situation gets out of control, remedial measures need to be taken in the transportation sector (Singh, 2016).

We have chosen the company Videonetics to get more insight about the Intelligent Transportation System in India as a case study.

7.3.2 Videonetics:

Videonetics has an AI & DL based Video Computing platform which is working to manage video data as well as other sensor generated data. With AI and Deep learning engines they analyse the video in real time for metadata generation and use them in different purposes. The platform provides solutions for a wide range of applications such as, Video surveillance, Traffic management, Retail management etc. With their solutions and services, Videonetics already secured more than 100 cities, 80+ airports, and 100+ large enterprises all over India. Currently their Intelligent Video Management Software is integrated over 100K + cameras which is being used to monitor 10,000 traffic lanes by its Intelligent Traffic Management System.

For providing all of their services and making the city better, they use Artificial Intelligence and Deep Learning engines. To make the system robust and smart these engines are trained with humongous data sets. Videonetics is recognized as number one video management software provider in India, and also among the top 5 in Asia (IHS/Informa Tech Research). For their excellent performance, innovative technology, and industry leadership, Videonetics has won a lot of prestigious awards from leading Indian as well as global institutions through their journey (VIDEONETICS, 2020).

Features of the specific service:

Using AI and DL they provide different kind of services which will discuss here:

Urban traffic monitoring: Being integrated with a city surveillance system, the custom-built, end-to-end solution is able to monitor road junctions 24x7 effectively and generate alerts in various forms if a vehicle violates any traffic rules. With the system interface, control room operators can search and view archived events anytime based on various search criteria, e.g., date and time, event type, license plate number, or any combination of these parameters.

For better traffic management Videonetics offers different solutions such as; to detect vehicles if they violate traffic signals or drive in a way that will violate the regular traffic speed. In India it is a very common factor that in two wheeler vehicles often the riders do not wear helmets or instead of two people there are more riders in motorcycles which causes a lot of traffic accidents. Another reason for traffic accidents is talking on the phone while driving. In order to admonish people, this system can detect those vehicles or persons who are violating traffic rules and generate fine tickets. Whenever such events are detected, the system will send messages to any other third-party software/device or the system itself will send emails and SMS to the authority as notification against an event. Moreover it is also able to generate a statistical measure of traffic volume/flow on a road for traffic analysis (VIDEONETICS, 2020).

Parking management: The system will generate an alert whenever there is a parking violation; such as a vehicle is parked in a restricted area or a no parking zone. It is designed in a way to detect vehicles even if there is movement of people on the scene. The system is also used for monitoring parking areas to determine empty parking spots in a parking area and the number of empty spots is calculated based on user-marked spots (VIDEONETICS, 2020).

Detection of vehicle pollution: It is a very common phenomenon in India that vehicles emit dark and black dense smoke. Those vehicles now can be detected by Videonetics' solution through its deep learning framework. Once a camera detects such an event, an alert will be generated with visual evidence snap and a brief video clip of that event. However smoke should be big enough to cover at least 10%~20% of the scene which is the pre-requisites of detecting such cases (VIDEONETICS, 2020).

Ensure Law Enforcement: Videonetics' ITMS is a great support system for traffic law enforcement agencies. The real-time data analysing ensures proper enforcement of rules and regulations. Again after integrating with the Police Database, ITMS solution can use country-specific vehicle databases, resulting in automatic processes to track, regulate and analyse vehicle movement on roads and to enforce trac rules for safety of citizens and their properties (VIDEONETICS, 2020).

Features of the specific medium (technology):

Here we will talk about the technologies that have been implemented to provide the services that have discussed in earlier section:

Automatic Number Plate Recognition System: Automatic Number Plate Recognition (ANPR) system is able to capture the license plates of any vehicle(s) automatically with the help of cameras and stores them in a database. That means all the details of the vehicles are available to be used at any later point in time. If any vehicle captured by the camera is recognised as 'suspicious', 'wanted', or any other category tagged by the authority, the ANPR software generates alerts automatically (VIDEONETICS, 2020).

Red Light/Stop Line Violation Detection System: The system architecture is scalable in order to add any additional road to the system for monitoring and incidence detection. This RLVD system supports both centralised and distributed computing architecture. In the centralised system architecture all the videos feed from all the cameras on a road will terminate in the central control room for being analysed in real time to detect violation of red light with automatic recognition of the license plates of the violating vehicles. However the system needs to be equipped with proper communication infrastructure, bandwidth, servers, storage and other IT infrastructure for real time analysis.

In distributed system architecture, instead of a central server, local mini servers will be used in each junction where multiple IP cameras are installed at each junction. Here the server can analyse the video feeds in real time for detecting violations locally. After that, only the violation clip and related information will be transmitted to the control room. The junctions and control rooms are centrally connected through VPN using private or public leased line/MPLS service (VIDEONETICS, 2020).

Speed Violation Detection: this is a video based speed violation detection solution that does not include any sensors like Radar or Laser, but is powered by computer vision and image processing algorithms (VIDEONETICS, 2020).

No Helmet Detection System: Two-wheeler riders who are violating traffic laws by ‘NOT’ wearing helmets while driving on road can be tracked by Videonetics No Helmet Detection System. Powered by AI and DL this Helmet Detection System is so intelligent that it can detect riders who fake to wear helmets by using caps, scarfs etc. for covering their head. The system is also trained with various

types of standard helmets so that it can filter out and detect non-standard helmets (VIDEONETICS, 2020).

Triple Riding Detection System: If the system detects any Triple Ride, it will generate events and store them. Evidentiary image/event is stored with time, stamp and vehicle number. Later for analysis such events can be retrieved based on needs. However in order to fine the specific vehicle for violating rules, the detected event is sent to another application installed at Central Control Room (CCR) where ticket/fine is generated. The Vehicle Owner database is also integrated with the ticket generation process to collect the name, address and other details of the Vehicle owner (VIDEONETICS, 2020).

Detection of Use of Cellphone While Driving: With their cutting-edge technology Videonetics is able to analyze gesture movement of the driver who is driving any type of four-wheelers such as private car, taxi, jeep, lorry truck etc. If the software detects any violation it will capture the license plate of the violating vehicle with ANPR, and also will generate an alert with the evidence video. Events are stored in the database for further analysis. Detection of Use of Cellphones while Driving is also integrated with e-Ticket Management Software for generating e e-tickets with details such as violation image, time stamp, date and vehicle number etc. (VIDEONETICS, 2020).

No Seat Belt Detection System: Videonetics 'No Seat Belt Detection System' analyses live video streams that can easily identify and detect four-wheelers drivers who are not wearing seat belts while driving. This system captures and stores the licence plate data of the violating vehicle that can be integrated with the country or state specific vehicle databases. This can then be used to issue e-tickets for seat-belt violation (VIDEONETICS, 2020).

Value chain:

Videonetics is creating value based on their 'Intelligent' Video Management Software (IVMS). This monolithic architectural framework is able to capture and handle video and audio data over an IP network efficiently. Again this software is deployable across multiple operating systems and hardware platforms. All the Videonetics offerings for better traffic management like Automated Number Plate Recognition (ANPR) system, Red Light Violation Detection (RLVD) system, vehicle entry/exit monitoring system etc. are integrated with IVMS.,

The software is quite investigation-friendly at the front-end, while all the complexity of the server software is handled well in the back-end. Users can interact with the system using a very simple and intuitive graphical user interface. The system is crush proof even when it is scaled for a distributed multi-server system, with thousands of cameras and storage.

For video and data analysis Videonetics use an AI & Deep Learning Framework named DeeperLook. This platform can be deployed both on cloud and in edge devices. DeeperLook is based on the self-continuous learning property of AI & Deep Learning technology. With this self-continuous learning mechanism it can automatically detect and recognize various types of patterns, features, objects, from an ocean of video data. Moreover even in tough environmental conditions, it showed the highest level of precision in detecting anomalies. DeeperLook not only improves the performances of the conventional analytics, but also opens the way for many new security and surveillance applications. However using DeeperLook for analytics is cost-effective and requires low carbon footprints (VIDEONETICS, 2020).

Societal Environment:

To make the operation easy for everyone, Videonetics provides Intuitive User Interface. Not only that, their web based central application also can be easily installed in any web server and Android based mobile App can be installed in any compatible mobile device. Videonetics's innovative and industry leading technology helps customers achieve better return on investment. However They are also dealing with security issues. To avoid any possible eavesdropping all the communication to and from the server is fully secured. Again all the Tickets that are generated for traffic violation are signed digitally by Digital Signature of the responsible authority to make the system authentic. Even the tickets are embedded with event images as evidence to avoid any confusion. Again to deal with privacy issues their system is integrated with the country database where authority is in charge of that database (VIDEONETICS, 2020).

7.4 Case Study of Indonesia (Nodeflux):

The republic of Indonesia is a country in Southeast Asia which is the world's largest island country with 1,904,569 square kilometers. This is the world's 4th-most-populous country where the population is 267 million (Wikipedia, 2020). In order to provide a safe and convenient transport eco system for this large population, the government has taken the initiative to implement an Intelligent Transportation System in the year of 2011 (GAIKINDO, 2015).

7.4.1 PESTLE Analysis for ITS in Indonesia:

How the Intelligent Transportation System in Indonesia is affected by political, economical, social, technological and environmental factors will be discussed first.

Political: With the rise in urban population, municipal governments are required to manage an escalating number of challenges in a smarter way. To cope up with rapid urbanization, the Minister of Communications and Information Technology of Indonesia has selected seventy four cities as a pilot project of 100 Smart Cities Movement. However, one political issue is there are no national regulations or platforms for smart cities in Indonesia and the local governments are developing their smart system with their own effort (Mahesa, Yudoko, & Anggoro, 2018; "Indonesia prepares US$685M," 2020).

Economical: Because of the Urbanization, Indonesia has seen economic growth which results in a high rate of owning cars, though the infrastructure of the city is still poor (Mahesa, Yudoko, & Anggoro, 2018). This condition has contributed to creating a crowded city and the ongoing traffic problem in Jakarta is responsible for Rp 8,3 trillion (USD 640,000,000) of loss per year. The consequences of traffic jams lead to a loss of Rp. 3 trillion regarding vehicle's operating cost. People kill their time in the traffic jam which is equivalent to Rp. 2,5 trillion and the impact of air pollution to health is estimated at Rp. 2,8 trillion (Muhammad, n.d.). So this urbanization requires the development of more infrastructure and services in the form of intelligent transportation systems to mitigate this congestion cost.

Social: Critical success of smart traffic systems depends on the capability of the people who are responsible for implementing the vision. Not only that, the users also need to have the digital competency to use the system. However, Education and training of citizens is also important to remove the gaps between a given technology and the users who will use it (Jakarta Global Insight, 2019).

Technological: Information and communication technologies act as a key for smart traffic management solutions. A lot of indonesian ITS companies are integrating Artificial Intelligence and Deep Learning to improve the development of the cities. These technologies are smart, cost-

effective, and resource-effective and help to achieve environmental sustainability targets (Mahesa, Yudoko, & Anggoro, 2018).

Environmental: Transportation sector is responsible for 70% to 80% of air pollution as well as contributing 23% of greenhouse gas (GHG) emissions. The government is working on a national emissions reduction plan and the smart traffic system will be helpful to achieve that (Leung, 2016). As a case study Nodeflux has been chosen, which is one of the largest ITS companies in Indonesia contributing to make the traffic system better.

7.4.2 Nodeflux:

One of the largest vision AI companies in Indonesia is Nodeflux based in Jakarta which was established in 2016 with a vision 'to continuously lead the highest standard of Indonesia technology advancement'. Nodeflux is incorporated in the NVIDIA Metropolis Software Partner Program. The main focus of Nodeflux is to develop deep learning and computer vision technologies, in order to provide Intelligent Video Analytics (IVA) solutions to solve complex issues faced by multi sectoral industries and modern society. With the IVA it is possible to empower client's existing cameras with AI-powered analytics such as facial recognition, license plate recognition, vehicle classification, people trajectory, and many more. Using Artificial Intelligence, Nodeflux has successfully engaged in several major solutions which includes smart city, security and defense, traffic management, toll management, store analytic, advertising etc. (Nodeflux, 2020).

Features of the specific service:

Using VisionAIre, Nodeflux provides solutions for Smart City Government and Business Enterprises. As our focus is only Intelligent Transportation System we will only discuss their contribution on traffic management and related issues to that.

Traffic Management Surveillance: The urbanization trend has created an unprecedented growth in traffic congestion in urban cities. This kind of growth requires safe and convenient traffic operations, as well as improvement in road infrastructure. Nodeflux's Artificial Intelligence (AI) technologies help in analyzing and identifying the efficiency improvements. This is implemented by using CCTV in each area while ensuring systematic traffic operations. After analyzing the data using AI they learn

patterns about traffic which is then used by the government and regulatory authorities to make a better data-driven decision or even automate the whole process of decision making.

For controlling traffic and reducing traffic gridlocks, Nodeflux uses Real-time visual processing systems for monitoring all the traffic periods in every city and every region. Their AI analytic is able to capture the unstructured data through this visual processing system. Later, the system converts the unstructured data into the structured one to provide insightful traffic information to the responsible figures. Not only that, the process can be elevated further to support a more reliable data-driven decision (Nodeflux, 2020).

Law Enforcement: Nodeflux is working with traffic safety issues, such as traffic regulations about vehicle registration plate expiration, driving restrictions including making a restricted U-turn, and casually parking vehicles. They use Artificial Intelligence (AI) for harnessing the process of managing a regulated vehicle registration and licensing system for ensuring the accuracy and reliability of the traffic operation system, that is also implied with the traffic regulations (Nodeflux, 2020).

Traffic Violations: As stated, Nodeflix's AI can identify any vehicles that are going through predefined areas. As a result, if a driver makes a restricted turn, or drives in the wrong lane, authorities are enabled to get that data. Later regulators can use these data to make more strategic traffic adjustments. Infractions can be even made more consistent with all day surveillance systems combined with their license plate recognition. However the system can also detect the movement speed of any vehicle (Nodeflux, 2020).

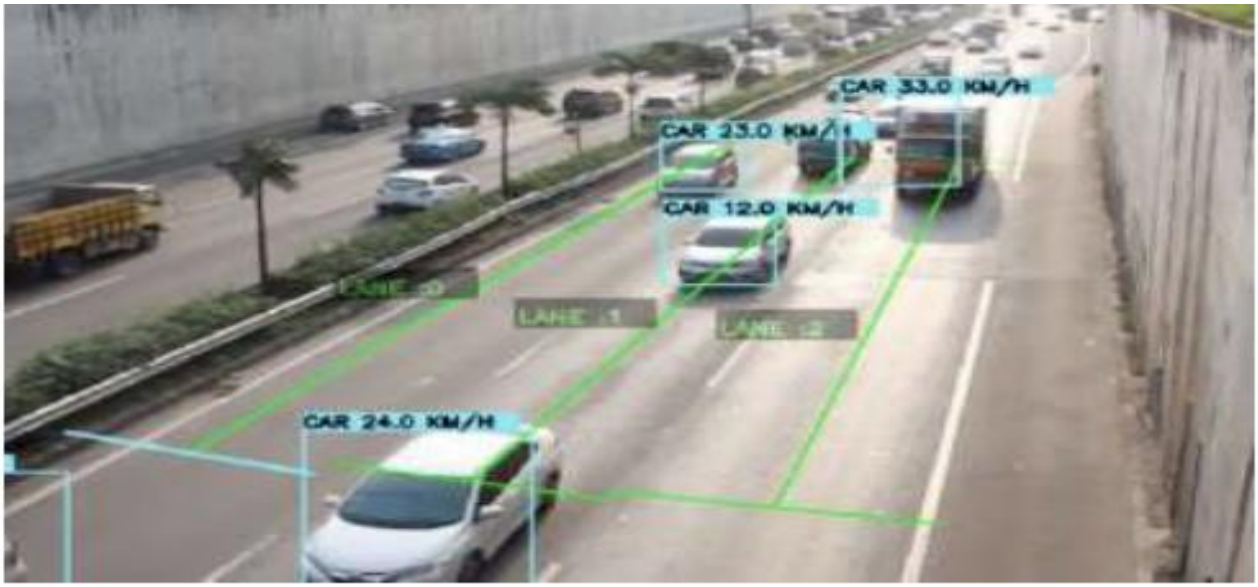

Fig 4: Vehicle Speed Detection (Nodeflux, 2020).

Illegal Parking Control: Illegal parking is one of the reasons for traffic congestion in highly mobilized cities. Though authorities put a lot of effort into preventing such infractions, there is always a limitation of human capabilities to observe vast areas persistently. But the analytics of Nodeflux empower surveillance cameras to track the stay duration of vehicles within a specific area, which can be used for illegal parking events (Nodeflux, 2020).

Features of the specific medium (technology):

Here we will talk about the technologies that have been implemented to provide the services such as: traffic management surveillance, preventing traffic violation and illegal parking. To monitor the traffic as a key analytics Nodeflux use vehicle counting and classification, vehicle dwelling and trajectory. In order to find any traffic violence Nodeflux uses vehicle trajectory and License Plate Recognition (LPR). LPR is also used along with vehicle restriction to solve the problem of illegal parking. In this part we will discuss all these key technologies/ analytics.

Vehicle Counting and Classification: Nodeflux Vehicle Counting and Classification is a Vision Artificial Intelligence Analytics Software that counts every vehicle passed in any certain area and classifies each of them into a motorcycle, small, medium, and big vehicle. This software is able to classify up to 23 types of vehicles and in the long run the number will be increased. Some key features of this vehicle counting software are:

- Can identify whether a vehicle is going in or going out in a specific area.

-It has multiple counting capability within a frame in order to cover a wider area for specific needs.

-Time to time comparison makes it easy to monitor the trend of any hotspot area.

-Besides counting, the detected vehicle objects can be categorized into predefined classes by size, body type and custom classification.

Using this Nodeflux Vehicle Counting software, vehicle density and capacity ratio on the road can be measured for determining traffic congestion and peak-time to make the traffic management better (Nodeflux, 2020).

Vehicle Dwelling: Nodeflux Vehicle Dwelling is a video analytic software, which can identify vehicle's stop duration in a certain area. Stakeholders (e.g police department, or local traffic department) can evaluate the efficiency of the current traffic system using these data (Nodeflux, 2020).

Vehicle Trajectory: This video analytic software can detect vehicle appearances and tracks their movement and trajectory in a camera view. With this powerful capability, it is possible to know which specific track a vehicle is going to choose, providing their travelling time and the vehicle classification as well (Nodeflux, 2020).

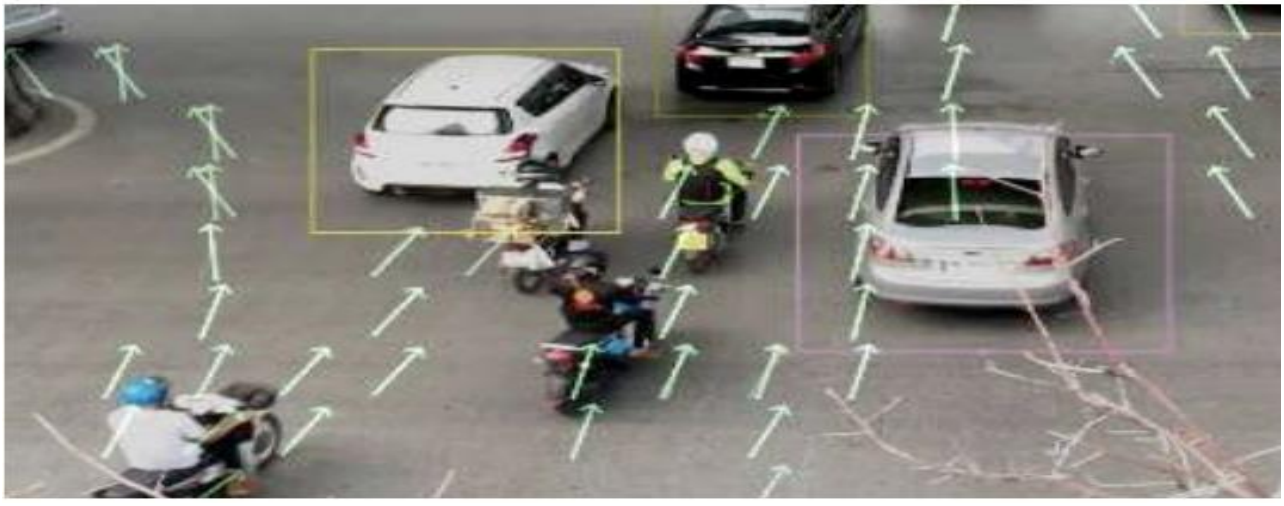

Fig 5: Vehicle Trajectory (Nodeflux, 2020).

License Plate Recognition (LPR): Nodeflux License Plate Recognition (LPR) provides recognition of license plates for all types of vehicles. Nodeflux LPR uses a Deep Learning algorithm which can adapt real conditions in Indonesia, such as various kinds of the plate, and any wide range of environmental conditions. Their LPR is well-trained to adapt to real environment and plate conditions such as rainy, sunny, visible low-light, and bent. The processing is super fast here which makes it possible to recognize the plate character within milliseconds; leaving no gap for missing any single vehicle. It is also capable of recognizing various Indonesian plate number types and colors such as black plate white character, yellow plate black character, white plate black character, and red plate white character. Again one of the features is Watchlist Management through which authority can find out whether high-profile vehicles are either blacklist or whitelist. And they also get real-time notification if any vehicle in the list is detected (Nodeflux, 2020).

Value chain:

As stated before Nodeflux is using Artificial Intelligence for their analytics named VisionAIre. It is the core of vision AI implementation across all of Nodeflux's solutions and deployments, representing years of experience in AI. Technically, VisionAire exists to implement all analytical functions, deployments, and tailor-made solutions. Combined with analytics modules, add-ons, and future developments to create solutions for different markets, It carries the optimism to resolve all the problems for societal benefit. All the solutions provided by Nodeflux use VisionAIre; since they are fully intelligent. Meanwhile, the use of those solutions also enable VisionAIre to learn and grow exponentially. By getting more used in the field VisionAIre is continuously developing to be a more capable engine and can be used for more solutions, more advanced analytics, and more implementation types in the future (Nodeflux, 2020).

Societal Environment:

Nodeflux's services are cost effective and easy to integrate. Their motive is to use the technology correctly which will not hamper anyone's privacy and security. They are creating value continuously in the transportation sector to improve the citizens social lives as well as to promote a better future (Nodeflux, 2020).

7.5 Case study for Bangladesh (Gaze):

Bangladesh, a country of South Asia, is the eighth-most populous country in the world. The country is about 148,460 square kilometres with a population exceeding 162 million people. So we can say it is one of the most densely-populated countries in the world (Wikipedia, 2020). This over populated country is suffering a lot because of the current infrastructure of the road and transportation system. No one can ensure how long it can take to reach the destination as vehicles wait on the road for hours. Again reckless driving is so common in Bangladesh which results in a high rate of accidents. To overcome such situations, it is high time for the Bangladeshi Government to implement ITS which can solve congestion problems, create awareness among drivers about their speed and so on.

7.5.1 PESTLE Analysis for ITS in Bangladesh:

In the context of Bangladesh, it is not as easy to implement an Intelligent Transportation System as overseas. There are several factors which have an impact on the deployment of such system. Using PESTLE we can find out those factors.

Political: A recent study shows that, in the last 10 years Dhaka's average traffic speed has dropped from 21km/h to 7km/h where 3.2 million work hours per day is lost due to the traffic gridlock. Though governmental bodies may disagree with the numbers, they have to agree that traffic is slowing down. However, to enhance traffic speed, the government has taken several projects which include the implementation of digital or smart signal systems. Under this project, the traffic police will be able to control the traffic lights with the help of remotes and can decide when they have to change the light from green to red or vice versa (Mamun, 2017).

However, for traffic management and crime control, digital surveillance systems have been implemented before, which is now integrated with smart technology to detect any vehicle or incident automatically (Tasbin, 2020).

Economical: Economic issues are hindering the deployment of ITS in Bangladesh. Because of the high unemployment rate and low per capita income, there is a lack of investment for ITS. However, with the increasing number of population requires change in the existing infrastructure and multiple innovative approaches should be taken to implement ITS. Despite the socio-economic constraints, different private sectors took the initiative to implement smart traffic systems. Moreover, many international development agencies have come forward to assist with intelligent transportation

networks. For instance, Dhaka Urban Transport Project (DUTP) got a fund of $284 million from the USA (Khan et al., 2014).

Social: It is very common in Bangladesh that most of the people are not willing to follow traffic rules which leads to traffic congestion as well as several accidents. This is very alarming that only 70% of people are aware of traffic rules and when it is about to follow the rules strictly, the number is only 13%. Again there is a Lack of understanding of certain technologies as well as a lack of knowledge on ITS systems. This knowledge gap along with the unwillingness to follow traffic rules make it hard for the authority to provide safety and efficiency (Mahmud et al., 2012).

Technological: As Bangladesh is a developing country, still internet connection is a big issue here which hinders the deployment of different Intelligent Transportation services (Tasbin, 2020).

Environmental: There are some environmental issues as well with the huge number of aged vehicles in Dhaka city resulting in hazardous environmental emissions on the roads. Adequate legal provisions have been made to monitor vehicle fitness, but they are not enforced strictly due to corruption. Because of poor quality buses or trucks which have already passed standard life expectancy but are still on the road, emit harmful gases (CO2, SO2 etc) and suspended particulate material (SPM). Several studies showed that the average SPM levels for 24 hours in Dhaka city are more than 10 times higher than the WHO guidelines (Khan et el., 2014).

Gaze is the first company in Bangladesh which has started the journey to implement ITS system in Bangladesh which makes it a crucial case study to understand the current situation in developing countries.

7.5.2 Gaze:

Gaze Technology Inc. is the first company in Bangladesh which took the initiative to use Artificial Intelligence in order to monitor the vast amount of visual data produced by cameras. This is a Canadian-Bangladeshi start-up company where the motive is to transform Dhaka into an AI city using intelligent video analytics and deep Learning (Iqbal, 2018).

An exponential rise in the number of road accidents in Bangladesh motivated a team of young Bangladeshi students to devise a project for managing the traffic of Dhaka and make the roads safer. With the help of AI powered video analytics software for CCTV cameras, the team is collecting real-time traffic data for traffic signal automation (Monamee, 2019). This Dhaka-based intelligent video analytics startup is also providing services for securities, attendance monitoring, analytics, optimization challenges, and much more, therefore has been selected for the prestigious NVIDIA Inception Program for AI startups. The purpose of this NVIDIA Inception Program is to nurture dedicated startups who are making a good change in the industries with AI and data science. Gaze technology was Founded in 2017 and from then they offer technologies like face recognition, license plate reading (even in Bengali), vehicle recognition, object detection, etc. (Future Startup, 2019).

Features of the specific service:

These are the services Gaze is providing right now:

Traffic Management and Safety: To deal with road safety, Gaze collaborated with Dhaka Metropolitan Police in October 2018 and is helping them to detect unfit vehicles and the ones without permits using Automatic Number Plate Recognition. It is now possible for DMP (Dhaka Metropolitan Police) to find out all the details of the vehicle owners using Gaze's technology (Monamee, 2019). The system can be integrated with any relevant databases to give proper notifications and warnings to the necessary departments according to their needs. That means, the system can analyze the patterns of vehicle movement and if find any anomalies or suspicious behavior can alert authorities to help avoid conflicts (Gaze, 2020).

Again in Bangladesh currently the traffic signals on the roads do not work properly, and the ones which are working are timer-controlled. So for the full automation of traffic lights this company is working hard (Monamee, 2019). They are also automating the payment system for toll collection and parking spaces in order to reduce traffic congestion (Tasbin, 2020).

Traffic Law Violation Detection: In Bangladesh it is a very common scenario - to violate the traffic rules. As there is huge traffic on roads it is not easy to detect the violations manually all the time. Gaze provides a traffic analysis system which is able to identify traffic law violations such as:

Wrong Parking Detection and Recognition: If vehicles make wrong parking, the system will be able to recognise their number plate and mark them as a traffic violation flag and then notify police with the vehicle's license plate number.

Wrong Way Detection and Recognition: If any vehicle is moving in the wrong direction, it can cause an accident and at the same time it is a serious law violation. So the system is designed to detect that vehicle by their number plate and mark them as a traffic violation flag.

Parking Management: To solve the problem of any unwanted parking, parking in any places for more than a specified time and two line parking though it was marked as one line will be considered by the system as a violation of traffic law and it will notify the responsible authority.

Blacklist Management: The authority will have a database where individual cars could be marked as Blacklisted. If the CCTV cameras capture any Blacklisted vehicle, it will notify authorities.

Finding Stolen and Unauthorized Vehicle: The licence plate recognition (LPR) system of Gaze Technology is 96% accurate which helps law enforcement agencies to track down any stolen vehicle in any street with the help of an AI based surveillance system (Gaze, 2020; Tasbin, 2020).

Features of the specific medium (technology):

In this section we will discuss how the system works with the help of Artificial Intelligence to make CCTV cameras an intelligent device to provide different services in the field of Intelligent Transportation System.

Automatic Number Plate Recognition (ANPR): The ANPR software which is powered by Artificial Intelligence can be handful for monitoring and keeping track of the licence plate number and also the time of all vehicles entering and exiting any premises. This monitoring is specially for VIP areas. Based on the VIP database, the system can offer better security for any certain period**.**
It is also possible for any organisation to manage guest vehicles in their premises by tagging any vehicle as Guests and use ANPR for better access control. The ANPR is also able to recognise the number plate for both front and back of the car and can also detect number plates for vehicles running in both single and multiple lanes. So the authority can search for any vehicle by number plate, time or date (Gaze, 2020 ; Tasbin, 2020).

Trajectory Map: With the Trajectory Analysis of the vehicle it is possible to track which specific points they are crossing during their whole movement. After analysing, the system generates detailed

reports and delivers it to the specific user. This is basically used for tracking a vehicle's movement for different purposes (Tasbin, 2020).

Vehicle Count by Type and Direction: Their AI technology is also able to count all the different kinds of vehicles that are running in the road and also can classify their type to help the authority for better traffic management (Tasbin, 2020).

Value chain:

All the services that Gaze Technology provides is based on IVA (Intelligent Video Analytics). Their intelligent video analytics software is named Alavya that has capabilities like face recognition, license plate recognition, vehicle tracking, person re-identification, and more. Alavya is a robust, customizable and secure suite of computer vision applications that can turn any dumb CCTV camera into an intelligent machines. With Alavya, cameras can be used in the field of ITS such as, vehicle surveillance, road safety analysis, industry automation and more. The features of the Alavya are given below:

Vehicle Registration: It is able to add any new identified vehicle Instantly in the system.

Multi-Camera Support: The software is super-scalable which can support infinity cameras.

Night Vision: Alavya software is quite compatible with night vision cameras. The system is as powerful in the dark as in daylight

Instant Notifications: If any undesired events occur, the system is able to detect that event and will send text/email notifications to the authority.

Spoof Detection: Alavya is designed in a way to make it capable of differentiate between spoofed images or videos and real feeds to avoid any unpleasant situation. (Gaze, 2020; Tasbin, 2020).

Societal Environment:

Since people in Bangladesh are not used to working with AI, it is quite challenging for this startup company to recruit the right people. Technological adaptability is another factor they have to deal with (Iqbal, 2018). Still now in Bangladesh IPV6 is not available everywhere, so internet connectivity sometimes becomes an issue. Though the system is capable of being integrated in the cloud, they are not able to launch it in the cloud properly because of network connectivity issues. However this company is also focusing on privacy and security issues. They are getting help from BCC (Bangladesh Computer Council) for data security. Bangladesh Computer Council (BCC) is a

government organisation which is working to support any ICT related activities such as formulating national ICT strategy and policy, creating standards and specifications of ICT tools etc. They also handle cyber security incidents and digital forensics (Cyber Security Intelligence, n.d.). In order to deal with privacy issues, Gaze has different strategies for their different services. For Gaze City application the company receives a lot of data from authority but they do not store any data for privacy preservation. They develop the system for the authority (police) based on collected and provided data and the authority has the access of this data by the law of Bangladesh. On the other hand when Gaze provides services for any private organisation they get the permission in a certified document to store the data for the purpose of service providing (Tasbin, 2020).

Chapter 8: Summary of Expert Interview:

In this section, the summaries of the interviews which were conducted will be presented. To get more insight of the system and how companies are using different technologies, two interviews were conducted; where one company is from a developed country, Denmark and another one from a developing country, Bangladesh. The purpose of choosing two companies from two different parts of the world was to understand how external and internal factors of ITS technology is different from the perspective of Developing and Developed countries.

8.1 ITS Teknik (Denmark):

The first interview was conducted with Per Hedelund the CEO, of ITS Teknik, Denmark and the medium was a zoom meeting. This company is developing their own system based on the needs of customers as well as the authorities of Denmark. Not only do they develop the system, they are also responsible for the installation of the system as well as maintaining it for 24/7. For their 98% project, they are working together with the danish authority though they do not get any financial aid from the government to build their system.

ITS Teknik is working with Danish Police enforcement for safety purposes. This company uses Automatic Number Plate Recognition to read the number plates of cars and put it in a database where the police are in charge of that database to find out if there is any criminal around, based on their black list. However, as an Europe based company they are abided by GDPR; so it is illegal for them to save any personal information. So after getting the data they deliver it to police for further action and do not have any personal data stored in their system. Nevertheless, they have their own legal department to deal with all GDPR issues.

Beside working for safety purposes with the authority their other main purpose is to deal with traffic congestion as it is a big problem for all over the world. For that purpose they are trying to deploy actuated traffic lights. For this purpose they are using sensors as well as raiders to detect the vehicles or pedestrians at the intersection. They also provide services for parking management and speed control. They have different dashboards placed on the roads to inform the drivers about their speed; if they are going faster than the usual speed. Again for privacy issues they do not take any picture.

When it is about the technology, they have started incorporating Artificial Intelligence in their system, especially for the traffic signal control. However their customers have shown interest to have more AI based products and the company is expanding the use of Artificial Intelligence for a couple of their products.

To deal with any system error, they have their own management department but at the same time they get help from other forign companies if needed. They have also started providing their services in different countries which are not that developed; for instance Spain and Colombia.

Lastly, with their current system they are able to solve the congestion problem of Denmark and they are also aware of the security issues related to this platform and are working regarding that issue.

8.2 GAZE (Bangladesh):

The second interview was held with Tasfia Tasbin, Head of business development team of Gaze, Bangladesh. Gaze is a first AI based company in Bangladesh which is providing their services based on three modules: Gaze control, Gaze city and Gaze API. First one is for small businesses (school and offices) where the school or the office can buy their software for automatic number plate recognition or face recognition by paying a certain amount of money. For the safety of the citizens and better traffic management which is as a part of Gaze city, they provide their software to the authority for various purposes including Traffic Monitoring, Anomaly Detection, Identity Verification and Emergency Recognition. They also provide Face Detection API, Face Recognition API and Fac Matching (Face Similarity) API to third party application developers.

They provide their services based on video analytics software named Alaviya integrated with deep learning algorithms which is responsible to process huge amounts of data (basically video/CCTV footage). Alaviya is scalable to integrate with any number of cameras, can work well at night and can send instant notification to the authority based on the incident. However they also use vehicle trajectory map and vehicle counting and classification technologies and are improving their algorithms day by day.

Though they have started their journey very recently, they are providing different services to ensure the safety of pedestrians and also to solve the congestion problem by multilane segmentation similar

to Developed countries. Based on the collected and available data, they designed a prediction model which solves the congestion problem in many areas, especially in the VIP areas. Wrong parking detection, Wrong way detection, automatic toll collection, parking management for the guest vehicles, finding the stolen or blacklisted cars are some of the new features they are providing in Dhaka city. However, they do not get any financial aid from the Government but are working along with the government to make the traffic management system better and also to ensure security.

To collect the data they only use CCTV footage, there is no use of any sensor or rader. However, they also have to deal with security and privacy issues though in the context of Bangladesh privacy is not a very big concern. To manage the security issues they get help from a government organisation named Bangladesh Computer Council (BCC) where for privacy concerns they can not store any personal data. However, when they provide their services to the small organisations via Gaze Control module, they take the written concern from that organization to store their data as it is mandatory to provide services like automatic attendance system or parking management. The situation is different when they provide services for Gaze City, here they transfer all the data to their integrated system for police and do not store anything.

As a new company in this field they got the opportunity to use the research which has already been done in this sector as there are a lot of companies using the same technologies to make the system intelligent. Though they have developed the whole system by their own with their own end operational procedure.

The biggest obstacle they face to provide their services is internet connectivity problems as IPV6 is not available everywhere in Bangladesh. For this reason though the system can be integrated in cloud, they do not launch it in cloud. Nevertheless, after they started their journey using deep learning algorithms for traffic management, the situation got better. It is now possible to identify any vehicle without going through all the CCTV footage for hours. This results in better security.

Chapter 9: Analysis

In this chapter, the findings which are obtained through the different parts of this study (Chapter 4,5,6,7,8) are being combined, analysed and discussed. We will start this chapter by analyzing and comparing the case studies using the components of the PESTLE framework to find out how different external factors can influence the implementation of Intelligent Transportation System and how challenging these factors are in the context of the developing countries. This analysis will help us to answer our first research question which is: "*What are the challenges a Developing country has to face while deploying a smart traffic system?"*

Political impact: From the case study it is very clear that the government of both developing and developed countries have taken several initiatives to carry out different ITS programs as development of a country depends on its transportation infrastructure. Developed countries like Denmark and Austria already have an infrastructure for the smart transportation system, thanks to their government for investing a huge amount in this sector. Another factor we have noticed from the case study is that political bodies from both of these countries have interaction with the public stakeholder in the transportation sector to make the smart system even smarter.

Case studies have shown us that rapid urbanization is the main cause that the politicians of developing countries have taken the initiative to implement the intelligent transportation system though the limitation in budget can hamper the initiatives. However, from the literature review we have already seen that developing countries can get late comer advantages while deploying a smart solution for the transportation system and do not need to invest in research. They can use the research done by other countries. Even from the interview we get to know that Gaze, Bangladesh is using the research done by other developed countries to build their system.

Economical impact: While a nation's economic issues can be a barrier for implementing ITS; after implementing such a system can have a great socio-economic benefit. It is pretty much clear from the case study that developing countries are still behind because of the reduction of GDP caused by traffic jams as well as road accidents. In the meantime they are facing trouble to implement smart solutions because of their poor economic condition. So the situation is quite contradictory. However these countries realized the importance of intelligent transportation systems and have started investing in such systems.

On the other hand, having a strong economical structure results in more investment in ITS for Denmark and Austria to increase their socio-economic value that can be achieved from the transportation sector. For instance, productivity can be increased if people will not lose their precious time in traffic.

Social impact: Implementing any service broadly depends on how citizens are going to accept that, or are they willing to use such a system, or do they have ability to use that system. Countries like India or Bangladesh, people are not respectable to the traffic rules. The number is enormous when it is about the violation of traffic rules. Implementing an intelligent transportation system can create awareness among the people as it is possible to detect that responsible person.
Again people need to have the basic digital literacy to use an intelligent system. While in Denmark and Austria, the local government has taken several initiatives to create awareness and educate people about smart traffic systems; there is no such program in Bangladesh, India or Indonesia.

Technological impact: Intelligent traffic systems are essential for increasing individual mobility as well as dealing with social challenges. However, implementation of such systems depends on advanced technology. Denmark has put the focus on combining different technologies to upgrade the system. For Austria the situation is the same as well; they are using all the advanced level technologies to improve their transportation system.

For India, they still need to integrate cutting-edge technology to make their traffic system better, where in Bangladesh the deployment of this kind of system is suffering from network connectivity/internet issues. However, Indonesia has made progress on using AI and Deep learning for intelligent transportation systems comparing other developing countries.

Environmental impact: To reduce the environmental impact of transportation, intelligent traffic management systems are mandatory. In Denmark and Austria they already have certain goals to reduce CO2 emissions which has a great influence on implementing intelligent systems for transportation.
The situation is even worse for developing countries like Bangladesh and India because of the congestion level and old vehicles. To mitigate these issues, ITS is a must in these countries.

In the next section we will dive into the **technological implications** to solve different challenges as well as other problems in the transportation sector for a developing nation to make a better and safer traffic system. A specific focus will be put on the following Artificial Intelligence and Deep Learning features: data ingestion, limited human cognition, vehicle detection, classification and tracking, incident detection and accident prevention etc. that can help a developing nation to overcome the daily problems they face in the transportation sector regarding congestion, safety and much more. However the components of digital ecosystem (service features, technology and value chain) will help us to have better understanding of the implications of AI and DL to answer the second research question which is "*What are the implications of Artificial Intelligence and Deep Learning in the field of Intelligent Transportation System to make a better traffic management system that can create value for both the Government and citizens of a developing nation?"*

Feature of specific services: Most of the features of ITS are the same for both the developing and developed countries. Combining Artificial Intelligence and Deep learning with different sensors, CCTV or other technologies, all of those companies are providing services like parking management, automatic incident detection, traffic management, automatic toll management as well as vehicle pollution detection.

From the cases it is quite clear that India, Indonesia and Bangladesh are implementing smart parking management to detect any parking violation (wrong parking detection) as it is a common scenario in these developing countries which is one of the main causes of traffic congestion. However, in Denmark and Austria the smart parking system is for finding empty spots to reduce parking-seeking traffic. In Denmark the system became more advanced as they are using access control for parking spaces to make the system more sustainable for the residents as well as employees.

Again different algorithms and models of Artificial Intelligence and Deep Learning (such as; Fuzzy logic, ANN, CNN etc.) can be used to detect different incidents. As mentioned earlier, traffic rules violation is a common phenomena in developing countries and companies from the case studies are using these technologies to detect any violation of traffic rules. However, in Denmark, the system is also capable of detecting incidents like slow-moving and stopped vehicles due to puncture or lack of fuel and send notification to the police to take actions.

The most important feature of an ITS is to monitor and manage the road traffic. Automated traffic surveillance solutions are being used for safety purposes in almost every country. Object detection, classification and tracking options of deep learning are being used for lane segmentation purposes as

well as automatic toll collection which can help to reduce traffic congestion both in developed and developing countries. Real time traffic signal monitoring along with actuated traffic signals became a popular option to mitigate the congestion problem. However processing the real time traffic data, developed countries (for instance Denmark) can provide information about travel time, delay and speed to its citizens.

Feature of specific medium (technology): One of the important components of the digital ecosystem is features of specific medium which focuses on different technologies that customers use to interact with the services. To provide services like parking management, traffic management, incident detection etc. companies are using different mediums where their working principle is based on either artificial intelligence or deep learning.

Automatic number plate recognition (ANPR) software is such a medium powered by Artificial Intelligence or Deep Learning. This medium is very handy in terms of parking management and safety purposes. With the help of ANPR it is possible to find a vehicle automatically which is either blacklisted or violating any rules or is allowed to enter a specific parking area. Vehicle counting and classification is another feature of AI and DL which makes it easy to manage the traffic for both developing and developed countries. Using vehicle classifiers it is possible to identify which vehicle needs to be prioritized during the peak hour or which kind of vehicles are restricted in a specific area. For example; in Denmark public buses or emergency ambulances get the priority during heavy traffic while in Bangladesh rickshaws are banned in certain VIP areas to control traffic jams; in both cases vehicle classification can be used. It can also be used for collecting the tolls automatically.

Some other technologies such as adaptive signal control, vehicle trajectory, analyse the gesture movement of drivers etc. are also crucial for better and safer traffic systems.

Value Chain: Artificial Intelligence and Deep Learning are two modern approaches that can change the whole transportation system and create value for the governments and citizens for both developed and developing nations. However, these technologies only work efficiently when there is a huge amount of data. All the data generated via sensors or video cameras are processed centrally by AI or DL based software, to get the analytics of traffic or to take real time action. Moreover this complex system needs to be user friendly to use and also crush proof as it is scaled for thousands of sensors or cameras as well as storage devices. Another important thing to keep in mind while implementing such a system is that it will work efficiently even in the rough environmental conditions.

Societal Environment: One of the barriers of implementing an Intelligent Transportation System is privacy and security issues. Collecting and storing private information raises a lot of questions. Using this Societal Environment component of the digital ecosystem we can find out how the implementation of an ITS can be hindered by the privacy and security concerns to answer our last research question: "*What are the privacy and security related issues an Intelligent Transportation System has to deal with and how they can deal with these issues?"*

As a part of an ITS system video cameras and GPS tracking are necessary which can gather personal data. Not only that, electronic credentials can also be gathered while electronic toll payments. However, these gathered data can be compromised in various ways. Service providers, involved parties as well as third parties can be responsible to compromise the privacy of citizens by using their data in different purposes or selling them. This issue became so important that every government has their own legislation on using private data for providing different services.

Another problem is related to security; the collected and stored data can be breached by different malicious attacks. Data can be altered and incorrect information can be used for various decision making which will cause catastrophic consequences. Again confidentiality can also be compromised via eavesdropping attacks. Nevertheless, to ensure the security different approaches can be taken by companies. The architecture of such a system should be strong enough to deal with different attacks. Data aggregation along with privacy preserving computing should be used while processing the data. Secure data storage and trusted third party is a must when it is about to secure the system.

From the case studies as well as the interviews it is quite clear that privacy and security issues are a company's biggest concern. From the interviews we came to know that they do not store any information; it's the authorities (police) who are in charge of the stored data and use the company's software to find out blacklisted cars, criminal activities or any violation of traffic rules. The CEO of ITS Teknik, Denmark mentioned that they have separate departments to deal with security as well as GDPR issues. From the interview with the Head of Business Development, Gaze, we came to know that for security they are getting help from Bangladesh Computer Council to follow the policy and standard. They are also not allowed to preserve any personal data according to the law of Bangladesh.

They can only store personal information when they provide their services in the private sector and for that they need to get permission from that organization.

Chapter 10: Conclusion

In this section, the findings of the analysis are being concluded in relationship to the research questions of this study which are being defined as follows:

- *What are the challenges a Developing country has to face while deploying a smart traffic system?*
- *What are the implications of Artificial Intelligence and Deep Learning in the field of Intelligent Transportation System to make a better traffic management system that can create value for both the Government and citizens of a developing nation?*
- *What are the privacy and security related issues an Intelligent Transportation System has to deal with and how they can deal with these issues in the context of a developing country?*

Summarizing the findings in analysis section, following conclusions were drawn:

Challenge 1: The biggest challenge for a developing country to implement an ITS is the limitation of budget.

Solution: Using the research done by other countries can save a lot of fundings. Again the government can combine with other private companies in the transportation sector to implement a smart traffic system to overcome the financial challenges.

Challenge 2: The economic condition of a developing country is often broken. There is a huge loss in GDP due to traffic congestion and road accidents.

Solution: Intelligent Transportation systems can reduce traffic jams and enhance road safety with the help of Artificial Intelligence and Deep Learning. Different features of AI and DL such as vehicle detection, classification, recognition can be used for better traffic management, parking management, automatic toll collection, lane segmentation which can solve the congestion problem. Again different

algorithms and models of AI and DL such as fuzzy logic and ANN can predict the accident and necessary actions can be taken on time. In sort, ITS can increase the socio economic value for a developing country by reducing conjestion and accidents rate.

Challenge 3: One of the social problems of developing countries are people are not willing to follow traffic rules. Also the older generation may not understand different technologies used in ITS.

Solution: Based on ANPR (Automatic Number Plate Recognition) and Video surveillance, AI and DL can power the smart traffic system to detect any violation of traffic rules. Using Artificial Intelligence and Deep Learning it is possible to detect the culprits with limited human cognition. Again government can take several initiatives for digital literacy programs to educate the citizens about the use of general technology.

Challenge 4: Cutting edge technologies are expensive and yet not available in developing countries.

Solution: Artificial Intelligence and Deep Learning can turn the dump CCTV cameras or simple sensors into an intellectual system which can create value for the government by solving different issues related to the traffic system.

Challenge 5: Environmental pollution has become a great concern for developing countries due to traffic congestion and toxic gas emissions from outdated vehicles.

Solution: Intelligent Transportation system can detect any vehicles which are not permitted to be in the road anymore. With the actuated traffic signal it is possible to reduce the waiting time on traffic signal and it will result in less CO2 gas emission.

Challenge 6: The working principle of AI and DL depends on processing a huge amount of data. It can raise privacy and security concerns; such as, service provider can use user information for different purposes or sell them or different malicious attacks can hamper the confidentiality and integrity of user data.

Solution: Secure architecture, trusted third party along with legislation regarding the use of personal data can solve different privacy and security issues. Companies should not store any data. However when it is about to detect any culprit (who violates the traffic law) or blacklisted car they can use the database which is controlled by the authority.

The aim of this study was to understand the current situation of an Intelligent Transportation system of a developing country which formulated three research questions. To answer those question state

of the art as well as different case studies were being researched. Furthermore expert interviews were conducted as well and based on all the information the research came to a conclusion that using Artificial intelligence and Deep learning is quite efficient to solve different problems of the transportation sector of a developing country. Different features of AI and DL such as data ingestion, limited human cognition, vehicle detection, classification and tracking, incident detection and accident prevention etc. have made it possible to make our road more secured and traffic is more managed. Though there are some issues related to data privacy, these issues can also be mitigated with different technology and policy.

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Appendix

Interview with ITS Teknik, Denmark
(Per Hedelund, Adm. director / CEO
peh@its-teknik.dk
+45 2010 0231

Medha: Hello.
Per: Yes, hello.
Medha: Can you hear me? Hi, how are you?
Per: Yes, thank you. And you?

Medha: Yeah, I'm good.
Per: Just one moment. I'm going to close the door.
Medha: Yeah. Yeah, sure.
Per: Yes, now I'm ready.

Medha: So, I am doing my master thesis based on the topic of Intelligent Transportation System. So maybe we can start with, how ITS Teknik works and what kind of technologies you are is using right now?
Per: Yes, of course. Yes. We are working with Intelligent Traffic Solutions.First of all, we are working with traffic signal lights and we are working with the police. Different kind of police enforcement systems. For example, we are reading ANPR and that means automatic number plate recognition. Yeah, we are putting all the number plates in database at the police and they have a black list and so they can immediately see if there are some criminals around them.
we also make speed enforcement for the police with cameras. We are making all kinds of parking systems, parking guidance systems in the bigger cities, you know, there. So you can see where we have the free spaces to allow them to park your car.
we are we deliver a lot of very, very ambitious signs and to to slow the speed for a lot of speed display so you can see your speed when you are driving. And if you are driving too fast, you can see some plates to tell you that you are driving just to drive fast. We're not making a photo of you, but we are going to inform you that you are driving too fast.

Medha: So is basically like there are devices in the road, not like any notification they are getting in their phone.

Per: Exactly.First of all, we have a lot of interviews. I mean, they are together with the customers, the authorities in Denmark. They plan how to build the things that we have a development department. We are developing our own systems also. We also work together with a lot of the foreign companies, for example, Siemens, the big company in Germany. We also work together with American and Canadian Australian companies. but also developing our own systems.

When we cannot find a system in the world to Denmark. Then we develop our own systems, we have a big installation and service department means we plan and we also install and make the 24/7 service afterwards. We are today 60 people working with our engineers.

Medha: And so for this whole thing, are you using artificial intelligence or deep learning or video analytics, Iot? What kind of technology you are incorporating in your company?

Per: We are also cooperating those kind of solutions in our system here in Denmark. Not that much at the moment, but we can see that the customers want more and more of this artificial intelligence systems.

For example, Normally we have detectors which detects the cars and the bicycles and so on. But for traffic signals, we have some algorithms to try to control the signals. But we in a couple of systems, we also have a fill in this kind of artificial intelligence.

Medha: OK, so according to you, it's not that much now you are implementing, but maybe in future you are going to implement it more.

Per: Exactly.

Medha: OK, and the next question is if you faced any kind of technical problem, how it affects the whole system and how you manage these problems?

Per: Yes, we are. We are system integration in our office. We have project managers which manage the problem. And we have a lot of technicians, of course, and we also need help from our partners in other countries. For example, Siemens, we have some difficult issues to solve, but normally we can solve the problems by ourselves. But we have a system integration, and that means that we have the full responsibility of the customers in make that decision that all the systems work.

Medha: OK, and is there any legal restrictions, like GDPR issues you are facing there? Because I already read into your website that you don't save people's data, but at the same time you are working with their video and their pictures. So is there any legal problems in this kind of platform?
Per: for ITS there can be a lot of legal problems. And we work a lot with the GDPR in our company. And of course, It's not possible for us to save photos, to save the data. We have to destroy the data immediately. When we have used the data, then we then destroy the data. When we work together with the police force, we deliver the data to the police and the police use the data. We don't have the data in our database.

Medha: And what about the security? Because there could be any security breach. And I mean, you already told me that you are just sending the data to police. So you are not like saving anything in your database. But do you think that when you are not saving any data, there won't be any security issues?
Or are you facing any security issues?
Per: There are always issues about those things, but we have our own data manager, for solving those things and when we have questions, we go to him. And so we are safe in that direction. So we know that we have no problems with the authorities.

Medha: OK, so I assume then you also don't have any problem regarding privacy risk?
Per: No not really.
Medha:. OK, but the thing is that when a company first start in this kind of platform like ITS, so what kind of problem they can face? Because for me my research is a comparison from developed countries and developing country in this field. Me myself is from Bangladesh and there is right now only one company who is trying to build this kind of system. So what do you think what kind of problem they can face, in developing countries?
Per: I don't know much about the third countries companies,. So it's difficult for me to say what they can do to solve a problems.

Medha: Yeah, so far, developed countries like Denmark, what problems that company can face if they like to start with the ITS system.

Per: I think the main issue is the traffic lights, that it might be the main issue. And I think in all countries they have a lot of traffic jams. And I think that the most important issue is to start with traffic signals. Traffic signals that they have to be traffic actuated not only by a time schedule, but traffic actuated. And that means you need sensors in roads. Today Instead of sensors, we are installing radars, one radar in each direction. And then we can see the cars, the bikes and the pedestrians coming across. And then we can control the traffic signal.

Medha: Are you exporting your service to any country?
Per: No, my company only work in Denmark. Mm hmm. We don't export anything, and that's not quite true. We have some bike meters which we export to different countries, but certainly to show how many bikes have been here today. You can see so many bikes today and so many bikes this year. And an instinct like this, we have exported to Spain, to Colombia and to some other countries.

Medha: So with the current system, do you think that the problem of traffic conditions can be solved or is there anything that you are going to develop further or like any new technologies that you are going to use later?
Per: we have already solve the congestion problem with the current system.

Medha: Are you getting any help from government financially?
Per: No, , I have my own bank and I have no need to get money from government. Of course, we work a lot together with the authorities in Denmark because that is our customers for 98 percent. That is the authorities in Denmark.
Medha: OK, that's great. And yeah, I think that's all I wanted to know. And thank you so much for your time. And it was really nice to talk with you. And I got like a lot of insight in this segment.
Per: Thank you too and have a nice day.

Medha: You too. Bye
Per: Bye.

Interview with Gaze:
Tasfia Tasbin
Head of Business Development
Gaze, Bangladesh

Medha: Hello Tasfia. How are you doing?
Tasfia: Hey, I am doing good. What about you?

Medha: I am fine as well. So maybe you can start telling a bit about the company Gaze. What kind of services you are providing right now?
Tasfia: Well we have basically three different modules. One is gaze control which is basically providing services to B2B companies where they buy our AI-powered access control system for limiting access for humans and vehicles through Face Recognition and Automatic Number Plate Recognition (ANPR). This system is used for attendance monitoring also. They have to pay a certain amount of money for a certain amount of period based on their camera and hardware requirement.
The next is Gaze city which is a City Surveillance system capable of monitoring activities in a city. This system has various capabilities like Traffic Monitoring, Anomaly Detection, Identity Verification and Emergency Recognition. The consumer of this module is the authority for the safety issues.
The third module is Gaze API. GazeAPI is a cloud API primarily focused for business or third party application developers to use Gaze's computer vision capabilities into their system. We provide Face Detection API, Face Recognition API and Fac Matching (Face Similarity) API.

Medha: Great. What I learn from your website you are using deep learning for providing various intelligent services. Tell me something more about it.
Tasfia: well right now it is an intelligent video analytics company where we use deep learning for processing data though our goal is to emerge as an AI company in future. We are aiming to sell our APIs to different countries in near future. However for Gaze City and Gaze Control we also provide consultancy where for Gaze API we just sell the API. We are also using different features of deep leaning like trajectory map and vehicle classification, vehicle counting.

Medha: Do you provide any service for the pedestrians' safety? As we can see there are a huge number of accidents in recent years.
Tasfia: Yes, we do. Well in our country the citizens do not want to follow traffic rules which results in terrific accidents. Through our system it is possible to detect if the pedestrians are using zebra crossing or not and the authority can take further actions.

Medha: What about Lane segmentation? In Developed country they have traffic actuators which can control what kind of vehicles will pass by which lane. Do you provide similar services.
Tasfia: We recently added this feature in our system. You know in Bangladesh there are a lot of Rickshaw (vehicle which has 3 tires) causing traffic congestion. In several area where these vehicle can cause traffic congestion are already banned by the authority. So our system can detect rikshaw in these areas and can notify the authority or traffic police immediately. In these area there are already police checkbox so when they get the notification from our system, they take actions.

Medha: So you are working with the authority to make the city safer. Are you getting any funds from Government to develop the system or to improve it?
Tasfia: No. We do not get any financial help from the Government. It is a private company which helps the authority for better traffic management.

Medha: Can you tell a bit more about Alaviya?
Tasfia: This is the name of our software. You can think it as azure platform of Microsoft. We call the main core of machine learning platform Alaviya which is responsible for all analytics to provide all of our services. It can support infinity number of camera and van work perfectly even at night.

Medha: What about security issues? How do you deal with that?
Tasfia: Yes. For the security purposes we get help from Bangladesh Computer Council (BCC). We get certified help from them.

Medha: What about the legal issues when you are dealing with huge amount of data?
Tasfia: Well, we have that limitation. Though we need a lot of data for analytics and we get that data from government using CCTV footage, we are not allowed to store any personal data. We just develop the system and analyze data. However when we work with any private company which is a part of

Gaze Control, for example one school is using our face recognition system for attendance and we have stored all of students data with their photo. We have taken the permission from that school to use these data in a certified document. Same goes for small offices. Basically this is for Gaze control where we need to take the permission of using their footage for providing services. For Gaze City applications things are a bit different as this is meant to help the authority(police and law enforcement department) and by Bandeshi law they are allow to have access of any personal data**.**

Medha: Super. So as this is first AI company in Bangladesh what kind of social or economical problems you are facing?
Tasfia: The biggest problem is Internet issue. Still IPV6 is not available all over the country. For network issues system does not work properly. This is not our problem but we get the blame. Secondly as we are working with video analytics, there are a huge amount of video data that need to be stored and sometimes client doesn't understand or have any proper storage plan which makes thing hard for us.

Medha: Are you providing cloud based online services?
Tasfia: Our system van be integrated with the cloud. But because of network connectivity problem we do not launch it in cloud. Though we have a lot of cloud credit from AWS and GCP. But we are unable to use it properly.

Medha: So what do you think? After launching your service does the situation get better than before? Is it possible now to have better traffic management and ensure road safety?
Tasfia: Yes, it has. As this is a new company our main focus right now is diplomatic zones of Dhaka where security is a must. In previous, in these diplomatic zones they have check posts where police stopped every single vehicle for checking. But now our system is integrated with Bangladesh Road and Transport Authority (BRTA). So now in these check post police have the data which car they need to stop for checking. Previously they had to go through whole CCTV footage to find a car manually but now with ANPR they can automatically find a car in second. Our system can also provide wrong parking detection, Wrong way detection and can find stolen car.

Medha: What about toll collection? It is also automatic?
Tasfia: We have started working on that. But it is not finalize yet.

Medha: Another thing is as Bangladesh is a developing country and the journey of AI just have started here. So do you get any help from any Developed country to build the system and as well as operational purposes?
Tasfia; Well for research purposes we have followed several cases but we have built our own system and have our own operation system.

Medha: Great! I think that's all I need to know. Thank you so much for your time.
Tasfia: Thank you too. Best of luck for your thesis.

Medha: Thank you. Have a nice day. Bye.
Tasfia: Bye.