Czech University of Life Sciences
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BACHELOR THESIS

Traffic Enforcement Systems Databases in Yemen

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Study programme:	Systems Engineering and Informatics
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BACHELOR THESIS ASSIGNMENT

Abdulsalam Abdulhameed

Systems Engineering and Informatics
Informatics

Thesis title

Traffic Enforcement Systems Databases in Yemen

Objectives of thesis

The main goal of this thesis would be to propose the design of traffic enforcement system database suitable for Sana'a, Yemen. In order to achieve this goal, following research questions will be addressed:

• How do traffic enforcement systems work and what are their components? What technology is used today to monitor traffic?
• What is the current traffic situation in Sana'a, Yemen? Is traffic enforcement system needed?
• What is a suitable model to implement in Sana'a's conditions and how will the database be incorporated within this model?

Methodology

The analytical part of this thesis will research the entirety of traffic enforcement systems and different components they contain. This will provide a clearer understanding of how the input of the system will look like, and what data need to be processed. Challenges of the processes and the solutions that could eliminate them will be discussed too. The next part will talk about Yemen, Sana'a and its specifics. This chapter will be supported by a survey focusing on what the public faces today on the road and how would they feel about the implementation of traffic enforcement system. The discussion will break down the results of the survey and highlight the current challenges drivers face in Sana'a. This will help in designing a system that takes inspiration from existing systems with the adjustment to our case study. Based on the synthesis of findings from the analytical part, a database prototype for traffic enforcement system will be proposed, which could be useful for electronic evidence of traffic violations.

The proposed extent of the thesis

40-50 pages

Keywords

Traffic, Enforcement, Databases, Traffic Enforcement system, Yemen

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Recommended information sources

Allan F Williams , Sergey Y Kyrychenko, Richard A Retting. ”Characteristics of Speeders”, Journal of Safety Research,DOI:10.1016/j.jsr.2006.04.001, 2006 , pp.37(3):227-32

Becky P. Y. Loo, Tessa Kate Anderson. Spatial Analysis Methods of Road Traffic Collisions. 1st edition, B/W Illustrations 2016 . ISBN: 9780429251535 {Page; 223}

Eshrak Alfalahi, Ali Assabri, Yousef Khader. ”Pattern of road traffic injuries in Yemen: a hospital-based study”, Pan African Medical Journal, DOI:10.11604/pamj.2018.29.145.12974

Richard A. Retting, Charles M. Farmer.”Transportation Research Record” Evaluation of Speed Camera Enforcement in the District of Columbia, 2003.Transportation Research Record Journal of the Transportation Research Board 1830(1):34-37. DOI:10.3141/1830-05

Saha, S. (2020) “Automated Traffic Law Enforcement System: A Feasibility Study for the Congested Cities of Developing Countries: Automated Traffic Law Enforcement System: A Feasibility Study for the Congested Cities of Developing Countries”, International Journal of Innovative Technology and Interdisciplinary Sciences, 3(1), pp. 346–363. doi: 10.15157/IJITIS.2020.3.1.346-363.

ULLMAN, Jeffrey D. a Jennifer WIDOM. A first course in database systems: a practical guide to secure computing. 3rd ed. Upper Saddle River, NJ: Pearson/Prentice Hall, c2008. ISBN 978-0-13-600637-4

Wen Hu , Jessica B Cicchino. ”Insurance Institute for Highway Safety” Effects of Turning on and off Red Light Cameras on Fatal Crashes in Large US Cities. DOI: 10.1016/j.jsr.2017.02.019, 2017, PMID: 28454859

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Declaration

I declare that I have worked on my bachelor thesis titled **Traffic Enforcement Systems Databases in Yemen** by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break any copyrights.

In Prague, 17^{th} of November, 2021 Abdulsalam Abdulhameed

Author acknowledgments

In the name of Allah, I dedicate my research in his name.

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Abstract

This thesis describes the components of a traffic enforcement systems, their different mechanisms, and implementations. The data in this research is explained using statistics and surveys published in books and research papers to further support the benefits of the system itself. The proposal takes inspiration for the implementation from multiple countries; Moreover, the research explores the challenges of the system and presents ways to overcome them. The capital of Yemen (Sana'a) is the basis of the proposal, and it takes the topography of the city in consideration as well as the urban planning to conclude the implementation of the proposal. Lastly, the thesis presents a DBMS model and concludes with results of survey conducted, followed by a detailed analysis and discussion to explore the current issues in today's traffic to prove the model's effectivity within society, if it were to be implemented.

Keywords: Traffic, Enforcement, Databases, Traffic Enforcement system, Yemen

Abstrakt

Tato práce popisuje komponenty dopravních systémů, jejich různé mechanismy a jejich implementace. Údaje v tomto výzkumu jsou vysvětleny pomocí statistik a průzkumů publikovaných v knihách a výzkumných pracích, aby se dále podpořily výhody samotného systému. Návrh čerpá inspiraci pro implementaci z několika zemí; Kromě toho výzkum zkoumá problémy systému a představuje způsoby, jak je překonat. Základem návrhu je hlavní město Jemenu (Sana'a) a při uzavírání realizace návrhu bere v úvahu topografii města i urbanismus. Nakonec práce představuje model DBMS a uzavírá výsledky provedeného průzkumu, po kterém následuje podrobná analýza a diskuse k prozkoumání aktuálních problémů v dnešním provozu, aby se prokázala efektivita modelu ve společnosti, pokud by byl implementován.

Klíčová slova: Doprava, Dozor, Databáze, Dozoru Dopravího Systému, Jemen

Contents

Chapter 1

Introduction

Since the manufacturing of first car in 1886, people drove on the streets as they pleased; However, in 1903 Eno "the father of traffic safety" introduced many road regulations. From the stop signs to writing first-ever manual of police traffic regulations, his contributions were the first steps to organizing the traffic we see today [1]. As time progressed, the world started seeing more technology getting on the road, with the world's first traffic light being installed in 1914 on the corner of Euclid Avenue and East 105$^{\text{th}}$ Street in Cleveland, Ohio [2]. These Improvements have effectively reduced the number of accidents and reduced traffic congestion's with seat-belts saving 329,715 lives just between 1960 and 2012 [3]. Technological advances in cars still take place, and our main concern is that if these safety features are being used and if the rules are being obeyed to protect the drivers, passengers, and pedestrians from any harm.

Sadly, the effects of poverty, corruption and war have hindered what little progress Yemen had. With recent statistics, studies have shown that the aftermath of war along with the unmaintained streets led to multiple accidents just one of which resulted in the death of 9, 3 of whom were women, and it was due to irregulated motorcycles on the road [4]. With also increasing amount of corruption within some of the police departments, writing a ticket or paying one is difficult as the government still uses paper archives which leads to difficulties in resuming paperwork which could end up in bribes. The decreasing awareness of these dangers is becoming difficult, since there is no campaign, regulation or simple advertisements that could take initiative to educate the masses.

This is where the abstract of this research comes to prove that with simple regulation and planning, things could slowly (yet surely) go to their own path.

Living in Czech Republic helped me realize that people do take serious precautions while driving or interacting with drivers (either on public transport or private). According to a news article posted in penize.cz the reason why over 40% of Czechs respect the law is the fear of paying a high penalty fee [5]. Even with a high rate, the Czech police does actively seek increasing that number to maintain relatively safe roads with the help of the online portal (portal.dopravniinfo.cz) as an example. As an example, in the Czech Republic, if a driver is caught running a red light, they would receive a letter from the police stating the fine, the number of points, and the violation committed. The citizen registered as the car owner must then go and present his papers to the designated office and go through the process of paying the fine or pleading in court. The clarification of the process and transparency makes people respect the law and ensures to take public safety as the priority. Similarly, Saudi Arabia has implemented a similar system called Saher that uses the same principle, only activated with an SMS code that is sent every time the driver is caught breaking traffic regulations [6]. These are just some of the systems that could be a step for Yemen to improve its enforcement systems to take one step towards a brighter future.

1.1 Objectives and methodology

1.1.1 Objectives

This topic will solely focus on the structure, pattern, mechanism, and function of a database model for traffic enforcement specifically for Sana'a, Yemen. Though certain systems already exist today, this research will use inspiration from SQL bases and models of real-life applications to make it more efficient.

This topic will venture in the theoretical part of database to explain basic concepts and principles of the system. Throughout the research, explanation of basic concepts, and recent statistics will be shared with the focus on multiple developed and developing countries. This is to ensure the transparency of the data and display the progress and exploit the drawbacks of other systems that may not be feasible to our study.

The main component of this research is to reduce redundancy of data and make sure the data model used is of efficiency and implementation could be integrated and has room to be pushed through various systems in the future. The design of the database will be further explained, and its structure further enhanced to elaborate certain aspects.

The questions we will revolve around in this research will be:

- How does traffic enforcement systems work? and what are the components?
- What technology is used today to monitor, and how could we extract what would yield better results?
- What is the best model to implement in Sana'a? and how will the database be incorporated within the model?
- How will the outcomes affect the laws/fines and processes of the civilians?

Lastly, There would be areas where the system could also see a future to integrate ITSMs and other systems to make it more user friendly and possibilities to expand the experience.

1.1.2 Methodology

This research will be divided into three separate parts. The first part will be exploring the entirety of traffic enforcement systems and different components it contains. This will give us a clearer understanding of how the input of the system will look like with other software. We will also briefly discuss the challenges of the processes and the solutions that could eliminate them.

Furthermore, the second part will talk a little about Yemen, Sana'a and the landscape. This will help us discuss a proposal system that took inspiration from existing systems with the adjustment of our case study. Seeing that it would be a unique case to Sana'a, information relative to the city will be studied through surveys. The results will give a clearer understanding of where these systems will serve to be more crucial.

The third part of this research will discuss the theory of the SQL structure of model to be discussed as well as recent models like it. It will also contain basic understanding of SQL knowledge as well as some theory to solidify and support future chapters. It's presented as the bases of the research based off multiple sources to help magnify the scope of the systems in question. Certain studies will be referenced, and statistics will be displayed to highlight the importance of the enforcement systems and its' current flaws to be further tackled in the following chapters.

Lastly, the final chapters will have a study case of what the public faces today on the road and how would they feel about the system if it were implemented. The discussion will break down the results of the survey and highlight the current challenges facing drivers today in Sana'a. This would also draw clear boundaries whether the proposal grasp the attention of the public and if it would be a project that one day will take place eventually.

Chapter 2

Traffic enforcement

2.1 Introduction

The deployment of traffic control at the start of the development of cars is not something unexpected. First car ever produced could travel at 16km/h [7], which at that time was relatively fast compared to walking. Through the passage of years, manufacturers made cars with less flaws and better engines increasing their speeds. It is only at the beginning of the 1900 that regulations started to arise and that was due to the high rates of fatality that cars brought reaching to 21,700 fatalities in 1925 in the USA alone [8].

One form of that control that was firstly introduced was by Charles Alder Jr. when he introduced an electromagnetic contraption that would slow cars down going at unsafe speeds. This inspired modern day technologies to push further by creating the first sensor triggered camera on 1965 which was by Gatsometer [9].

2.1.1 Types of traffic enforcement systems

There are multiple kinds of traffic enforcement systems. The main ones are automated enforcement systems and manual enforcement systems. In this research we focus on the automated enforcement systems. Most famous kinds are:

- Red-light cameras
- Automated speed enforcement cameras

2.1.2 Red-light cameras

Red light cameras are dedicated to photographing the vehicle entering intersection after a red light has been triggered. In most scenarios sensors on the pavements detect this offense. The sensors are connected to a system which uses timing of the offense with respect to the timing of the red-light trigger. The camera then is triggered and takes a picture of the license plate, vehicle, and/or driver. This picture is usually taken when the driver has already committed the offence. The photos are then reviewed by police or camera vendors and the jurisdiction officials, and afterwards the process is taken to court where citation would be given [10].

Chapter 3

Automated Speed Enforcement Cameras (ASE)

Technology is used to monitor an influence posted speed limits. Some of the ASE systems include:

- Fixed cameras
- Semi fixed cameras
- Mobile camera operations
- Average speed enforcement systems.

3.1 Fixed cameras

Are cameras equipped with a speed triggered sensor which is activated as soon as the speed of the car is considered as an offence. It is installed to monitor traffic without any operator [10].

3.2 Semi fixed cameras

These Cameras are rotated within housings. Posing as active or inactive cameras to create the illusion of an active camera present in its housing.[11]

3.3 Mobile camera operations

These cameras are installed in vehicles with or without the presence of enforcement officers. Usually, this activity is called pacing and requires a present police officer.[11]

3.4 Average speed enforcement systems

This way of measuring speed is set up between two check points on the road with two cameras constantly monitoring traffic [12]. According to (www.autosalon.tv), which wrote an article about where drivers should slow down in Prague in 2020, they asked technical administration of communications TSK (Technická správa komunikací) about the how the traffic system works. Their response explained that two cameras would measure a section the certain road which creates a monitoring zone. This way the two cameras can take pictures and in their further explanation the stated "Based on the vehicle identification according to the registration plate, geodetically measured section length and time data, the average vehicle speed in the measured section is then calculated, which is then reduced by the tolerance and compared with the maximum speed limit." Based on the result the cameras will capture the picture(s) of the cars speeding.

The aim of ASE is to make sure that drivers not only stop speeding, but also to alter the speeding behavior of the driver. Usually, ASE systems are deployed in areas where speeding could be dangerous for drivers, the occupants of the vehicle and/or pedestrians [13]. These include areas such as:

- Sharp curve sections of the road
- Downhill or uphill driving
- Heavy lane changes area such as exit/entrance to a highway

Chapter 4

Mechanism of the Automated traffic enforcement system

Automated traffic enforcement works thoroughly when the drivers of the vehicles are aware that their driving actions could be monitored on every street possible. The offenders however must be aware of their violations as soon as possible. The punishment will often include a financial fine with some demerits to their license point (depending on the violation that took place) [12]. The administrative process of collecting the penalty could be tedious for the authority if the violator does not wish to comply and pay the penalty. Therefore, certain things must be very transparent to the violators:

- The proper jurisdiction authorities have the accurate evidence of the violation having taken place.
- There is no possibility of wavering the fine.
- The fine will increase if the violator delays payment

The Automated traffic enforcement system is designed in a flow chart-like way so that the process cascades to the following entity without intervention nor redundancy of the process. Figure 4.1 is a flowchart diagram showing the different steps of the mechanism. It starts with the detection and ends up with the citation hearing or paying the fine. The links of the system are as follows:

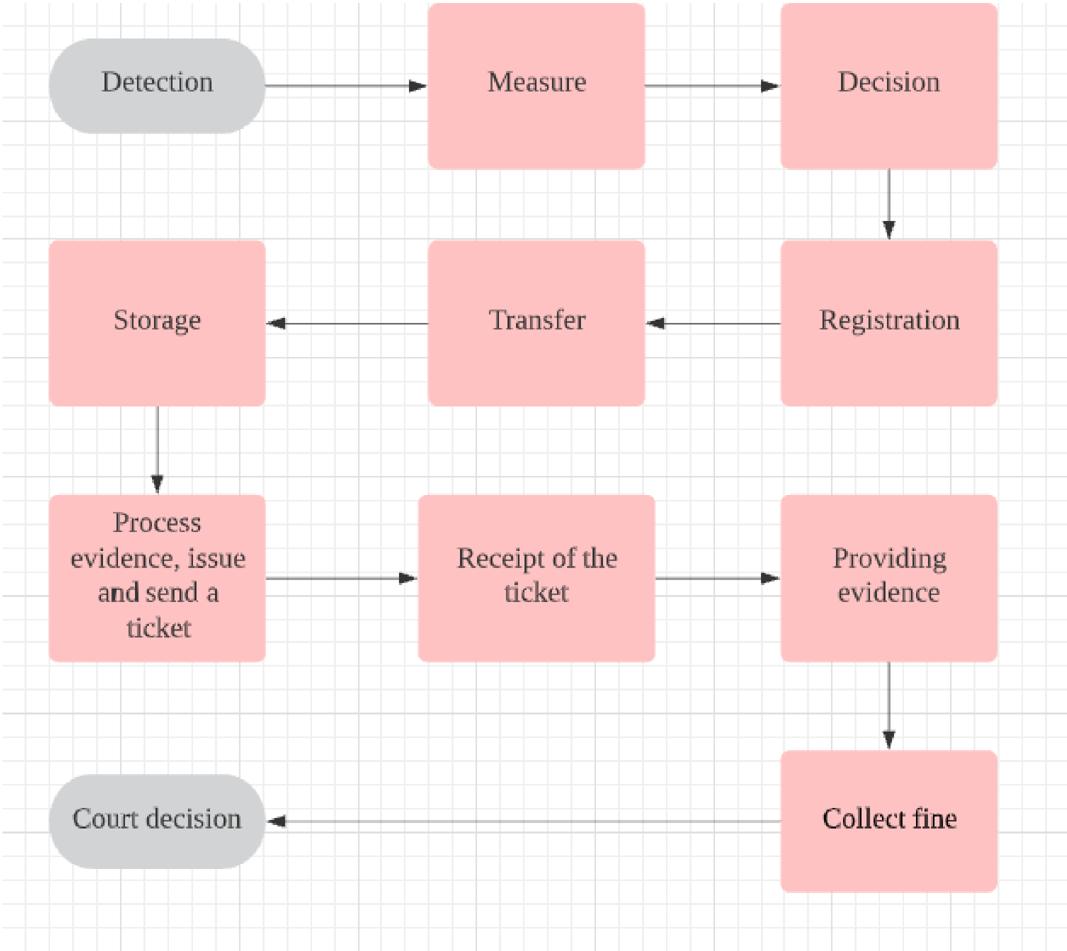

Figure 4.1: Flowchart diagram of the Automated traffic enforcement systems

4.1 Detection

High accuracy equipment is a necessity as it's our first input in our system. While these systems are motion triggered, common errors could occur. As an example, if there were a high volume of drivers and some were committing violations, the system would be able to pick up most of them; However, if there is a low percentage of vehicles, implying a low density of traffic violators, some may be able to escape for driving in an unsafe manner [13]. This could lead to public frustration of unfair judgement but thanks to new hardware and technologies, these problems could be overcome.

As for many things, detection sensors have their pros and cons. High detection rates are feasible with reliable technology such as inductive loops or modern tracking radars. Their proper use could render limit many of those disadvantages and although methods such as piezo and laser are more accurate, their biggest drawback is the vulnerability to weather changes (snow, rain, fog etc.), lighting conditions, dirt from passing vehicles, vandalism, which could damage the hardware and speed up its wear and tear therefore reducing its performance causing in an increase in operational costs and/or reducing the quality of its detection [12].

4.2 Measure

After the detection phase, the speed must be measure accurately, not just having a single spot for the specific measurement, but an area where the average velocity is taken. This is usually done by taking a measurement of a predefined area usually between two cameras/sensors [11]. Of course, this is only applicable for the instances of speeding and not for red-light enforcement. Since there is a predefined line for the red-light enforcement, the actions of the drivers distinguish them from being violators by if or not they cross the defined line. This could be visually observed through picture(s) [12].

4.3 Decision

Any vehicle exceeding the average speed limit will be considered as a violation for the owner of that vehicle. The algorithm would compare the value of velocity measured by the detection camera system and compare the speed recorded, with respect to the speed limit. Older systems could only detect one vehicle at the time if multiple were to break the law, it would lead to the rest to escape without penalty. Thanks to modern day technology and processing power, we can render multiple vehicles at one time, making it easier to extract and process data at a larger scale. This would sometimes lead to unique cases such as false positive (where vehicles were registered as speeding but where not) or false negatives (where vehicles were speeding weren't caught). In both cases, having a governmental and impartial sector approval solves the issue in those cases. [12] [11].

4.4 Registration

After confirming a positive decision, the evidence e.g.: picture or video should be stored and unchanged in a secure matter. This is where we are presented with cryptography [11]. The aspects of it could:

- **Encryption**-provide readability for authorized entities
- **Authentication**-data provided from the correct source
- **Integrity**-unchanged data

The data of regular vehicles should be disposed of. The biggest question underlying this issue "how long is the system allowed to store data of non-violating vehicles" and this is dependent on the privacy regulations and laws present within the country [12].

After the picture is captured, the image is usually processed by an automatic number plate recognition software (ANPR) and the information is merged within the evidence file. Every ANPR software has a confidence level. This means that the processing threshold of the software should reach a certain percentage to have a correct read. If not, then it may require manual intervention to input the correct license plate number. In France and Netherlands, with a fully automated system processing and handling notices for violation, a high "autoratio" is a must. This is to ensure minimum intervention from dedicated personnel and that is to reduce cost in the long run. This on the other hand, creates a challenge which is if the authorities want to ensure a high "autoratio", they must invest in high end equipment [12] [11].

4.5 Transfer

After the registration phase, the information must be relayed to the right authorities. This could imply police, or a governmental sector responsible for processing the details and making sure that the data secured through cryptography is stored properly in a secure manner. In modern day era this implies the usage of servers for storage, as well as having the data transferred over a secure connection. Security of the data is crucial in this case since personal information will be processed in latter stages. Depending on the set up of the system and the feasibility of the hardware, the topology of the network of the system will be determined [11].

4.6 Storage

As mentioned earlier, once a violation takes place and is registered, evidence must be taken in consideration for the proper process to take place as well as a possible citation. This in turn means that the information must be kept in data-centers/servers to secure their storage. In case of damage to the hardware (cameras or office computers in the central hub) the mirrored information can serve as backup [12] [11].

4.7 Process evidence, issue and send a ticket

The picture(s) taken by the camera must be prepared by designated employees for processing. Such information will be sent by the system in most cases; However, if the details in the picture are not clear due to the picture quality or the ANPR unable to recognize numbers on the license plate, human intervention will be required [12].

In terms of recognizing the accountability, there are two systems: driver accountability and owner accountability. With driver accountability, the system must receive input on the individual that was in the care while committing the violation. This could take time and effort to produce the individual's name. Prosecution rates will be affected negatively under such system yet vice versa happens in owner accountability system since the owner of the vehicle will be held accountable.

In the case of France, the national agency for automated processing of offences (ANTAI) along with National Processing Center (CNT) are responsible for fetching the data, processing it, and making it available for the right authorities to act. In 2019, the French authorities were able to report 18,265,268 violations thanks to their automated control system [14]. This emphasizes on the processing power of the hardware needed to make sure that these systems do not bottleneck and shut down causing a crisis of unmonitored violations.

4.8 Receipt of the ticket

After sending a citation letter to the citizen with the violation, the designated office should be notified with the letters receival. As sensible as this can be, the factors associated with the procedure could be somewhat challenging (whether the person with the violation has received/not received the letter). Since most countries use the postal service, this heavily relies on the quality [12]. Since 2012, countries such as, Saudi Arabia, Belgium, and Canada have switched to an electronic system [15] [16] [17]. This means that the information of each of the legally registered cars have an email and a phone number tied to the to the owner. This requires a database that requires constant update in case the vehicle changes hands or personal information (email, phone number) change.

4.9 Providing evidence

After the violator receives their citation, they may request additional information regarding the violation itself. This means that information from the storage should be presented to them whether if it's pictures or videos and, in that way, evidence could be presented to the court. This also means that the system should also register the information about the violation (time, location, violation type, occurrences etc.) and to select the fittest course of action to be taken. The violator has the means to defend their claim in court in case they do not agree with the violation; Otherwise, they can pay the fine to clear up their record. To reduce escalation in all cases, evidence of high quality should be always presented to avoid excessive administrative procedures. Certain legal issues arise with regards to the privacy of the passenger in the car with the driver and so the picture of the passenger should be blurred in the case that the court is held publicly [11][12].

4.10 Collect fine

Sending the citation with details of the violation is only a part of it. With the citation; The procedure of the escalation as well as payment should be mentioned. This encourages the violator to -as soon as possible- either pay or seek objection through escalation. The faster the violation is paid, the less the fine imposed upon the violator and vice versa. This creates an urgency for the citizen to act upon the notification once received [12].

4.11 Court decision

After all the steps above have taken place, and if it still does not engage the violator, then the judge must rule according to the case presented. This means the person with the violation will receive news about the final verdict and prosecution will take place [12].

The Process of this system is usually the base ground of every traffic enforcement system. The difference between European and American enforcement systems are significant mainly regarding privacy and public opinion. This will be detailed in the following sections explaining the benefits such systems have on the road and public safety, as well as the challenges that they face and the possible solutions to minimize/eliminate them.

4.12 The benefits

As mentioned above, the benefits that such system carries are various. From increasing safety on the road, to decreasing fatalities due to car accidents, the system is usually under constant development. This is to ensure the least amount of error and human intervention possible. Some of the benefits that this system brings are:

4.12.1 Reduction of the rate of car accidents

The planning of the installation of the cameras and sensors in these systems are carefully planned. These areas usually include [12]:

- Heavy traffic areas
- Speeding black spots
- Roads with blind curves
- Heavy lane changing roads (highway exits, entrances, mergers etc.)
- Areas with a lot of crosswalks

This is due to high traffic (high volume of pedestrians and drivers), and thus planning is crucial to minimize loss of resources [12]. Referencing a study conducted in Saint Petersburg, Russia in 2018, statistical data was used to measure the effects of automated traffic enforcement systems. After raw data was obtained, the study provided a regression model that is:

$$Y = 2379.24 + 1543.63_{X1} - 3.9134_{X2} + 9.4035_{X3} + 1.0307_{X8} \tag{4.1}$$

Where the variables chosen were the main causes of car accidents. *X1* - number of orders regarding traffic violations; *X2* - The penalties paid; *X3* - number of traffic enforcement sensors; *X8* - Population density per Km^2. [18]

As such, the following values obtained are shown in 4.2:

Parameter	Estimate	Standard Error	T Statistic	P-Value
CONSTANT	2379.24	377.889	6.29614	0.0243
x1	1543.63	193.139	7.99232	0.0153
x2	-3.91341	0.472106	-8.28924	0.0142
x3	9.40355	3.09578	3.03754	0.0934
x8	1.0307	0.153725	6.70487	0.0215

Figure 4.2: Statistical characteristic of a mathematical model

The study further on states that:

> "The obtained data on the relation between the ATES (automated traffic enforcement system) parameters and the accident rate confirmed the results of the theoretical studies on their influence on traffic safety."

To further explain: The data collected and processed through the regression model seen above dictates to prove one of either hypotheses. The null hypothesis was stated that the ATES and car accidents have no relation and therefore render ATES obsolete as it would not influence the traffic violation rate. Judging from Figure 4.2, the null hypothesis is rejected and therefore there is a relationship between Car accident rates and the implementation of the ATES [18].

4.12.2 Reform of traffic fines

To make things easier for the citizens who are driving, fine reformation could be a next step to reducing the amount of the fines paid. this could be done through enforcing the automated traffic enforcement systems and bring them online instead of having police officers enforce citations upon traffic violations. Since the automated traffic enforcement systems depend on providing evidence against the violator for the violation that they have committed, it usually ends up with a closed case scenario where the violator must pay the fine imposed on him or seek escalation in some cases. This reduces the amount of fees if a police officer were to give citation on the spot. For example, New York city's speed safety system has reduced the percentage of speeding cars by 63% at the average location and opposed to paying tickets with a high fine expense, citizen that are caught violating traffic law only pay $50 as instead of $600 citations given by police officers for the same offense. Included states that followed this strategy was also Massachusetts which had the legislation AB550 that poses a $25 penalty [19] [20].

The legislation also states that the fines will start at $50 for going 11-15 MPH(17.7Km/h - 24Km/h) above the speed limit. Further on the fines will increase proportional to the excess speed done; However, this will not create a record point on the violators driver's license. The violation recorded will be also correlated to the income of the driver (the less money earned; the less money paid). The legislation also included the reduction of penalties from 50%-80% for those who are unable to pay. In short, the legislation was created to reduce speeding cars to make the public safer, with the aim of less financial harm to the driver, and not as revenue for the government. [20]

4.13 Challenges to overcome

With the enormous advantages from preventing car accidents to the ease of the process of paying the fine, there are still certain challenges that the automated traffic enforcement still faces. The two main factors are:

- Public opinion
- Privacy

4.13.1 Public opinion

Public support in terms of implementing these systems is very crucial, and that's in the sense that the public must be fully aware that certain systems would be implemented that could perhaps be stricter than having regular police officers providing citations. In Europe, countries such as Belgium have a high support towards the automated traffic enforcement system [21]. Neighboring countries to the European Union such as the UK have also a high acceptance towards the automated traffic enforcement system with an astonishing 82% of the support going towards the safety cameras as a supporting method for reducing casualties on the road. The survey conducted had a very strong support for the use of sensory cameras to prevent fatalities with a 71% support [22].

In the United States however, the opinion seems to change towards the opposite side of the spectrum. Judging from the history of the racial biases taken place in the past couple of years, American citizens find themselves in the fear that the government would implement these systems in areas where there is a high level of impoverished communities targeting the minority within these communities. This is despite the fact that the legislation AB550 states that the traffic violation ticket given to the violator is going to be judged upon his yearly income and could have a chance to be reduced to 50%-80% [20]. This still poses a threat to the minorities since some of the software was found to inaccurately identify people of color [23].

The second factor is the fact that the traffic enforcement system protocols are usually managed within the police agencies and because of the police brutality in the recent days a large of the incidents happening usually occur within the minorities of the United States [23].

The next reason is disproportionately increasing the speed sensors within the minority community to exploit them financially. A recent study conducted by the DC policy center states that:

> "This initial investigation suggests that absent an affirmative effort to equitably site automated traffic cameras, a disproportionate burden of enforcement could be borne within the District's predominantly black neighborhoods. While research shows that traffic cameras do reduce vehicle speeds, collisions, and injuries, this analysis highlights the racial inequities that can happen when a city relies too much on enforcement as a Vision Zero strategy." [24]

4.13.2 Privacy

The ALPR software incorporated in the speed cameras identify license plate numbers for all the cars that it gets. the mechanism of the system depends on cross referencing license plates with the DMV database for it to obtain the information. A survey conducted in California in 2020 found out that no monitoring agency complies with state laws and therefore violating privacy and security requirements [24]. Multiple instances have been recorded that the ALPR software has been used to monitor low-income neighborhoods which targets minorities. In 2019 the ACLU in Northern California found out that ICE had signed a $6.1 million contract with a company "Villigrant solutions" which owns an ALPR software to access their database which has 50 billion datapoints from 80+ local law enforcement agencies in 12+ states. This gave ICE the access to search the database, and classify some of the individuals who have misdemeanors or traffic offenses as "hot lists". This allowed the pinpointing and illegal monitoring of non-consenting citizens as well as undocumented immigrants. Sharing any data without any consent from the person with the rights to that data violates the first rules of privacy laws in most western civilizations [24].

4.13.3 Possible improvements

With the challenges mentioned above, the room for improvement for these systems is still in the horizon. We will first discuss the first two obvious challenges and then we shall name the rest of the critic's accusations have been imposed on the automated traffic enforcement systems. With the lack of knowledge and skepticism of the general mass in certain countries, there is still room for people to have enough awareness of how these systems work and reduce the spread misinformation.

4.13.4 Bettering society opinion

To convince the public that the implementation of such system is necessary for the safety of the people, we first must state the distribution of the sensory cameras around the city. As mentioned above in 4.12 the implementation of the sensory cameras must be in the following locations:

- Heavy traffic areas

- Speeding black spots
- Roads with blind curves
- Heavy lane changing roads (highway exits, entrances, mergers etc)
- Areas with a lot of crosswalks.

This will allow us to reduce costs as well as treat the public in an equal matter without any segregation or skepticism [23].The awareness in the public could be elevated through campaigns that such systems are being implemented. The European Union has been successful to launch multiple campaigns regarding the disadvantages of speeding and its effect on public safety through multiple statistics [25]. Providing the public with more transparency of why systems are also implemented within the certain regions that they are installed gives a valid argument to having more public support towards the safety of the community. For example, a certain street could have 8 crashes, 4 injuries and 2 fatalities in the past 2 years, and that's why that exact certain St has the system implemented on it so that the violations could be recorded to prevent such catastrophic endings to drivers or pedestrians alike [12].

4.13.5 Tackling Privacy problems

Privacy in today's world is a crucial thing to everyone. Having personal information exposed meaning that the person does not have the right to preserve their data to have it processed by only certain sectors that they consent to. This poses a problem for people who have committed violations regarding not having them available to the wrong authorities or be used as a tool of exploitation. To resolve this issue, we reference a part of the research in 4.4. Cryptography is a powerful tool to protect the identity of those who violated the law potentially this means that the violators information whether if it's a personal information or registration for their vehicle must be protected while detecting their violation [11].

4.13.6 Criticism from the public

From the status of the development of the automated traffic enforcement systems, there are certain concerns from the public due to the lack of awareness of the mechanism of the system or its execution. The automated traffic enforcement system is not rendered to replace police enforcement or authority; However, it is designed to help ease the duties or police and authorities and make a clear separation between violators and law-abiding citizens. Some of these concerns are as following:

Automated enforcement systems do not change the driver's behavior

A series of studies from different resources show that the significant change in driver behavior has been altered ever since the implementation of such systems. some of those changes are:

- The reduction of exceeding the speed above 16Km/h has declined by 70%, 88% and 82% respectively on different residential roads in Maryland, a high-speed road in Arizona and certain city streets in the District of Columbia. This happened at approximately 6-8 months after the installation of the cameras [26] [27] [28]
- Study conducted in Maryland concluded the finding of the reduction of 10% in the mean speeds and 59% in the likelihood that a vehicle will be traveling over 16 Km/h above the speed limit on roads that have cameras installed. This was conducted just half a year shy from 8-year mark after the launching the speed camera program. [29]
- A recent study conducted in Arlington VA found a sharp reduction in red light violations on intersections only one year after the launch of the ticketing system [30].

There are more studies that nullify the claim; However, the studies posted above are the most recent.

Automated enforcement systems do not prevent car crashes

- A study conducted in 2016 compared large cities that have red light cameras in their intersections to those that didn't. It discovered that the cities with the systems installed have an overall reduced fatality crash rate; 21% less fatality crashes due to running a red light and 14% of fatal crashes that are signalized by intersection respectfully [31]. It also highlighted the use of red-light cameras. 14 cities that decided to shut down their traffic enforcement systems between 2010 and 2014, had fatal car crashes due to red light running increased by 30% as it wouldn't have if the system were still running. Rate of fatal car crashes at signalized intersections rose by 16% as well [31].

- A study conducted in Maryland also found that streets with speed cameras where link to a reduction of 19% in the likelihood that a car crash could result in a fatal or an incapacitating injury [29].

Strict enforcement's target the good drivers instead of the violators

- An observational study conducted on roads with speed limits from 64km/h-80Km/h compared drivers that we're going 25 Km/h above the speed limit versus the drivers adjacent to them with no more than 8Km/h above the speed limit. The drivers speeding above the speed limit were significantly younger than the other groups of drivers all while having higher violation and crash rate on their driving record [32].

Automated enforcement locations are chosen to maximize violation rates

- Not to be confused with speed traps, automated traffic enforcement locations are chosen according to their criteria based on the regulations. This means that the difference between speed traps and traffic enforcement system mainly relies on the transparency and their implementation. Traffic enforcement systems are visible by the public and their tickets are only registered with a significant over speeding incident. Usually, traffic enforcement systems recognize a 16 Km/h above the registered speed limit as a violation. In residential areas or school areas, the tolerance for over speeding becomes less as there is a high density of population and it concerns the safety of the pedestrians as well [33].

- A 2021 survey conducted in the District of Colombia found out that 801 residences agreed that the use of speeding cameras is effective. 88% of the interviewed concurred that speeding poses as a threat to them in their community [34].

4.14 A brief look into Sana'a, Yemen

In order to emphasize the effectivity of the implementation of the system, we must take into consideration three factors:

- the city's topography
- the population density
- the layout of the traffic/roads

This will help us draw a clearer picture of what the city has as an advantage and highlight the drawbacks/challenges that the city might have. With all that information diagnosed, we can then look further into the most effective way the system could be implemented in. In this chapter we will make use of resources on the Internet (news and studies) as well as a conducted survey.

4.14.1 Sana's topography

Sana'a city is a valley consisting of multiple boroughs and neighborhoods. The city is surrounded with a series of mountains mainly from the West east and South was the most famous mountains being Nuk'um, Aiban, and Asr respectfully (see Figure 2). The city is vulnerable to weather changes, since it has a 4-month rain season which puts the infrastructure at a stressful point [35].

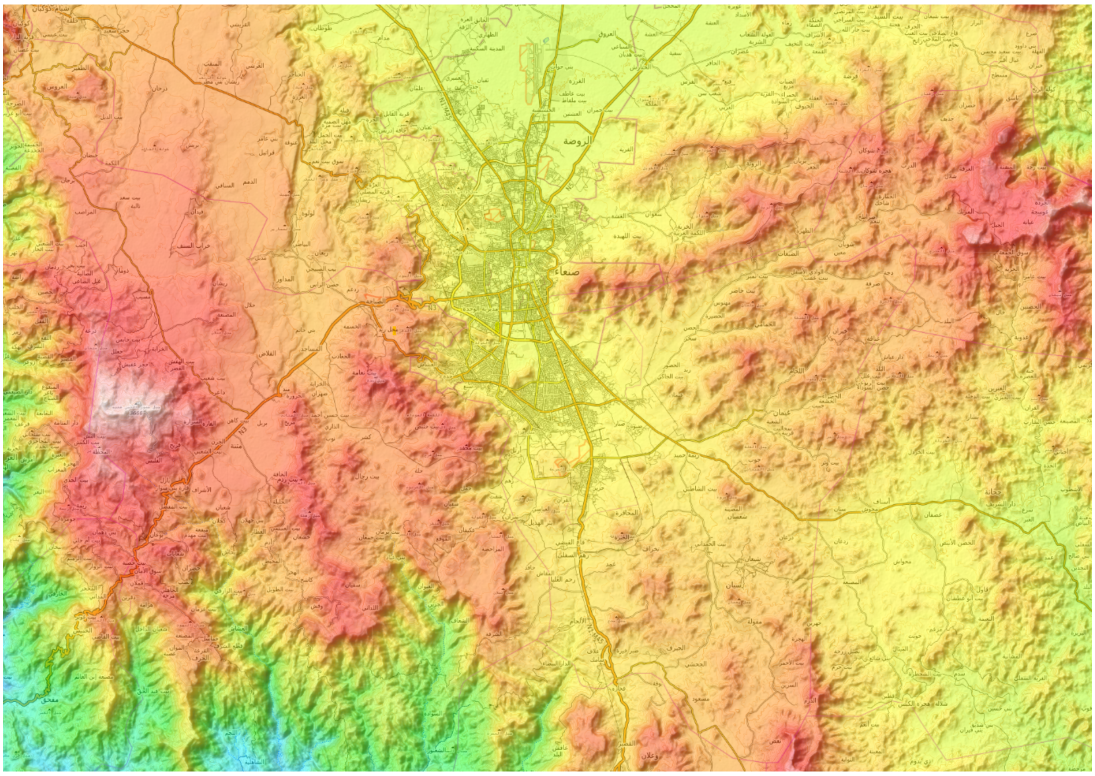

Figure 4.3: Sanaa's topographic map

4.14.2 Population density

Population density determines the activities of the citizens in the city daily. The political and economic factors play a very important role in the relocation and diversity of that population. The population density within the main capital is 130 people per hectare and this is considered as the mean. This is due to the "horizontal construction" instead of complex apartment buildings. The result costs the city's infrastructure, and destroys the lands used for farming. However, there are certain areas within Sana'a that have a higher average of population density such as Sana'a old city which has 390 people per hectare and Sana'a downtown which hosts 245 people per hectare. Because Sana'a is the capital of Yemen, most of the economic factors that interest public, such as opportunity for investment or jobs, are available in a variety of standards whether that be a level entry job or an expert or diplomatic related position. This has attracted a lot of Yemeni citizens from different cities towards the main capital which grows at a 5.5% annually in regards to its population. That all contributed into the competition of resources within the capital as well as pose a challenge to its infrastructure and high demand on services. It is also contributed to affecting the urban planning of the city itself which will be discussed in the next section [35].

The reason why population density is important in this matter is because we can determine a higher demand for means of transportation since the public transportation is unstable and therefore more expensive due to the raising of the prices. With the determination of the population density, we can accurately measure where our system could be the most effective as well as tackling the most vulnerable spots in the city first to improve the driver's behavior behind the wheel.

Recent statistics

A recent study conducted in 2018 shows that the patients arriving in the ER in two hospitals in Sana'a (recorded between August and October of 2015) that 156 casualties from 128 Road traffic crashes have attendant the two hospitals during the study phase. 73% of the victims of the car crashes were under the age of 30. Due to the lack of awareness the study found that most victims did not abide by traffic laws mainly not wearing a seat belt or use a helmet in case of riding a motorcycle. Bad driving skills were over 85% of the casualties and vehicle errors contributed to 12% of the road traffic crashes. From 156 casualties those who were rushed into the ICU were 17% and 38% of the patients that ended with disabilities due to fractures or damage to limbs was 29% which 18% had recovered and 5% have deceased [36].

4.14.3 Sana'as urban planning

Urban development in Sana'a had a very long history and multiple stages that it went through from local and foreign entities. Throughout the stages of development, there were multiple factors that affected the development of the urban layout in the city. Some of which are:

- **Natural factors:** this involves the location and see geological composition of the soil as well as the weather within the region. The location involves the heavy activity within the city due to the economical and industrial nature of the region. The surface involves the geological composition of the soil as well as the sources of water and the structure of the dirt.

- **Human factors:** this could impact the development in either positive or negative way. It involves the activities' that are performed by society whether if it's political, or economic and its effects on the citizens.

As mentioned in section 4.14.2, population density plays a role in the urban planning. The more people move from rural areas into the city, the higher the demand for the new construction of housing and services within a certain region. Due to the poor supervision of certain entities within the government and horizontal planning, this made it difficult for people to sustain proper housing the depends on the infrastructure of the city. Sana'a kept growing exponentially from 1962 and its first organized planning prepared in 1978 pushed the city further from the center. This was followed by the modernized planning in 1998 with the strategic development of the city outskirts and its development in its infrastructure. In 2005 the study was conducted for the strategic development of the city and prepared a plan to further develop the city; However, in 2010 due to the war, the situation reached a halt. During 1978 up till 2010, the exponential growth of the city was too quick to contain the demands of the population and regulate its planning. This led to randomized planning and unauthorized building from some citizens independent from the infrastructure of the city making it difficult for a unified city grid plan [35]. **How does that relate to traffic enforcement systems?**

The structure of the city and its infrastructure makes it easier for the implementation of the system itself. With a solid infrastructure and a harmonized planning of the city, it becomes easier for the system and more effective for the hardware to be dispersed throughout the city. Within this research, we will explain the first steps that this system could be used to plant the seed of monitoring its traffic. Future steps could be taken to include/improve monitoring within other regions making the system more inclusive of the city and its outskirts.

4.15 The database

All the main interest of the research is about the automated traffic enforcement systems, the core of this research focuses on the database model designed to make sure that the storage and access of data is as coherent as possible. In this coming chapter we will discuss the possible ER diagrams, and commands that could be a proposal for the database model designed for the automated traffic enforcement system. The following parts will ensue as follows:

- Classes, Attributes, and their data type
- Relationship between the classes
- Normal forms (1NF, 2NF,3NF)
- SQL commands

4.15.1 entities, attributes and their data type

In this sub-chapter we will be discussing the possible entities required to formulate a proper cohesive database model. First, we must fully understand the entities and their outcome so to follow certain SQL knowledge. Basic rules of any database are the integrity constraints. Integrity constraints are used to maintain the quality of information. Ensures of the data insertion updating and other processes better perform an away so as not to affect the integrity of the data itself. integrity constraints are used to protect data against accidental data damage. It is formed from 4 branches that are following:

Domain constraint

o This basically defines the data type inserted in entity itself that could include: character, time, date, string etc. Entering a different data type than what the entity accepts not be processed, or would return an error. This leads to a conflict that needs to be corrected and therefore reducing the margin of error for our database.

Entity integrity

Entity integrity states that the primary key cannot be a null value. Reason being is that the primary key identifies each single entity in a unique way. Having the primary key and no value defeats its purpose and therefore it is a crucial step while setting the database. Some constraints could contain different values if they are not the primary key.

Referential integrity

This states that the foreign key specified in the table should be linked to a primary key to the other table. The values from the primary key from the second table should coincide with the values of the foreign key in the first table. The values also have a chance to become null if not having existed in the primary key in the first place ie: having a data entry on the first table only.

Key constraints

This clarifies the setup of the keys identifying each entity, respectfully. While the setting up of primary key in multiple entities, there is bound to be foreign keys replicated within certain tables. Key constraints state that every entity must have a non-null unique key identifying it despite having other keys possibly set up.

Following those simple guidelines, we can finally deduce our own database model from our proposal for an automated traffic enforcement for Sana'a. The following approach is based on an abstract of models the systems in different countries in use. Some alterations have been used for example having the license plate number associated with the car is linked with the violation instead of having social number registered in the violation. This is so that the accountability falls on the owner and not the driver of the car.

The following is a tabular representation of our SQL model:

Class	Attribute	Data type
Car	License Plate	Varchar (12)
	VIN number	Varchar (17)
	Make	Varchar (20)
	Model	Varchar (20)
	Color	Varchar (20)
	Country	Varchar (15)
Person	Social Number	Int (11)
	First Name	Varchar (20)
	Last Name	Varchar (15)
	DOB	Date
	Country	Varchar (15)
Violation	Violation number	Int (7)
	Violation type	Varchar (15)
	Location	Varchar (20)
	Time stamp	Timestamp (fsp)
	Picture	BLOB

Table 4.1: Classes, attributes, and their data-types

4.15.2 Relationship between the entity models

This section represents the database in a visual form. The visual form is named ER diagram short for entity relationship diagram. It is a pictorial representation of the data that describes how the data is communicated and how classes relate to each other. This will shed light on the classes, relationships, and their attributes. It'll give us a clear understanding of the entire database model making it relevant for the research.

The ER diagram is a structural analysis of the database design which identifies the important data. Relationships are also characterized in the model which help us understand the flow of information between classes and the difference in the connection between attributes of different classes as well.

One-to-one relationship

In the case of a one-to-one relationship, the record in the table is only associated with one record in the other table. For example, an individual could be assigned one social insurance number. The social insurance number could be provided by the government and once linked to the individual it becomes the attribute that is linking the 2 entities.

One-to-many relationship

In a one-to-many relationship, multiple attributes could be common between two entities. The link between the two entities could be established with multiple entities giving the relationship the concept of having to deal with primary key and foreign key. Primary key is a unique attribute that distinguishes the entity with that attribute. In another table, that primary key could be used as a foreign key which helps the access of the first entity through the second entity. For example, this could be highlighted when the customer is linked to their order through the customer ID itself. The customer is usually identified with their customer ID and once they place an order on an online website, their customer ID becomes linked to their order ID making it easier for the company to trace their order.

Self-joining relationships

The self-joining relationship is usually linked to reference a table to itself and use it to different entities with the same structure. This is very common within employee and employer tables where they contain the same structure and use different references to find out the supervisors for each employee or the employer's number in order to trace the team members that they supervise. In this research, this kind of relationship will not be used since the entities in question have different sources and structures from each other.

Many-to-many relationship

The many-to-many relationship occurs when multiple attributes in a table are linked with multiple attributes in another. An example for many-to-many relationships exists between students and courses. Where multiple courses could be assigned to multiple students and vice versa, this complicates the database entirely where redundancy occurs. Redundancy is where the data has been duplicated in multiple times making it difficult for us to trace which attribute belongs to which table and might unnecessarily exhaust computing resources. In this scenario, many-to-many relationships are broken to one-to-many relationships using a mediatory table to ease the connection between the two tables. In the case of the students and courses the immediate area table is usually as the enrollment table where it breaks down the relationship to a manageable one.

4.15.3 Normal form (NF1, NF2 and NF3)

The first draft of every SQL database is usually the outline of the concrete idea. With many instances of attribute repetition, data redundancy and entity similarities, normalization comes to eliminate undesired excess and helps create a more comprehensible database. Normalization SQL is defined as the process to organize data to reduce data redundancy. It is usually the process to divide a complex table to multiple and simplify many-to-many relationships to one-to-many relationships making it more cohesive within the data structure and efficient to understand the different structures between the tables.

The advantages of database normalization are:

- better database organization
- reduction of data redundancy
- consistent data within the database
- increasing flexibility in database design
- enhancing database security

The normalization of data is categorized into three separate categories. Each of those categories enhance and improve the database structure to be at most efficient stage. the stages are as follows:

The First Normal Form

This normal form focuses on eliminating repeating attributes in each table. This ensures the access of information is uniformly and easy to update, insert and delete. Within the [1NF], we must create separate tables for related data types.as an example, the same customer ordering two different orders with the same account should have two entries, not one entry. Finally, each of the tables must be identified with a primary key. Figure 4.4 is a first demonstration of the [1NF] being created. Although it is a clear visualization of the concrete idea of the DBMS, it still contains many-to-many relationship and other undesired attributes. This will be resolved in [2NF].

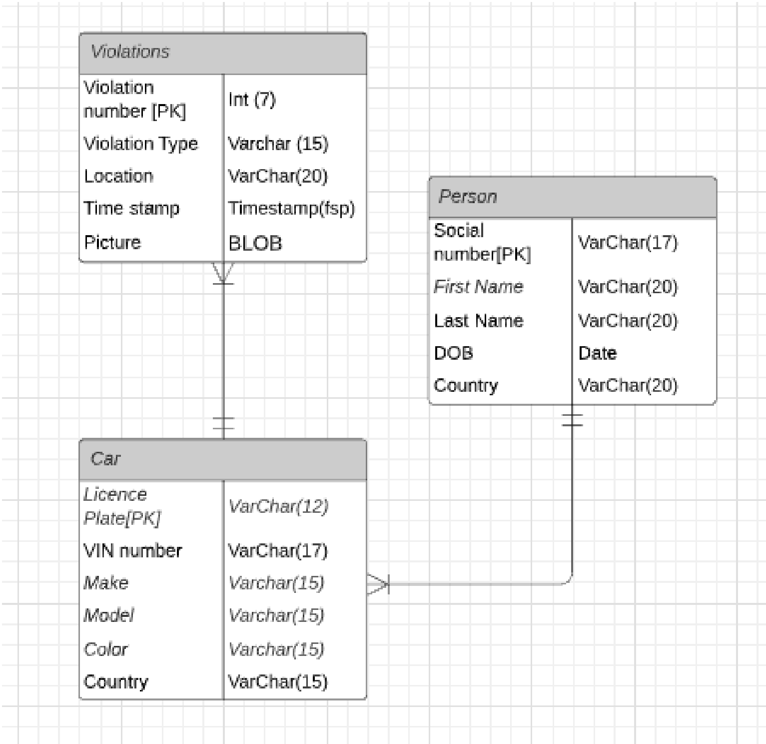

Figure 4.4: [1NF] of the automated traffic enforcement systems

The Second Normal Form

In the second normal form we focus creating a foreign key for the desired tables and split complex tables into multiple tables to achieve the desired structure. By breaking the tables into smaller, more manageable entities, it creates an easier structure for us to manage. While designing the DBMS, we must also avoid using unnecessary attributes to make sure we use the system resources as efficient as possible.

Looking at figure 4.4, we can deduce that there are partial dependencies in the violation table. Partial dependency issues occur when there are two primary keys for one table that are necessary to uniquely identify it. Figure 4.5 is a clearer representation from figure 4.4.

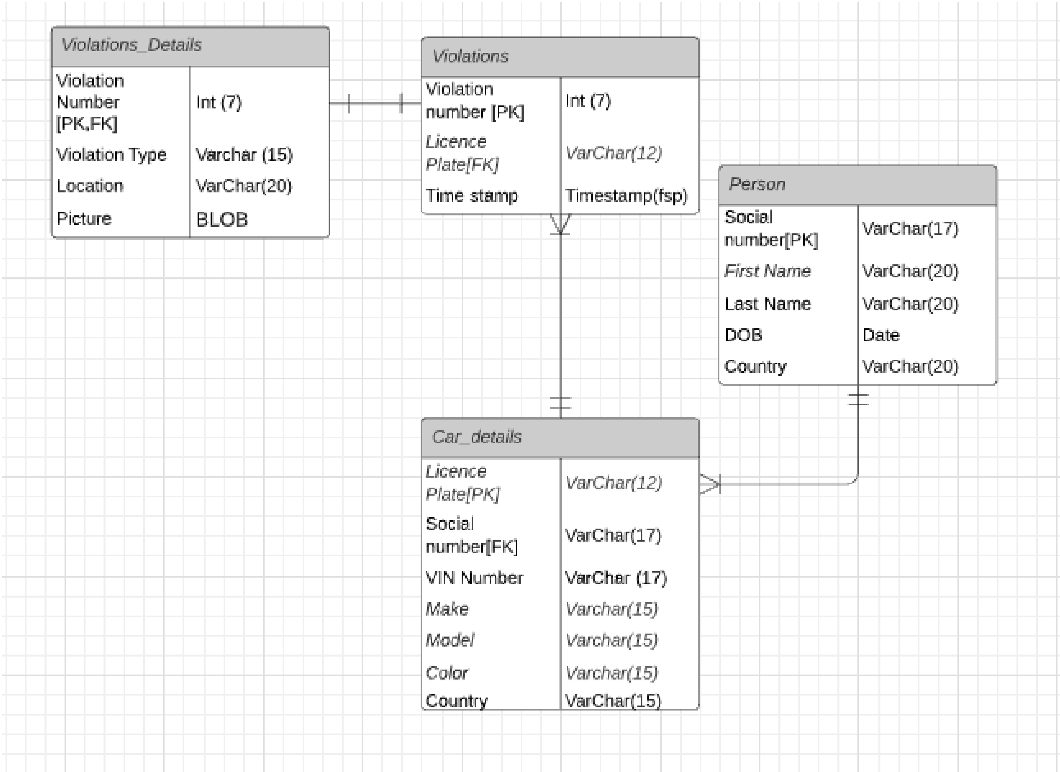

Figure 4.5: [2NF] of the automated traffic enforcement systems

The Third Normal Form

In figure 4.5, we notice that the connection between the tables has improved with reduced redundancy and with the elimination of Partial dependency. We potentially can split the "car" table and therefore eliminating the transitive dependency. Transitive dependency is in direct relationship between two values in the same table that cause functional dependency. In this DBMS, the transitive dependency occurs between the attribute license plate type and license plate. since the license plate type describes a different aspect of the license plate number, splitting the table in two separate entities makes it more manageable in the long run. The only condition that should be satisfied in the third normal form is that the table must be in its second normal form. From figure 4.5, we simplify the DBMS into Figure 4.6. By having the third normal form, we must update the entities that were set up in the table 4.1 , to satisfy all the conditions necessary.

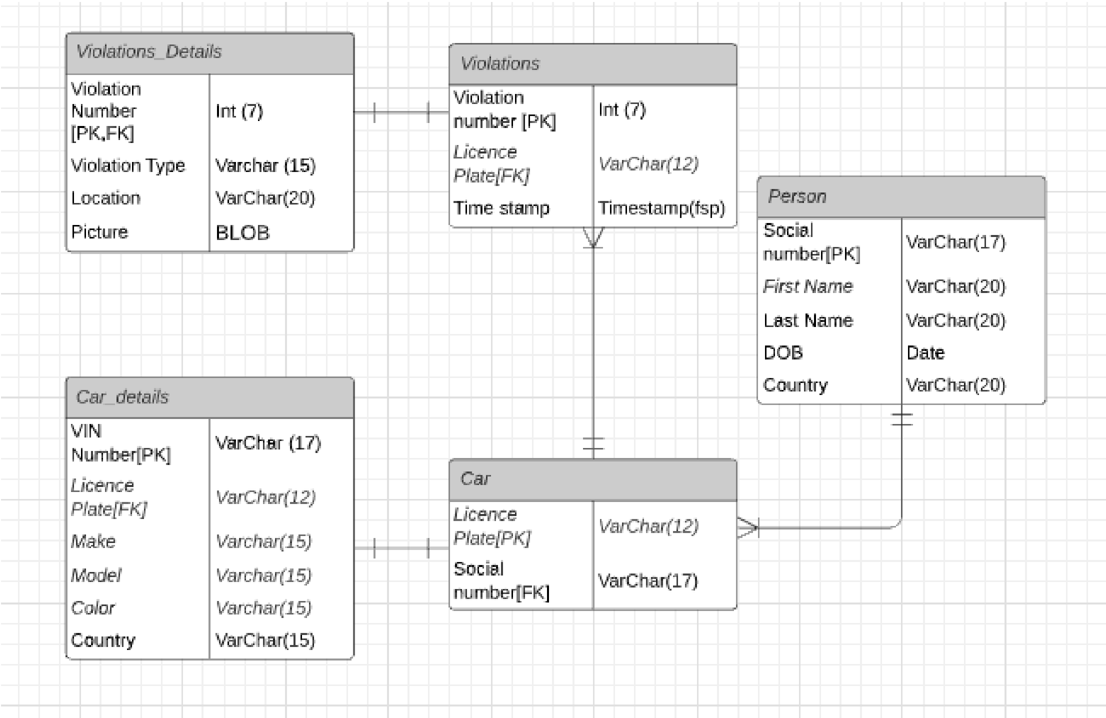

Figure 4.6: [3NF] of the automated traffic enforcement systems

4.15.4 Final stages of the DBMS

In this section we will reveal the final form of the DBMS and correct the attributes and their types from table 4.1. Table 4.2 is a clear representation of the systems concrete form.

Class	Attribute	Data type
Car	License Plate [PK]	Varchar (12)
	Social Number [FK]	Varchar (17)
Car details	VIN number [PK]	Varchar(17)
	License Plate [FK]	Varchar (12)
	Make	Varchar (20)
	Model	Varchar (20)
	Color	Varchar (20)
	Country	Varchar(15)
Person	Social Number [PK]	Int (17)
	First Name	Varchar (20)
	Last Name	Varchar (15)
	DOB	Date
	Country	Varchar (15)
Violation	Violation number [PK]	Int (7)
	License Plate [FK]	Varchar (12)
	Date	Timestamp (fsp)
Violation details	Violation number [PK,FK]	Int (7)
	Violation type	Varchar (15)
	Location	Varchar (20)
	Picture	BLOB

Table 4.2: Classes, attributes, and their data-types

4.15.5 The SQL commands

In this section we will display the connections between the entities through SQL code commands. The commands used will only display the creation of the tables and the alterations to the respected tables. Due to the length of the code, we will insert the skeleton of the database without filling it with any data input.

```
CREATE TABLE Violation (
  violation_number Int (7) primary key not null,
 Time_stamp timestamp
);

CREATE TABLE Car (
    license_plate VARCHAR(12) PRIMARY KEY NOT NULL,
    social_number VARCHAR(17) NOT NULL,
);
```

```
CREATE TABLE Person (
    Social_number VARCHAR(17) primary key NOT NULL,
    First_name Varchar (20),
    Last_name Varchar (15),
    DOB date,
    Country Varchar (15),
);

CREATE TABLE Car_details (
    VIN_number varchar (17) PRIMARY KEY NOT NULL,
    License_plate VARCHAR(17) NOT NULL,
    Make VARCHAR(20) NOT NULL,
    Model VARCHAR(20) NOT NULL,
    Color VARCHAR(20) NOT NULL,
    Country VARCHAR(15) NOT NULL,
        foreign key (license_plate) references car(license_plate)
);
CREATE TABLE Violation_details (
     Violation_number INT(7) PRIMARY KEY NOT NULL,
    Violation_type VARCHAR(15)  NOT NULL,
    Location Varchar (20) NOT NULL,
    Picture BLOB ,
);
   alter table Car(
add foreign key (social_number) references Person (social_number)
);
alter table Violation_details(
add foreign key (violation_number) references violation (violation_number)
);
alter table Violation(
add foreign key (License_plate) references car (License_plate)
);
```

Chapter 5

Case study

5.1 Objectives and methodology

5.1.1 Objectives

For us to investigate whether the implementation of the system is valid within Sana'a, we deducted a survey to understand current driver behavior and have a clearer understanding of the experience within the city. The survey focuses to:

- Understand where traffic problems occur around the city
- Detect what areas in the city make it more vulnerable for drivers to speed in.
- Have a clear understanding of how many traffic accidents last drivers are prone to
- Find out the cause of traffic accidents in Sana'a, and presenting the solution to eliminating the issue
- Understand the public opinion regarding the system, and implementing the right execution to accommodate for the city's infrastructure

The survey is designed to focus on today's data. The questions focus on driver feedback and thus giving a clearer picture for us to implement the system in the right areas of the city.

5.1.2 Methodology

The survey was conducted from the 6th of November until the 12th of November of 2021. during the six-day period, Residents from Sana'a provided their feedback to the survey questions by choosing multiple choice answers.

A total group of 173 people, that were each asked a series of questions; Starting by their gender and age criteria ending to their public opinion. The youngest on the survey must be 18 years of age -due to driving license laws- and all applicants must be residing in Sana'a. We designed the survey as multiple choice questions to acquire direct answers and to satisfy the current conditions due to the a limited internet access, and COVID-19 pandemic.

The survey was conducted on survey legend and the questions allowed people to determine their gender, age criteria, alongside other specifics through the questions provided. These questions and answers are provided in appendix A.1.

5.2 Results and Discussion

5.2.1 Results

Gender division

To present an accurate picture of the kind of drivers in Yemen, we decided to split the survey between male and female drivers. This is because cars in Yemen became affordable to females in the last 20 years and the exponential growth of female drivers in Yemen is still needed. To demonstrate a more accurate sample, the following results were harnessed from 173 total applicants, of which 54 were women. This presented us with a 31.21% to 68.79% split respectively. The split was also necessary for us to obtain a more concrete value and a more diversified driving experience from both genders. The percentages are displayed in the figure 5.1 below:

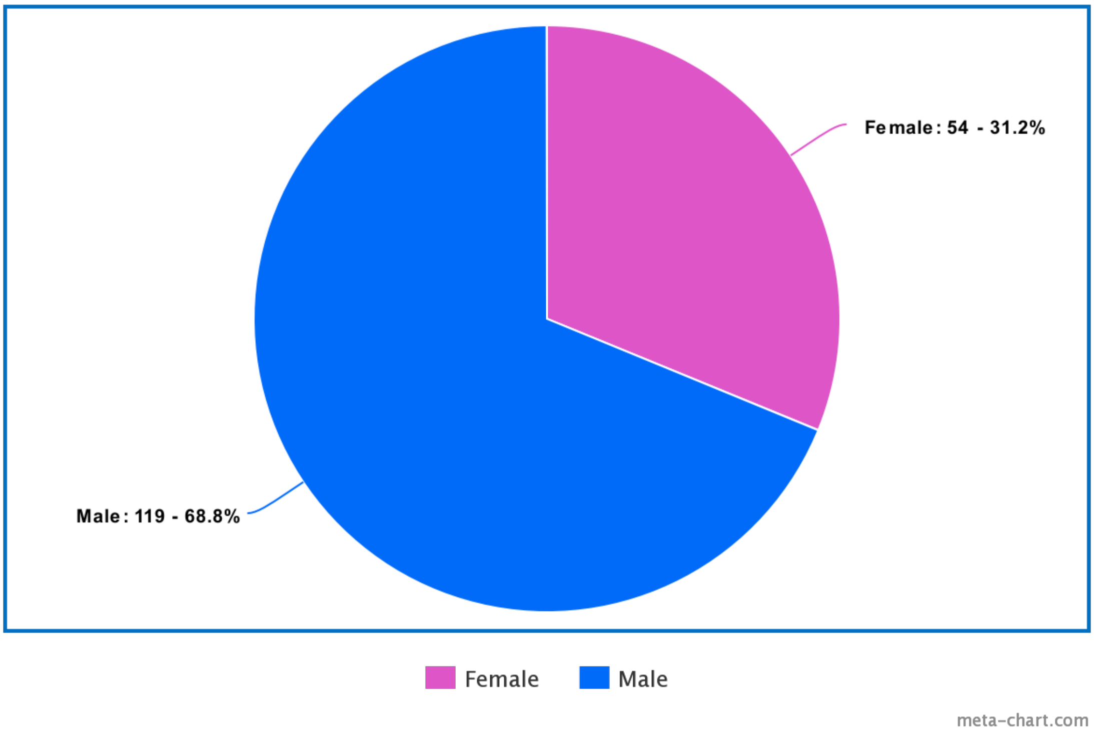

Figure 5.1: Gender split between male and female drivers

Age range

The second question determines the age criteria of the drivers in question. The first criteria were from 18 to 25 years old, the second one was from 26 to 33 years old, the third one was from 34 to 43 years old and the 4th one was from 43 years old and above. The purpose of this split is due to the occupation of each group. This was necessary so that we're able to relate to each group based on their activities better performed during the week. 68 out of 173 drivers were from the 2nd criteria and the second largest where from the 3rd criteria. This gives us a concrete idea that most drivers on the road have had a certain amount of experience and therefore renders their opinion more valid. 19.6% of the data harvested were drivers from the age 18 to 25 and only 10.4% or are people above the age 43. This question was able to give us the experience of the kind of drivers that are currently on the street. Figure 5.2 is a pie chart representation of the data.

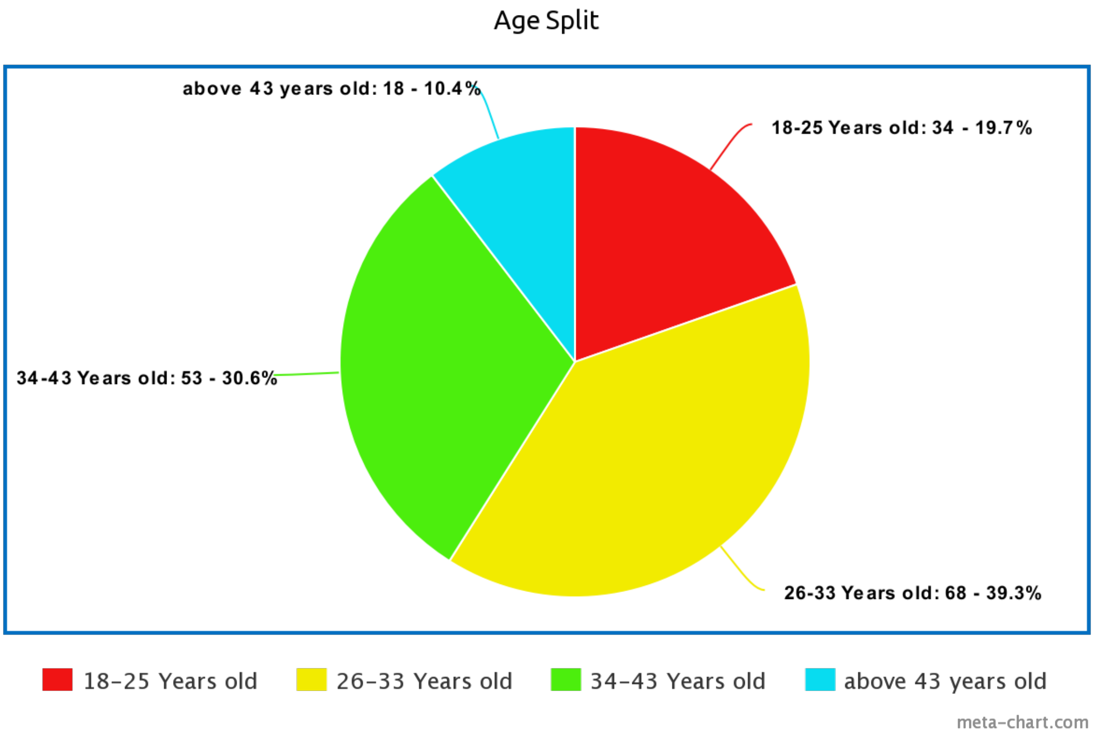

Figure 5.2: Age split for drivers in Sana'a

Frequency of drivers

From this question lean further investigate the frequency of the drivers in Sana'a. The results that were obtained show that three out of every four drivers are daily drivers, and this goes to show that the biggest mean of transportation is via personal car. Occasional drivers are within the mix; However, the least obtained value where are the drivers that seldomly drive. Figure 5.3 is a visual representation of the data obtained.

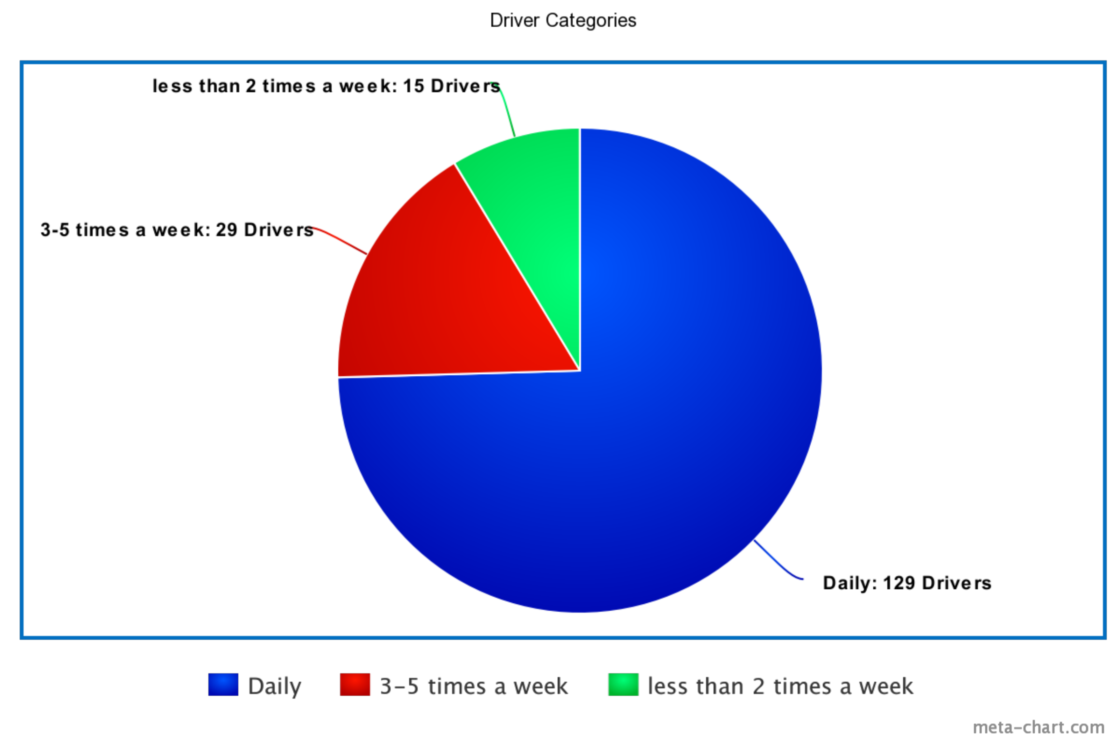

Figure 5.3: Driver categorization per their driving routine

The Encounter of Accidents

This part of the survey required feedback from active drivers within the city. The feedback required an answer of four choices from 7 in total: Therefore, providing us with a more concrete answer. If we had to choose one answer from 7 districts this would have given us and a skewed result leading to an uncertainty and inaccuracy within the survey. The division of the city was determined based on the largest boroughs within Sana'a, namely:

- Mo3een (pronounced Mo'een)
- Al Wahdah
- Old Sana'a
- Tahrir
- Al Sabeen
- Althawrah

- Haddah

The top 4 districts were Al Sabeen, Haddah, Alwahdah, and Mo'een respectfully. The result yielded is presented in the pie chart below:

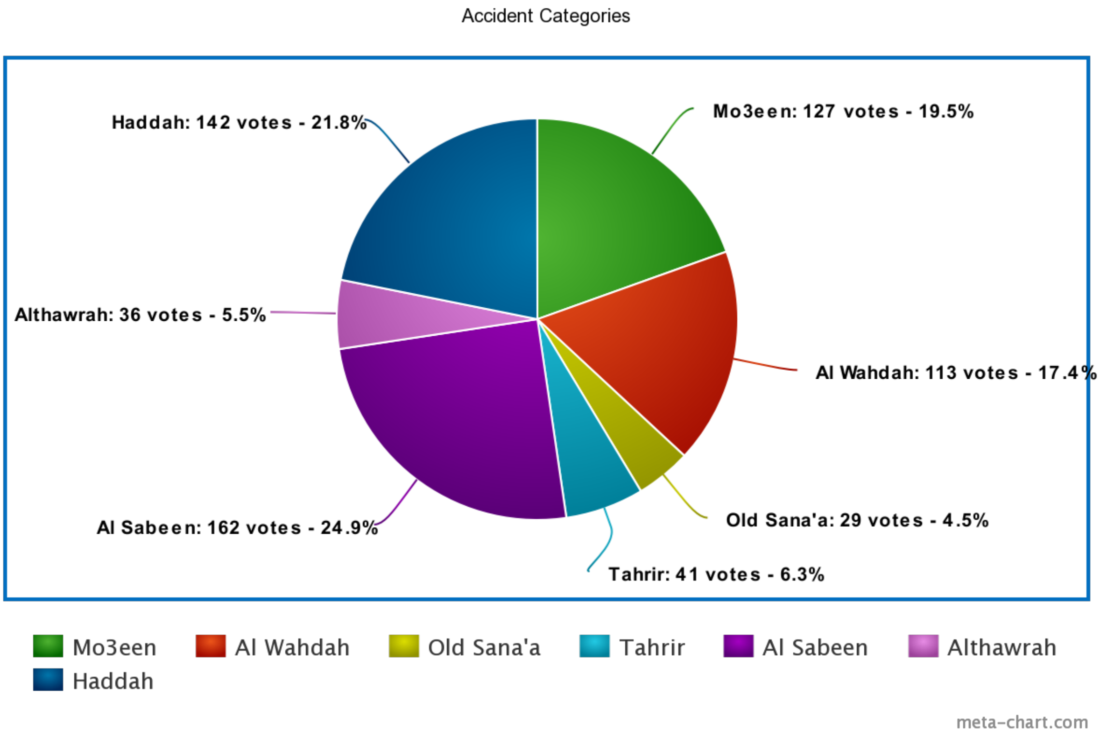

Figure 5.4: Accidents within the districts

Recklessness in drivers

This part of the survey was the dedicated to investigating the recklessness observed on the street by the drivers in question. This question is also in the survey to confirm the previous questions about accidents occurring within the same region as there are reckless drivers. As discussed in 4.12, the automated traffic enforcement systems are implemented in:

- Heavy traffic areas
- Speeding black spots
- Roads with blind curves
- Heavy lane changing roads (highway exits, entrances, mergers etc)

- Areas with a lot of crosswalks

Based on the feedback from the survey and the population density in that region, the results yielded were like the previous answer. The top 4 districts were Mo'een, Haddah, Alwahdah, and Al sabeen respectfully with the top Al Sabeen at 159 votes and the fourth being Alwahdah at 129 votes. The following figure is a visual pie chart showing the areas.

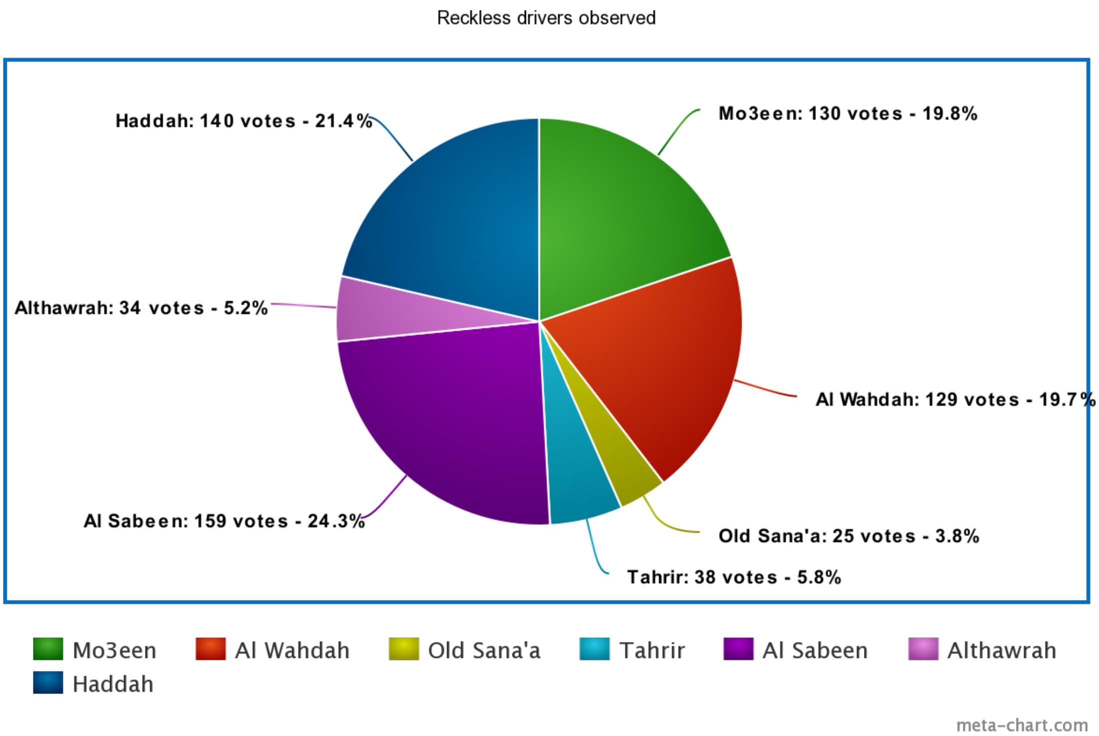

Figure 5.5: Reckless driver areas

Reasons for accidents

In this section we openly ask applicants of what the main reason behind most car accidents is (in their experience). The choices given were four of which they could choose two as the main reasons. The results yielded where significantly close to each other where the "lack of awareness of traffic laws" was 47% compared to 46% for "speeding". The remaining two choices were "poor technical state of the cars on the road" which scored 21 votes and "driving under the influence" at last scoring one vote. The pie graph below showcases the results:

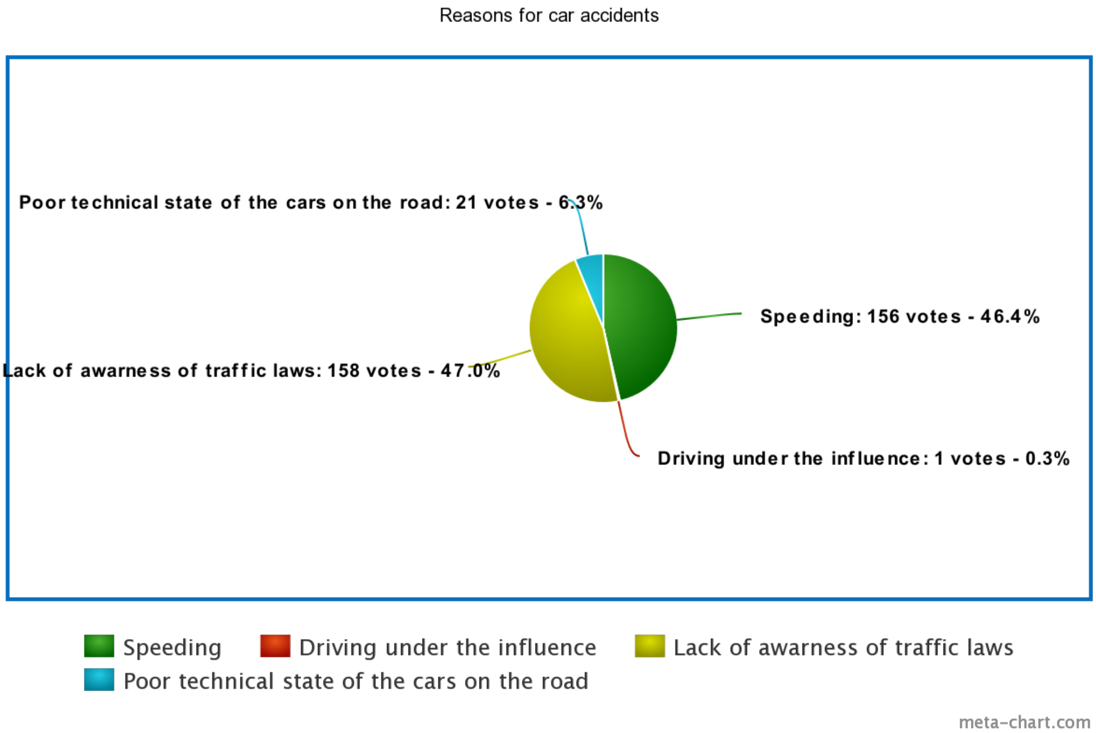

Figure 5.6: Reasons for car accidents

Car accidents Based on experience

This part of the question outlines the experience of the drivers that were in car accidents. the purpose of the question is to have a clear outline of how many car accidents are caused from 2016 up till 2021. This is just for an estimation of the current situation in the city since the numbers will allow us to measure on the current damages. The highest frequency of accidents are two accidents through the whole five-year period at 40 counts. 73.9% of drivers have between 2 till 5 car accidents throughout that duration. Figure 5.7 presents the following data for more details.

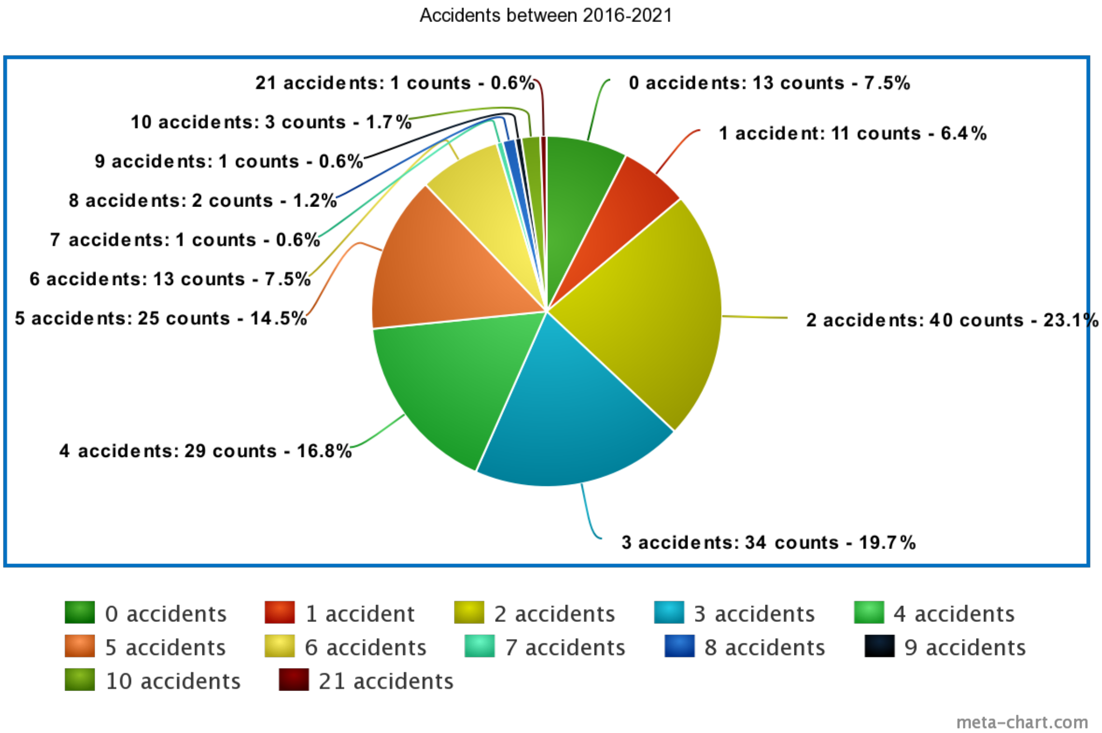

Figure 5.7: Accident count between 2016-2021

Public opinion

Finally, the last question judges public opinion. The question asks if the applicants of this survey will support a traffic enforcement system that could take place within city region to regulate and enforce traffic laws. It simply shows through the results that 99% of the applicants do approve of the proposal offered and only one vote opposes. The chart below.

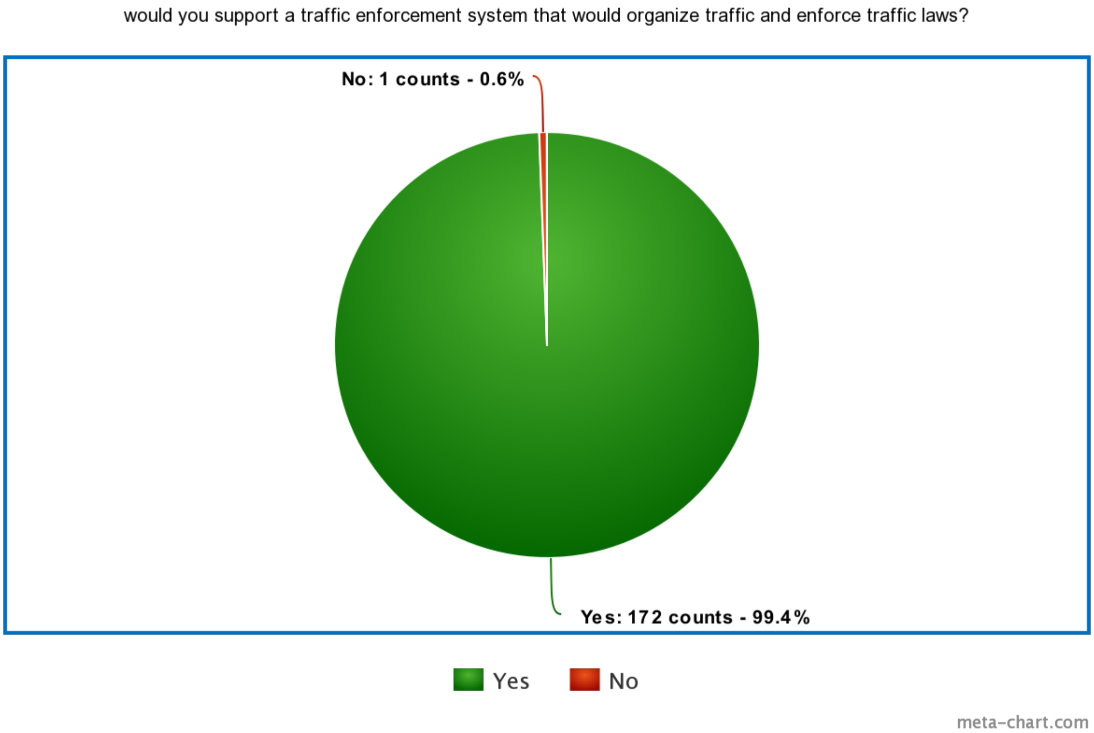

Figure 5.8: Public opinion

5.2.2 Discussion

As mentioned earlier within the survey, the questionnaire was designed to understand the current situation of the driving experience in the city as well as to explore the main issues within the driving experience right now. As per the last question, the results for the public opinion were significantly positive; However, there are multiple steps needed to be taken for us to reach a conclusion that could seem fruitful for the situation presented. First, we start with the driving experience itself. By having the majority of drivers being over 25 yet under 43 we can conclude that the drivers themselves have had a certain experience on the road whether that is male or female respectfully. The issue presented at end are the main two:

- **The lack of awareness of traffic laws and regulations:** This is one of the biggest reasons why accidents occur today within the city. The lack of awareness and the misinformation spread within the driving community and new drivers on the road makes it impossible to manage without a systematic solution to it. Therefore, PSAs should be aired on TV and radio to increase awareness, correct driving rules must be accessible to stop the spread of misinformation, and additional training should be given to active drivers and new drivers alike. These campaigns in European countries have proven effective from countries like Belgium and the UK.[27]

- **Speeding:** The second most voted reason why accidents happen in the city is speeding, and the reason being is the location. If we look at the districts voted for reckless drivers and the likelihood of accidents, we find that they are the areas are either are downhill areas, and close to highways. While most of the areas are straight ahead highways or streets, the lack of monitoring plays a role in the issue which results in accidents and traffic conflict. The resolution to minimize the issue is to have the cameras installed in the designated areas where speeding takes place and secure the blind spots with speed bumps. The following image 5.9 shows the areas where speeding and reckless driving takes place.

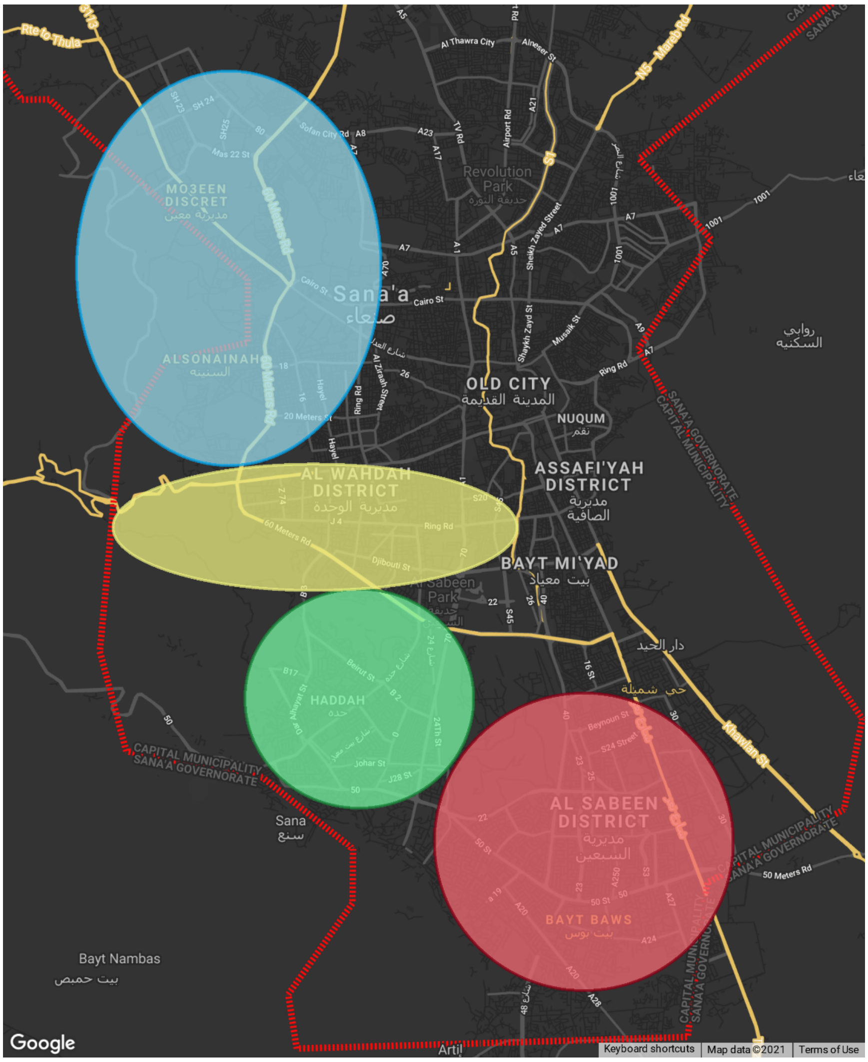

Figure 5.9: Areas with high car accidents/reckless drivers

While resolving the main two reasons of car accidents and traffic conflicts is the main purpose of this project, we still must make the structure and mechanism of the system. The first step for the system is to have its sensor triggered by an external factor such as speeding or breaking a traffic law. After the sensor is triggered, the camera takes a picture of the violation and the scene itself. While using the ALPR do identify the license plate of the violating car, the program fetches the picture information and converts it into a binary in the database. After having the necessary fields filled in the system, the information is stored within the database for further investigation and serve as evidence in court in case a citation is given. There are certain main concerns that should be covered after the violation has been taken care of such as the privacy of the driver and the car itself. This could be resolved by developing Internet privacy laws which are still not precedented in Yemen. The system is demanding and requires high skilled maintenance and development all the time, and the steppingstone is in the high populated areas while the branching out of the system is necessary to provide equal quality of service throughout the city. To match the system requirements and scale the proposal as transparent as it could be the following process in figure 5.9 promotes the initial structure of the system flow from the start (camera sensor being triggered) until the notification sent to the violator. This does not include judicial processes or penalties being involved since our focus is the database itself.

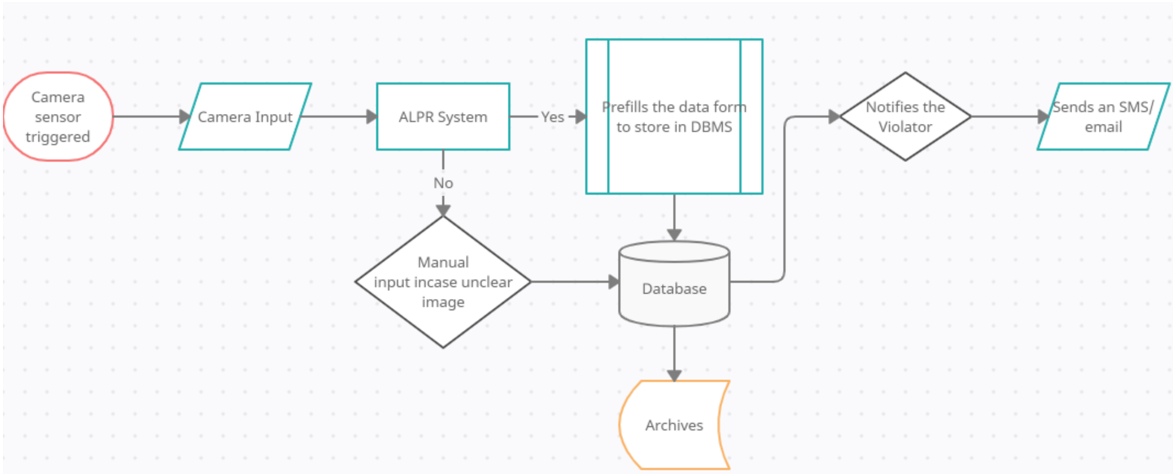

Figure 5.10: Flow diagram for the process of the ATES

Chapter 6

Conclusion

With the various ways of improvement for the system, we can say that this thesis has accomplished the basic structure of the most important of it. The Automated traffic enforcement system comes at a significant financial cost and requires maintenance at a constant pace; however, its advantages yield many results that affect the safety of the public and reduce casualties.

The lack of public access resources such as police records and surveys from traffic institutions made it challenging to create this research. Public opinion was one of the challenges of the developed countries in Europe and America, but in our case, it was not a problem. The steady support from the population will pave way for the systems constant development and help improve the quality of life in the country. Even though the research is at its infant stages, the project itself could also create job opportunities that would lead Yemen to the right direction in many aspects. This will also be the first steps of digitization of the country as whole, creating more access of information for the public, instead of regular physical archives.

The system itself could serve great benefit to society and help reform traffic which in turn gives us a safer environment for pedestrians and drivers as well. The possibilities to expand this research are endless. With more access to financial resources the technological advancements could be purchased, and further inspection of data could take place. As an example, we can create online portals with a back-end system access for the right authorities to allow access to individual records by giving them username and password. Further on it could have online payments as a method of settling penalties as well as giving them access to further support online.

Centralizing the service is a necessity as well, and while the Yemeni government is not in its ideal position today, we hope this work becomes future inspiration to a nation that is desperate for change. Responsibility lies upon everyone, and more on those who know its value towards progress.

Bibliography

[1] Eno Center for Transportation, "Our history – the eno center for transportation." Accessed at 21-10-2021, https://www.enotrans.org/mission-history/.

[2] Larry Clark, "Traffic signals: A brief history." Accessed at 21-10-2021, https://magazine.wsu.edu/web-extra/traffic-signals-a-brief-history/.

[3] National Highway Traffic Safety Administration, "Seat belts save lives." Accessed at 21-10-2021, https://www.nhtsa.gov.

[4] Zakaria Al Kamali, "Traffic accidents are unforgiving for yemenis." Accessed at 21.10.2021, https://www.alaraby.co.uk/society/.

[5] www.penize.cz, "More than 40 percent of czech drivers comply more strictly with traffic regulations abroad. they are afraid of heavy fines." Published 9/6/2015, last accessed 21.10.2021, https://www.penize.cz.

[6] Ministry of Interior Saudi Arabia, "Saher system." Last Accessed 21.10.2021, https://www.moi.gov.sa/wps/portal/Home/.

[7] Suzanne Deffree , "Karl benz drives the first automobile, july 3, 1886." published on 3/7/2019, last accessed 21.10.2021, https://www.edn.com/karl-benz-drives-the-first-automobile-july-3-1886.

[8] injuryfacts.nsc.org, "Car crash deaths and rates." Last accessed 21.10.2021, https://injuryfacts.nsc.org/motor-vehicle/historical-fatality-trends/deaths-and-rates/.

[9] Becky P. Y. Loo, Tessa Kate Anderson, "Spatial Analysis Methods of Road Traffic Collisions." ISBN: 9780429251535, B/W Illustrations 1st edition, 2016. Page; 223.

[10] safety.fhwa.dot.gov, "Speed enforcement camera systems operational guidelines." Last accessed 22.10.2021, https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa09028.

[11] Shormee Saha, "Automated traffic law enforcement system: A feasibility study for the congested cities of developing countries." DOI:10.15157/IJITIS.2020.3.1.346-363,International Journal of Innovative Technology and Interdisciplinary Sciences. DOI:10.15157/IJITIS.2020.3.1.346-363.

[12] Philip Wijers, "The automated enforcement chain." published 2017-03-15, last accessed 23.10.2021 https://www.researchgate.net/profile/Philip-Wijers/publication/313478310_Implementing_Automated_Traffic_Enforcement/links/589c4793aca2721ae1b92506/Implementing-Automated-Traffic-Enforcement.pdf.

[13] Jeong-Gyu KANG, Ph.D., "Changes of speed and safety by automated speed enforcement systems." DOI:10.1016/S0386-1112(14)60041-8, Highway Research Center, Korea Highway Corporation Seongnam, Korea. Page; 39-42.

[14] ONISR, "2019 road traffic violations annual report." Written on 21/09/2020 Published on 18/06/2021, last accessed 23.10.2021, https://www.onisr.securite-routiere.gouv.fr/en/road-safety-performance/annual-reports-on-offences-and-demerit-points/2019-road-traffic-violations-annual-report.

[15] M. eServices, "Fine payments." last accessed 23.10.2021, https://eservices.alberta.ca/fine-payments.html.

[16] www.absher.sa, "Absher platform new services." last accessed 23.10.2021, https://www.absher.sa/wps/portal/individuals/Home/homepublic/.

[17] Federal public service justice, "Manage your fine." last accessed 23.10.2021, https://justonweb.be/fines/.

[18] Alexey Marusin, Aleksander Marusin, Igor Danilov, "A method for assessing the influence of automated traffic enforcement system parameters on traffic safety." DOI:10.1016/j.trpro.2018.12.136, Saint Petersburg, 2018, Last accessed 25.10.2021.

[19] Susannah Parsons, Senior Policy Associate, "Can automated speed safety systems advance racial and economic equity?." Published April 28, 2021, last accessed 25.10.2021, `https://cutt.ly/jTUNHGA`.

[20] Members Chiu and Friedman, "Ab-550 vehicles: Speed safety system pilot program." Published 04/29/2021, last accessed 25.10.2021 `https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220AB550`.

[21] European Transport Safety Council, "Belgium takes action on speeding." Published October 26, 2016, last accessed 25.10.2021, `https://etsc.eu/belgium-takes-action-on-speeding/`.

[22] Dr Adam Snow, "Automated road traffic enforcement: Regulation, governance and use." published October 2017,last accessed 25.10.2021 `https://www.racfoundation.org/assets/rac_foundation/content/downloadables/Automated_Road_Traffic_Enforcement_Dr_Adam_Snow_October_2017.pdf`. page 20.

[23] J. B. Woods, "Key challenges for automated traffic enforcement to succeed as a measure of police reform." June 7, 2021, Last accessed 30.10.2021 , `https://theappeal.org/the-lab/explainers/key-challenges-for-automated-traffic-enforcement/`.

[24] WILLIAM FARRELL, "Predominately black neighborhoods in d.c. bear the brunt of automated traffic enforcement." published JUNE 28, 2018, Last Accessed 30.10.2021, `https://cutt.ly/cTUNcCL`.

[25] Pilgerstorfer, M., Eichhorn, A., "Awareness raising and campaigns – speeding." June 2017, Last accessed 2.11.2021 `www.roadsafety-dss.eu/assets/data/pdf/synopses/Awareness_raising_and_campaigns_Speeding_26072017.pdf`.

[26] Richard A Retting , Charles M Farmer, Anne T McCartt. Evaluation of Automated Speed Enforcement in Montgomery County, Maryland, Traffic Injury Prevention, 2008. DOI:10.1080/15389580802221333, page 440-445.

[27] Richard A. Retting Sergey Y. Kyrychenko Anne T. McCartt, "Accident analysis and prevention." Evaluation of Automated Speed Enforcement on Loop

101 Freeway in Scottsdale, Arizona, 2008. DOI:10.1016/j.aap.2008.03.017, pp. 40:1506-12.

[28] Richard A. Retting, Charles M. Farmer, "Transportation research record." Evaluation of Speed Camera Enforcement in the District of Columbia, 2003. DOI:10.3141/1830-05,pp. 1830: 34-7.

[29] Wen Hu, Anne T. McCartt, "Traffic injury prevention." Effects of Automated Speed Enforcement in Montgomery County, Maryland, on Vehicle Speeds, Public Opinion, and Crashes. DOI:10.1080/15389588.2016.1189076, 2016, pp. 17 (S1):53-8.

[30] Anne T. McCartt, and Wen hu., "Journal of safety research." Effects of Red Light Camera Enforcement on Red light Violations in Arlington County,Virginia. DOI:10.1016/j.jsr.2013.12.001, 2014, pp. 48: 57-62.

[31] Wen Hu , Jessica B Cicchino, "Insurance institute for highway safety." Effects of Turning on and off Red Light Cameras on Fatal Crashes in Large US Cities. DOI: 10.1016/j.jsr.2017.02.019, 2017, PMID: 28454859.

[32] Allan F Williams , Sergey Y Kyrychenko, Richard A Retting, "Characteristics of speeders." Journal of Safety Research. DOI:10.1016/j.jsr.2006.04.001, 2006 , pp.37(3):227-32.

[33] G. Ullman, M. Brewer, J. Bryden, M. Corkran, C. Hubbs, A. Chandra, K. Jeannotte, "Traffic enforcement strategies for work zones." National cooperative highway research program report no. 746. transportation research board, Washington, dc, 2013.

[34] Jessica B. Cicchino, Joann K. Wells Anne T. McCartt, "Journal of safety research." Effects of Red Light Camera Enforcement on Red light Violations in Arlington County,Virginia. DOI:10.1016/j.jsr.2013.12.001, 2014, pp. 48: 57-62.

[35] Prof. Mohamed Ahmed Salem Al Madhaji, "The challenges of economic development and investment trends and their impact on the planning and management of urban growth in the city of sana'a." May 2013, Last accessed 5.11.2021, `https://scholar.cu.edu.eg/?q=mmyoussif/files/paper_03.pdf`.

[36] Eshrak Alfalahi, Ali Assabri, Yousef Khader, "Pattern of road traffic injuries in yemen: a hospital-based study." Pan African Medical Journal. DOI:10.11604/pamj.2018.29.145.12974, 2018.

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Appendix

A.1 Survey

- **I am a:**
  - Male
  - Female
- **Please Select your age range:**
  - 18-25 Years old
  - 26-33 years old
  - 34-43 years old
  - Above 43 years old
- **How often do you drive?**
  - On a daily basis
  - Usually(3-5 times a week)
  - Rarely (less than twice a week)
- **Where do you usually encounter/almost encounter car accidents?**
  - Old Sana'a
  - Al Sabeen
  - Haddah
  - Al wahdah
  - Tahrir
  - Mo3een

  - Althawrah

- **Where do you usually encounter reckless drivers?**
  - Old Sana'a
  - Al Sabeen
  - Haddah
  - Al wahdah
  - Tahrir
  - Mo3een
  - Althawrah

- **What is (in your experience) the main reasons for car accidents in Sana'a?**
  - Speeding
  - Driving under the influence (alcohol or others)
  - Lack of awareness of traffic laws
  - Poor technical state of the cars on the road

- **How many car accidents were you in? (2016-2021)**
  - Fill in the blank

- **Lastly, would you support a traffic enforcement system that would organize traffic and enforce traffic laws?**
  - Yes
  - No