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A FRAMEWORK FOR THE STUDY OF TRAFFIC COLLISIONS AT
INTERSECTIONS IN THE CITY OF ABU DHABI (UAE)

Researched and Written by:

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A thesis submitted to the
Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Master of Applied Science in Engineering

Department of Civil and Environmental Engineering
Carleton University
Ottawa, Canada
August, 2002

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The undersigned recommend to the Faculty of Graduate Studies and Research acceptance
of the thesis

**A Framework For The Study Of Traffic Collisions At Intersections In
The City Of Abu Dhabi (UAE)**

Submitted by

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In partial fulfillment of the requirements for the degree of Master of Applied Science

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August, 2002

The Master of Applied Science in Civil Engineering is a joint program with the
University of Ottawa, administered by the Ottawa-Carleton Institute for Civil
Engineering.

ABSTRACT

Signalized intersections in the City of Abu Dhabi experience high collision occurrence. An investigation was carried out based on data collection about intersection characteristics, accident data (from the 1999, 2000, and 2001 police database) and the results of survey involving experts' opinions about safety of intersections. The collected data were analyzed and utilized to identify the causes and variables most contributing to safety at urban intersections at Abu Dhabi. The results were used to develop a tool to measure safety at 48 intersections, Safety Index. The developed approach utilizes expert's opinions and it employs artificial intelligence techniques (AI) to estimate safety index (SI) for signalized intersections. Using accident data the algorithm is calibrated and the correlation between the algorithm results (Safety Index) and accident rates in 48 selected signalized intersections is performed. The results of the thesis present a framework to analyze safety of urban intersections in Abu Dhabi. It can also be used to evaluate the effect of intersection improvements on the safety of the intersection.

ACKNOWLEDGEMENT

I would like to acknowledge H.H. Sheikh Saif Bin Zayed Al Nahyan, H. H. Sheikh Mohamed Bin Khalifa Bin Zayed Al Nahyan and H.H. Sheikh Tahnoon Bin Saeed Al Nahyan for their generous support.

I would like to thank my thesis supervisor Professor A. O. Abd El Halim for his continuous support, motivation, effort and valuable advice which was very important to complete my thesis and expand my perspective. I am also greatly indebted to the thesis committee members Professors S. Mahmoud, S. Easa, Y. Hassan and H. A. Khoo for the time and effort invested.

Special and sincere thanks are due to Dr. A. M. Garib whose knowledge and experience has been a great asset to have during the conduct of this study. I would like also, to thank Dr. W. Parker; the Chairman of the Civil and Environmental Engineering Department for his invaluable guidance, encouragement and advice through my stay at Carleton University. Also, sincere thanks go to Dr. A. Al-Bakery, Mr. A. Al-Warawra and Mr. Khaled A. Awadh for their effort, time, and help during all the different stages of this thesis. Many thanks to the General Directorate of Abu Dhabi Police, UAE Embassy in Ottawa, and all friends at Carleton University for their help and support.

Finally, I would like to thank my family, relatives, friends, and colleagues who supported me with love and prayers throughout the long days and nights spent working on this project. Special thanks to the Fraiji's family. It is difficult to adequately thank them for their endless love, support, endurance, and prayers.

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CHAPTER 1: INTRODUCTION

1.1 IMPORTANCE OF TRAFFIC SAFETY

In the early thirties and up to late sixties, traffic volumes and vehicle speeds were low compared to today's traffic conditions. As a result, the number of automobile collisions, particularly fatal accidents, was significantly less and safety on roads was not considered to be of a paramount concern. Accidents at intersections became a major concern of traffic engineers and road planners. In the USA, it was reported that 20% of all crashes and 7% of fatal accidents were related to signalized intersections (1).

Over the last 30 years, rapid growth in population, urbanization, and industrialization, coupled with advanced technologies in the automobile industry have increased traffic volumes and operating speeds on the roads and highways. This in turn increased the risk of automobile accidents, therefore, necessitating more attention towards improving road safety standards. Improving road safety requires first the understanding of factors that contribute to accident occurrence, and then controlling the conditions under which those factors lead to the accident. Highway officials have been performing research and field studies to identify and evaluate accidents-causing factors. These studies involved the type, frequency, and severity of accidents, as well as their relationships to contributing factors. Most of these studies estimate the effect of selective variables and the number of traffic accidents (2,3,4).

Recently, statistics all over the world has shown tremendous increase in the number of road accidents accompanied by many serious injuries and fatalities. In the United States, the loss of life due to road accidents exceed losses due to major diseases such as AIDS, cancer, and heart disease (5). Also, accidental deaths due to motor vehicles exceed those of all earlier U.S. wars including the two World Wars and the Vietnam War. The results of a recent study performed in Europe estimated the cost of a fatal accident to be as high as 244,000 Euro and

22,100 Euro for a serious injury (6). Also, it was reported in the same study that the costs of accidents could vary by a factor of five as a result of the degree of curvature of the road. As a result, importance of the road and highway safety has substantially increased, and researchers began to study the impact of various factors that contribute to road accidents in one way or the other. These factors can be classified into the following categories:

- a) Road related factors
- b) Vehicle related factors
- c) Driver related factors
- d) Environmental factors

A detailed description of these factors, and their impact on road safety will be discussed in the next section.

Improving road safety can be achieved by minimizing the risk of accident occurrence, in terms of its probability and severity. Minimizing probability of accident occurrence can be achieved through accident prevention, or at least reducing the number of accidents. Previous studies (7,8,9) indicated that this is the most difficult and complex task to accomplish. Minimizing accident severity deals with death and serious injuries prevention, or at least reducing them. In the last 20 years, many improvements to automobile design, structurally and ergonomically, have been made to minimize fatalities and serious injury. These include redesigning the body, improving seat belts, introducing front driver and passenger airbags, as well as side airbags, and improving the design and quality control of the tires (10,11, 12,13).

In general, there are three avenues that may be used to improve road safety. The first two are considered a part of the highway and traffic engineer's duties, while the third avenue is a part of the duties of the motor vehicle industry. The first avenue deals with identifying locations at which accidents are most likely to occur, then improve them in such a way as to

give drivers the time and space necessary to recover from any accident leadings situation. This would certainly reduce the risk of road accidents. The second avenue deals with enriching the driver's experience through training and education programs. The third avenue deals with improving the crash survivability through improving the vehicle's capability to absorb most of the crash impact. As mentioned above, the motor vehicle industry has done an admirable job in achieving this goal through enormous improvements to the automobile design.

Earlier research focused on studying the causes of accidents as related to highway characteristics, vehicles, drivers' behavior, environment, and traffic control devices. Such studies usually relied on the analysis of previous accident records from police reports to find a bridge between accident rates and their contributing factors (14, 15, 16). However, the contributing factors to accidents usually interact with each other, which make every aspect of the traffic system connected to one another. This study, however, is different since it only concentrates on studying intersection features that may have effects on road safety. It employs artificial intelligence techniques (AI) in developing a safety index algorithm for intersections within Abu Dhabi, which can be used to evaluate signalized intersections based on safety capability. The evaluation process can be used to better plan and select the required improvements for these intersections. Furthermore, this study uses data and recorded information about accidents from the Police Department but it differs from traditional approaches in two aspects. Firstly, it addresses the problem at the specific locations of urban intersections, and secondly, it provides a statistical model, which can be utilized to assess the effects of the design and operation of the intersection. Clearly, in order to upgrade safety standards, relationships between key intersection features and safety have to be fully

understood. A critical review of previous research and studies of these relationships are presented in the subsequent sections.

Intersection accidents represent a significant portion of the total automobile accidents. Research results show that 43% of all roadway crashes and 23% of fatal accidents took place at intersection related sites at the USA (1). Clearly, the knowledge of the existing conditions of the roadway system is essential to making appropriate decisions to improve safety of intersections. These decisions are taken to achieve the objective of reducing the number of traffic accidents and decrease the potential for accidents on the road network. In order to establish this base of knowledge, a number of studies proposed models that examine the relationship between accidents at intersections and different variables at the locations including distances traveled and traffic volumes (17, 18, 19). The following section deals with the factors affecting safety at intersections.

1.2 FACTORS AFFECTING SAFETY OF INTESECTIONS

Enhancing and improving safety at intersections are considered important elements of the overall concept of road safety management. As a result, several investigations dealt with the identification of dangerous intersections, the causes of safety problems at specific intersections and assessment of safety improvements. (4, 6, 7). Several studies dealing with road accidents used traffic volume as the only independent variable (16). Advanced methods proposed the use of safety performance models to predict the expected safety of an intersection when its features are known (17 - 21). The main characteristics governing the safety performance of intersections are discussed below.

1.2.1 Engineering and Roadway Effects

Adequacy of geometric designs, construction methods, and maintenance practices in constructing road intersections is of great significance for optimum performance during their anticipated service life. Higher standards of geometric design and other intersection conditions such as signs and markings, as well as proper traffic control and monitoring devices would enhance safety at the intersections. AASHTO and other international guide have specified guidelines or procedures to determine acceptable values or conditions of engineering parameters in intersection design (22). Design and condition of vehicles, training, age and sex of drivers also play an important part in causing accidents and determining their severity. Accidents may be due to the involvement of one, two, or more vehicles. Also, the mass of the vehicle is a significant factor for survivability during the accident. Occupants of heavier vehicles are likely to be at lesser risk of sustaining serious injuries than occupants of lighter vehicles.

1.2.2 Environmental Effects

Consideration of environmental factors that could undermine the performance of road safety is essential in highway engineering design. Road design must be able to adequately withstand the effects of weather such as extreme temperatures, wetting due to fog and rain, exposure to salts, surface erosion due to high winds, blowing sand and floodwater. It must cater for quick dispersal of surface and sub-surface water (23,24). In addition, geometric design should allow for the need of sufficient stopping distances under varying environmental conditions (25).

1.3 Previous Research

Over the last 50 years, several studies have been carried out in the United States and Europe (26, 27, 28) after serious concerns were raised over the deterioration of level of safety on rural and urban highways. These studies were related to safety problems at federal, primary, secondary, and urban highways. During this period, various U.S. organizations have proposed minimum standards for highway geometry and other specific features for adoption at the Federal level (28, 29, 30).

In light of the 1982 Surface Transportation Assistance Act, the U.S. Congress asked the National Research Council, the principal operating agency of the National Academy of Engineering, to review the highway safety standards and their cost-effectiveness of design. The Transportation Research Board (TRB) committee, after gathering recommendations from highway officials and researchers, submitted a “*Special TRB Report, 214 - Designing Safer Roads – Practices for Resurfacing, Restoration, and Rehabilitation*”. In addition, the committee was asked to undertake a critical review of the relationships between road safety and highway geometry, keeping in mind the expected changes in vehicle design characteristics. A summary of these reviews was published in the TRB, State-of-the-Art Report No. 6 (1987) (30). It included qualitative and quantitative analyses of relationships between safety parameters and key highway features. Further discussion of the findings and recommendations contained in this report will be discussed in the following sections.

1.4 FACTORS CONTRIBUTING TO SAFETY HAZARDS

In order to minimize Fatalities, injuries, and property damage from traffic accidents, there is a need to understand of the factors that contribute to such safety hazards. Knowledge of the relative importance or impact of these factors on safety is necessary for the set up of priorities for engineering standards, laws and regulations as related to Traffic Management and Control, and provisions of post-crash Emergency Medical Services. These priorities differ from one country to another, and may even differ among different areas within the same country because of differences in roadway patterns of traffic, particularly, driver behavior. In view of this, the task of quantifying these factors to obtain general standards is far too complex (6). In addition, most of these factors are so interrelated that individual contribution of each factor becomes difficult to quantify. It is, therefore, more prudent to utilize historical and social analysis with seasoned judgment to compare and combine these factors for particular countries or societies (6, 26, 30).

Tables 1.1 and 1.2 present the total number of fatalities and injuries reported in 1996 for several countries. Fatality is defined as the death resulted from an accident that occurs within 30 days of its occurrence. Worldwide, more than half a million people are killed each year in traffic accidents. These losses are unevenly spread among nations of the world, with variations in fatality rates for countries having different levels of motorization (31). For example the data in Table 1.1 show that the highest number of fatalities due to traffic accidents was highest in the USA followed by Republic of Korea and Japan. On the other hand, the data indicated that Finland, New Zealand and Sweden had the lowest number of deaths. Furthermore, when the number of fatalities were taken as ratio of the density of vehicles, Korea, Turkey and Poland show higher percentages while Sweden, U.K. and Japan appeared to be less risky places to be in a vehicle. Clearly, these data demonstrate the difficulty

associated with the analysis and evaluation of traffic accidents and its relation to the overall concept of road safety. The data given in Table 1.2 indicate that the number of death per 10,000 vehicles is higher in countries in the Gulf region such as Oman and Saudi Arabia. Also, with the lower population densities of the region it is obvious from the table that Oman, Saudi Arabia and Bahrain are facing a serious problem with respect to death due to road accidents. The UAE is also located in the same region with expected higher number of vehicles and foreign nationalities, which may make the problem more serious.

It has been reported (5) that decline in fatality rate reflects improvement in safety by virtue of improvement in driver behavior, engineering standards for roadway, vehicle characteristics, traffic management techniques, and post-accident medical emergency services. Furthermore, it was concluded that drivers' behavior, social norms and attitudes, and risk perception had the largest effect on reducing fatality rates.

Earlier research (2, 4, 15, 26, 32, 33) has tried to establish relationships between various parameters of geometric designs and traffic flow characteristics. Such studies made qualitative judgments based on engineering experience and available traffic records. Real life data was then used to quantify relationships related to congestion, accidents, cost implications as well as setting minimum standards, mainly for geometric designs of roads.

1.5 NEED FOR SAFETY EVALUATION TOOLS

Roads and highways are built to transport people and goods in safe, comfortable and economic manner. Accidents, on the other hand, cause immense loss of life and property damage. More research on improving road safety is required to help reducing these losses. This can be achieved by studying the relationships between road safety and the factors contributing to hazardous conditions that can lead to an accident. It has been reported that more than 122,000

accidents were recorded in the state of California between 1979 and 1985. These accidents occurred within 250 ft of studied 2498 intersections (21). In addition, fatalities due to traffic accidents became a major cause of death in the U.S. where more than two and half million people have been killed between 1928 and 1988 (5). For example, traffic fatalities between 1977 and 1988 have exceeded all those killed during the U.S. previous wars. In addition, injuries outnumber fatalities by a large margin. In 1985 alone more than 45,600 people were reported killed on American highways and additional 1.7 million suffered serious injuries (34). In 1988, the annual financial cost of motor vehicle accidents in the U.S. was estimated at about \$70 billion U.S. dollars. Globally, about half a million people are killed each year in traffic accidents (5). In view of such immense losses, it is of paramount importance that more reliable evaluation tools be developed to evaluate the level of safety on the roads and intersections, allowing the proper authorities to have the opportunity to plan and budget for improving the safety conditions on these roads. Consequences of traffic accidents can be summarized as follows:

- a. Human losses, such as injuries and deaths.
- b. Economic losses, such as congestion, traffic delays, loss of wages, and property damage to vehicles and/or roadside objects.

Currently, “Road Safety Audit (RSA)” systems are being developed and used in certain countries such as Great Britain, Australia, New Zealand, South Africa and America (35). Road Safety Audit provides a comprehensive introduction to the road safety audit process. Designed for use by road safety and traffic engineers, police, academics, government officers, consultants and many others, Road Safety Audit provides a comprehensive overview to the application of the audit process to new and existing road designs (36).

Previous studies on road safety, despite their limitations, could however serve the useful purpose of providing guidance for further research. It seems important to develop criteria to categorize roads and highways according to their level of safety in addition to performance requirements of applicable codes or standards. At present, no such tools are available which can determine the level of safety on roads by considering critical accidents contributing factors. Improvement of roads and intersections safety is only possible if effective evaluation tools are developed; which is the main objective of this thesis.

1.6 TYPES AND USES OF ARTIFICIAL INTELLIGENCE TECHNIQUES

Artificial Intelligence (AI) is the study of intelligence using the ideas and techniques of computing. Artificial Intelligence, or AI for short, is a combination of computer science, physiology, and philosophy. AI is a broad topic, consisting of different fields, which includes machine vision and expert systems. The element that the fields of AI have in common is the creation of machines that can "think". Research into the areas of learning, of language, and of sensory perception have aided scientists in building intelligent machines. In order to design and build intelligent machines, the field of Artificial Intelligence has split into several different approaches based on the opinions about the most promising methods and theories. These rivaling theories have lead researchers in one of two basic approaches; bottom-up and top-down. Bottom-up theorists believe the best way to achieve artificial intelligence is to build electronic replicas of the human brain's complex network of neurons, while the top-down approach attempts to mimic the brain's behavior with computer programs.

Unlike conventional programs where it is easy to represent data and use them to carry out calculations, representation of human knowledge and intelligence is different and it is the main interest for AI researchers. Human intelligence is based on experience, knowledge,

heuristics, rules of thumb, and intuition. Researchers have long been trying to develop computers that have some ability to think. In this pursuit, they have been successful in developing software algorithms that can use human knowledge and expertise to solve various problems in social, commercial, industrial, engineering, and medical fields. This has greatly helped in the sharing and utilizing knowledge and experience of the experts in such fields to solve complex problems with a certain level of certainty (37, 38,39).

Development of software architecture is based on the so-called Artificial Intelligence, contrary to the Natural or Biological intelligence. The AI techniques have proven to be effective in forming some kind of expert systems. Designers of expert systems typically assume that knowledge and actions of a human expert in a certain field can be embodied into a set of facts and in an accompanying hierarchy of explicitly stated rules involving symbolic manipulation of those facts and lower-level rules. Expert systems used for diagnoses of certain diseases and applications in industry and engineering fields often equal to or exceed the success rate and cost-effectiveness of human experts. However, AI attempts to capture intelligent behavior without regard to the underlying mechanism producing that behavior. This approach involves describing behaviors, usually with rules and symbols. There are many branches of Artificial Intelligence such as Knowledge-based systems, Natural language systems, and Automatic programming. Expert Systems are the part of AI that deals with the presentation of knowledge in computer systems to replicate the thinking, reasoning, and decision-making process with the ability to provide advice with a certainty factor. Although applications of the AI are being utilized in nearly all branches of science, the two mainly used techniques in civil engineering are the Expert Systems and the Neural Networks (38, 39).

The Neural Network is a system composed of many simple processing elements operating in parallel, whose function is determined by network structure, connection strength, and the processing performed at computer elements or nodes.

1.6.1 Types of Artificial Intelligence Systems

The broad-based classification of AI systems includes Expert Systems and Neural Networks. Each of these can be sub-divided into further classes depending on their architecture, and performance criteria. The selection of the most suitable system for a certain application depends on a number of factors, such as:

- a) Nature of the problem, i.e., statistical, mathematical, diagnostic, or behavioral.
- b) Type of data available, i.e., facts, heuristics, patterns, past experiences.
- c) Amount and complexity of data, i.e., database is large or small, relationship between variables is linear or non-linear, data contains inconsistencies or is missing.
- d) Details or errors.
- e) Accuracy required in analyzing or predicting data.
- f) Weighting or strength of connections between parameters or variables
- g) Expected outcome, i.e., a single solution or a set of multiple alternative solutions

All the above factors are considered when selecting the most appropriate AI Systems to develop an algorithm for determining the Road Safety Index for United Arab Emirates (UAE) intersections. It seems prudent that before attempting the final selection, an appraisal of salient features of both the AI systems is made.

Fuzzy logic is one branch of the AI that is gaining more potential, especially in the environmental field. There are many applications of the AI in Civil Engineering such as preliminary seismic design, repair of concrete structures, concrete mix design, highway serviceability and maintenance, and bridge management (38, 39, 40, 41).

1.6.2 Expert System (ES)

Expert knowledge is often scarce and valuable. Expert systems are computer programs that capture some of that knowledge and allow its dissemination to others. It emulates the interaction a user might have with a human expert to solve a problem. The end user provides input by selecting one or more answers from a list or by entering data. The program will ask questions until it has reached a conclusion. The conclusion may be the selection of a single solution or a list of possible solutions arranged in order of likelihood. The program can explain how it arrived at a particular solution. The system may be based on a tree-structured logic and include confidence factors allowing several possible solutions to be selected with different degrees of confidence. A system may be highly interactive (directly asking the user questions) or embedded where all input comes from another problem (33, 37, 42).

Definitions of expert systems vary. Some definitions are based on function, while others are based on structure or a combination of both functional and structural components. In general, these are rule-based or knowledge-based systems that utilize a database of knowledge and a set of inference rules to solve problems within a defined and limited domain. It is assumed that the expert system should model the human decision process within a certain framework. Expert systems should be considered supportive of the decision making process; they cannot replace the human expert (37, 38).

1.6.3 Neural Networks (NN)

Neural Networks are computing architectures or algorithms based on a number of small and relatively simple processing units, which are connected to each other by a system of links operating in parallel. The principle of their functionality has been derived from animal brains consisting of large numbers of simple processors, called neurons operating in parallel and connected to each other by a system of axons and dendrites along which relatively simple signals are passed. Most often, neural computing or Neural Networks refers to Artificial Neural Networks (ANN). Natural or Biological Networks are much more complex than the mathematical models used for ANNs. There is no universally accepted definition of an ANN. However, most people agree that a NN is a network of many simple processors (units), each possibly having a small amount of local memory. The units are connected by communication channels or connections, which are carrying numeric as opposed to symbolic data, and encoded by various means (37).

It has been indicated (43) that neural network is a massively parallel-distributed processor that has a natural propensity for storing experiential knowledge and making it available for use. It resembles the brain in two respects:

- a) The network through a learning process acquires knowledge.
- b) Interneuron connection strength known as synaptic weights is used to store the knowledge. A neural network was defined (44, 45) as a circuit composed of a very large number of simple processing elements that are neurally based. Each element operates only on local information. Furthermore, each element operates asynchronously; thus there is no overall system clock.

In principle, NNs can compute any computable function, i.e. they can do everything a digital computer can do. NNs are especially useful for classification and function

approximation/mapping problems which are tolerant of some imprecision, and which have lots of training data available, but to which hard and fast rules, such as those that might be used in an expert system, cannot easily be applied (46).

The structure of an artificial neural network mimics a simplified view of biological neural architecture. An artificial NN has only three building blocks: neurodes (an artificial model of the biological neuron), interconnects (the paths or links between neurdes), and synapses (the junction where an interconnect meets a neurode). These correspond to the neurons, axons, and synapses of biological systems.

Applications of ANN in transportation are numerous. It has the unique advantage of not requiring any a priori assumption on relationship between variables. Furthermore, NN offers greater opportunities to deal and analyze problems where the phenomena are not well known (45, 46).

1.7 STATEMENT OF THE PROBLEM

Improving the level of highway safety is one of the major problems facing highway authorities and engineers in the UAE. The persistent increase of accident frequencies and rates is a matter of concern that disturbs highway users, authorities, engineers, and communities. In the past many highway researchers have focused on developing algorithms and techniques for pavement condition evaluation as well as some economic evaluation techniques. None of the previous studies investigated the development of a safety evaluation tool, which is needed to measure the safety aspects of any signalized intersection. As mentioned previously, safe and comfortable highways that transport people and goods are the first and most important goal. This emphasizes the need for a highway safety evaluation model. Such a tool should guide decision-makers to improve and upgrade highway safety. It should take into consideration

significant variables that may affect highway safety. The highway system consists of four elements: the vehicle, the driver, the highway and the environment. Each element contributes to highway safety. So far, researchers have not been able to identify the contribution of each of these elements.

The safety condition at any intersection on a highway has a significant effect on the overall safety and operating performance of the entire highway. Thus, improvement of the safety condition at each intersection usually results in an improvement of the overall safety condition of the entire road or highway. Accidents usually take place when drivers approach a location where they have to make a decision to perform a specific action. Approaching an intersection requires more attention from drivers. Also, it requires many actions and decisions to be taken. Intersections usually accommodate different movement (cars from other directions, pedestrians movement etc.). This makes the task of passing through intersections very difficult. Such task becomes more difficult in cases where the geometric, pavement, traffic control devices are not in perfect condition. Accident statistics supports the previous argument. They indicate that a high percentage of accidents take place at intersections.

Abu Dhabi is the capital of the United Arab Emirates (UAE), a country established in 1971 as a federation of seven Trucial States: Abu Dhabi; Dubai; Sharjah; Ras Al Khaimah; Fujairah; Umm Al Quiwain; and Ajman. Since 1971, the Emirate of Abu Dhabi has gained prominence nationally, within the Arabian Gulf region and internationally. Over the past 25 years, population in the Abu Dhabi emirate has grown from 200,000 in 1975 to over 900,000 in 2000. The city of Abu Dhabi (within the emirate of Abu Dhabi) and its environs has a total population of 620,000. The city of Abu Dhabi is located on the southern shore of the Arabian Gulf.

The urban structure of Abu-Dhabi Island is laid out in a grid network of major high-capacity urban arterials. The road network in Abu Dhabi is a modern, rectilinear system. Major arterial streets typically have dual 3-lane carriageways. Within the sectors are smaller internal roads. Most of the internal roads are linked to the major arterials with right-in/right-out only connections. As a result, the junctions often have a high percentage of U turns. Junctions of major arterials include signalized intersections, roundabouts (rotary intersections), and a few grade-separated interchanges. Most of the junctions were originally constructed as roundabouts. As traffic increased, congestion caused many of these roundabouts to become signalized, or reconstructed as signalized intersections. Most of the signalized intersections have free-right-turn lanes and separate left turn/U turn lanes. Downtown signals are controlled by a centralized computer system.

As will be shown later, data collected over the past three years showed that signalized intersections in Abu Dhabi are experiencing increasing accident occurrence. Reducing accident rates or number of accidents at intersections is expected to have a major positive impact on the overall safety record in Abu Dhabi.

To improve highway safety in Abu Dhabi this research will, therefore, provide a detailed signalized intersection safety evaluation algorithm. This algorithm will utilize expert opinion and will employ AI techniques to estimate safety index (SI) statistics for signalized intersections. Using accident data, the algorithm will be calibrated and the correlation between the algorithm results (Safety Index (SI)) and accident rates in some selected signalized intersections in Abu Dhabi will be performed.

1.8 RESEARCH SCOPE AND OBJECTIVES

This research focuses only on accidents that occurred at urban intersections within the City of Abu Dhabi. Furthermore, this study examines only accident data at different types of intersections and not on links. In general the main aim of the study is to identify the most critical variables that determine the potential of having an accident occurring at an intersection. Therefore, more effort was made to characterize the main causes of accidents and explain the relation between the accidents and these causes. More specifically, the objectives of this research are to:

1. Identify the main causes of the road accidents at urban intersections in the City of Abu Dhabi,
2. Collect data and information relevant to accidents at specific intersections within Abu Dhabi,
3. Design and implement a survey that includes interviews with local traffic and highway experts with respect to conditions of intersections and their effect on safety,
4. Develop an algorithmic framework and architecture for signalized intersection safety evaluation techniques in Abu Dhabi.
5. Utilize the algorithmic architecture in developing a computer program that can estimate signalized intersection safety index using artificial intelligence.
6. Determine the correlation between the developed safety index (the software output) and real life accident rates.

The outcome of the study is the use of a mathematical model to quantify the effect of hazard associated with a specific intersection and environmental conditions.

1.9 BENEFITS

The death and injury as a result of traffic accidents have been recognized to be a worldwide problem. In 1996, the total reported deaths due to crashes were estimated to be close to 700,000 and expected to increase to a total of 1,100,000 by the year 2010. In addition, the number of people injured as a result of traffic accidents was estimated to have been 34,000,000 by the end of the 20th Century. Therefore, it is expected that road accidents will rank the sixth cause of death on a list of 100 different causes.

Economic estimate of the cost due to these accidents was estimated to stand at 2% of GNP per year. Estimates were derived of what this meant in global and regional terms and it was found the global cost in 1998 might have been of the order US\$520 billion (31).

The above estimates and numbers clearly show that highway accidents can and will cost society enormous economic losses. More pre-retirement years of life are lost due to highway accidents than from the combined effects of the two leading diseases, cancer and heart disease. Also, half of the 19 year olds who die do so as a result of highway accidents. Accidents not only cause deaths and serious injury, but they also cause delay to travelers, wastage of fuel, secondary accidents, wear and tear of vehicles and roadways, and environmental pollution. Accidents reduce traffic flow and increase delays and distress for road users.

One area that may assist in resolving this problem is intersections in large cities. The strong interest in developing signalized intersection safety index for Abu Dhabi has been sparked by the serious highway safety problems that many intersections around the world are facing. Using artificial intelligence, this research provides a powerful safety evaluation tool. It will assist policy makers in fund allocation to satisfy highway goals (transportation of people and goods in safe, economic, and comfortable manner).

1.10 THESIS ORGANIZATION

This Chapter introduces the subject of traffic accidents and the importance associated with its prediction and subsequently reducing them. Next, a discussion of the specific problem associated with accidents at urban intersections and the main variables governing their occurrence. Then a brief discussion of the use of artificial intelligence methodology and its application on traffic problems was presented. Finally, the scope and objectives of the thesis were presented.

Chapter 2 deals with the research methodology and the main phases and tasks adopted to achieve the main objectives of the thesis. Data collection and evaluation are presented in Chapter 3. The developed Safety Index Algorithm is discussed in Chapter 4. The proposed applications of the developed algorithm and training process results are presented in Chapter 5. Model calibration is provided in Chapter 6. Summary, conclusions and recommendations are provided in Chapter 7.

Table 0.1: 1996 Road Accidents Data for Highly Motorized Countries

Country	Fatalities	Injuries	Fatalities per 10,000 vehicles	Fatalities per 100,000 people
United States	41,967	3,399,000	2.0	15.8
Canada	3,082	230,885	1.8	10.3
Austria	1,027	56,700	2.3	12.7
Japan	9,942	942,203	1.2	7.9
Netherlands	1,099	10,462	1.5	7.1
United Kingdom	3,598	316,704	1.5	6.1
Greece	2,068	31,658	4.0	19.7
Turkey	5,428	104,599	10.5	8.7
Republic of Korea	12,653	355,962	10.6	27.8
Sweden	537	20,810	1.3	6.1
France	8,080	170,117	2.6	13.8
Germany	8,758	493,158	1.9	10.7
Poland	6,359	71,419	5.7	16.5
Finland	404	9,299	1.7	7.9
New Zealand	514	16,600	2.2	14.1

Table.2: 1996 Road Accidents Data for Middle Eastern Countries

Country	Fatalities	Injuries	Fatalities per 10,000 vehicles	Fatalities per 100,000 people
Bahrain	57	2,257	3.2	9.5
Egypt	4,400	22,135	20.0	7.4
Iran	2,963	29,509	5.9	4.7
Jordan	552	15,375	18.8	12.8
Lebanon	328	3,032	2.4	8.0
Libya	1,080	7,750	8.3	20.9
Oman	512	6,654	16.4	23.6
Saudi Arabia	4,077	32,133	13.9	21.0

2 CHAPTER 2: RESEARCH PLAN

2.1 INTRODUCTION

As discussed in the previous Chapter, the proposed intersection safety index is not a new concept. Safety index has been employed in evaluating bridges. A number of studies (47-48) were carried out to develop a bridge safety Index (BSI) that would relate the degree of hazard associated with a bridge to its physical characteristics. Also, the concept of utilizing expert opinions has been employed in evaluating pavement condition and the well-known Pavement Serviceability Index (PSI). Similarly, several procedures have been developed to evaluate pavement condition. Each procedure has proposed an index by which highway officials can evaluate their highway sections. For example, Pavement Condition Index, Pavement Serviceability Index, and Pavement Quality Index are employed today by many pavement agencies around the world. Those indices were based on highway experts' opinions. Clearly, one can adopt a similar approach to deal with traffic accidents situation. Deficiency Index was developed and used in Tucson, Arizona to rank intersection operational deficiency (49). In Washington State, a severity score, which is the scaled sum of the accident and delay costs, was considered to measure effects of improvements at intersections (50). This Chapter introduces a step-by-step approach for transforming experts' opinions into mathematical forms and curves, which can be used to evaluate accident scenarios at a given intersection.

Improving traffic safety in general and at road intersections specifically may require large amounts of resources to achieve. It calls for developing more accurate estimates of actual effectiveness of safety treatments in addition to more reliable techniques for determining the dangerous intersection sites. It has been stated, "the simplest way to estimate the effectiveness

of a safety countermeasure is to compare the accidents statistics at each location *before* and *after* implementation” (20). This approach was further criticized for a number of reasons. First, there are at least three technical problems identified to hinder the reliability of this method. Those problems include random fluctuations in accident frequencies, changes in external factors, and the effect of bias by selection. In addition to these technical problems, a couple of practical issues were determined. Historically, there exists a lack of the required data due to the extreme difficulty associated with linking the data sources. The second problem has to do with the determination of the length of the evaluation period. It has been agreed that a period of three years before and three years after the implementation of safety treatment is recommended (51) Since the intersections conditions under consideration in this study are representative of a “before” case a three years data is adopted.

The proposed Intersection Safety Index (ISI) is an extension of previous approaches used in evaluating highway section safety, pavement conditions, and/or bridge safety conditions. It considers only the physical characteristics of signalized intersection. This by no means suggests that driver’s behavior and vehicle design are less important in improving intersection safety. It has been shown that significant improvements in reducing accidents and in crash survivability can be achieved by way of training/education of drivers and improved vehicle design. However a tool for estimating safety index at signalized intersections utilizing the physical characteristics can help highway officials to develop plans for physical improvements. Also, the proposed framework for signalized intersection safety along with the previously developed safety index for the highway links can be integrated together in the future in one algorithm which can be employed to define safety condition for the whole highway network.

This Chapter presents the main components of the research methodology. Figure 2.1 illustrates the research framework followed in this thesis and as seen in the figure it involves four main phases. Section 2.2 introduces the research methodology and its main components. Section 2.3 presents a brief explanation of the principles behind the proposed safety index. This is followed by a description of the Neural Network program and a summary of its application in section 2.4. Section 2.5 describes the proposed calibration methodology and the data required for the model calibration.

2.2 RESEARCH METHODOLOGY

It is important to define what “safety” means when intersection evaluation is concerned. Over the past 30 years, several research studies were carried out attempting to resolve the question of “what safety is” as far as intersections are involved. It was common to define safety in terms of count of safety, measures of accident frequency or accident rate (52). One recent definition calls for safety as the number of accidents by kind and severity expected to occur on a system or entity during a specific period. It also attempted to resolve the question of “rate” vs. “frequency” when assessing safety (51, 52, 53, 54, 55, 56). They concluded that at low traffic flows the number of single vehicle accidents is expected to be proportional to flow, thus one could use the “rate” as indicator of safety. They also, concluded that as traffic flow increases, it becomes more probable that cars will hit another car. Clearly, the single car accidents-low traffic flow proportionality cannot be expected to hold at higher flows.

The accident rate was used throughout the current study. This was done due to the following reasons:

1. The traffic flows inside most of the City of Abu Dhabi are not considered very high.

2. The studies which uses the “frequencies” instead of the “rates” were based on assumptions which are specific to two lane rural highways.
3. The changes assumed to happen were hypothetical.
4. The main objective of the study was targeting multi-vehicles crashes or accidents.

2.2.1 The Four Phases

As discussed earlier, the causes and factors contributing to road traffic accidents are complex and combine several variables. The approach suggested and followed throughout this study was designed and implemented in four phases. The first Phase dealt with the identification and understanding of the issues associated with traffic accidents at urban intersections. It consisted of four tasks or steps.

The second Phase involved 3 tasks dealing with the actual implementation of a large scale field survey, selection of urban intersections in Abu Dhabi, carrying out field measurements of the pre-determined variables and characteristics of the selected intersections, and collection of historical accidents data covering the years from 1999, 2000, and 2001. The main tasks of the third phase were carried out to deal with the collected data and information, preparation and management of the database, selection of suitable computer software and the generation of artificial conditions describing 1000 virtual intersections. The fourth and final Phase of this research included four tasks. These tasks dealt with the application of the Neural Network technique to estimate the Safety Index at each intersection and examining whether there were any correlation between the Safety Index and the reported accident data. Also, the subjective data was checked to evaluate if it can be used to estimate the same Index as estimated using the objective data of the selected urban intersections. The following subsections present more details of the main phases and tasks completed in this research.

Phase 1

The main tasks of this first Phase involved the design and implementation of a preliminary field survey to establish a “feel” for the actual causes using data and information obtained through a questionnaire distributed to traffic and highway experts. The survey consisted of two forms designed to collect experts' opinions. The two forms contain a total of 25 variables, which are expected to have effect on the safety of intersections. The 25 variables have been classified into five major groups as shown in Table 2.1. These groups are:

- Group A Pavement condition**
- Group B Geometric Design Characteristics**
- Group C Traffic Signal Characteristics**
- Group D Traffic Control Devices Conditions**
- Group E Traffic Characteristics**

In the first form each variable has been assigned four or more different rating levels. Also, the form is used to gather expert opinions to evaluate each variable in each group by estimating the total grade (out of 10 points), keeping in mind that the total grade should not exceed 10. In the second form the experts were asked to select the most important 15 variables out of the suggested 25 variables. Also, experts were asked to rank the selected 15 variables and suggest the weight by which each variable should affect the signalized intersection safety. A group of 100 experts has been selected to gather the information. In selecting the experts, a specially designed criterion was employed. The criterion stated that the expert should be a highway or traffic engineer with a minimum of five years experience in either planning and design of highways, highway construction, highway management, and/or highway research.

The forms were equally distributed between government highway engineers, highway consultant engineers, highway contractors, highway professors and researchers across the United Arab Emirates.

Task 1:

This task involves the definition of the candidate factors and variables that may affect safety at signalized intersections.

Task 2:

This task is concerned with the design and determination of the main points of the questionnaire. Two forms were designed during this step. In the first form each variable was assigned four different values (levels). The experts were asked to give a max grade of 10 for each variable where 10 means the safest value and zero means the unsafe condition. The second form was designed to let the expert select and rank the 15 most effective variables (factors) affecting safety.

Task 3:

During this task a pilot study was conducted. The first designed versions of the two forms were distributed among selected group of 10 experts. A number of meetings were conducted to explain the objectives and procedures, as well as to clarify any questions that they might have in relation to filling the forms. They were asked to fill the forms and provide comments. The results of this step were analyzed and used to carry out the actual research phases.

Task 4:

During this step, the questionnaire forms were further modified as a result of the pilot study conducted during the previous step. Experts' comments were carefully studied

and incorporated in the final questionnaire forms. Table 2.1 shows the five groups and the variables associated with each one.

Figure 2.2 demonstrates details of the first phase.

Phase 2

The main objective of the second Phase was to implement the actual field survey where 100 traffic and highway experts were selected to participate. A number of field meetings, site visits and face to face interviews were arranged and completed. The results of these activities were summarized and thoroughly analyzed. The tasks and efforts invested in this Phase are shown in Figure 2.3 and are explained below.

Task 5:

During this step, 100 experts were carefully selected following well-defined selection criteria as explained previously. The forms were distributed to them and several meetings conducted with each expert to ensure that he/she understood the main purpose of the survey. Also, the meeting involved an explanation of how to fill the forms. The distribution and collection of the forms consumed a period of more than 3 months. The results of the survey were analyzed and tabulated for further use and more analysis.

Task 6:

This task was concerned with selecting 48 signalized intersections. At each intersection, data concerning number of accidents, main geometric and operational characteristics, and the surface and physical conditions were recorded and reported.

The 48 intersections are the only intersections in Abu Dhabi monitored with CCTV cameras. Also, this step involved the selection of the artificial intelligence technique to be used. Neural Networks have been selected after detailed investigation and testing of the available techniques due to its simplicity and flexibility.

Task 7:

This step was completed after all information and measurements were reported. Also, during this step three different types of data were collected. The first is the expert opinion data or the completed forms by the 100 selected experts. The second is the selected 48 intersection characteristics data. This involved filling 48 forms similar to the first questionnaire form where the value of each variable in the form is measured in the field and documented in the form. The third data set is the accident data records for each intersection. Three years of accident data records were requested and received from the traffic police (1999, 2000, 2001). The data covers only the selected 48 intersections. A hard copy of each accident occurred within 50 m from each side of the intersection were considered intersection accident (this is consistent with the traffic police definition for intersection accident). Chapter 3 illustrates this step in more detail.

Phase 3

The main thrust of this phase was to perform the analysis and calculations with respect to the development of the Safety Index. The data and information collected in the previous phase were utilized and used to develop a set of models and relationships relating the expert opinions, objective measurements of the intersections and the accident rates. The details of Phase 3 are given in Figure 2.4. The following tasks were performed to complete Phase 3.

Task 8:

This task was designed to carry out an assessment of the importance of each variable from the expert opinion data. To do so, the collected expert opinion data was used to define the importance of variables. As mentioned previously, the experts were asked in form 2 to select and rank 15 variables out of the 25 variables, which have the highest effect on safety. Also, they were asked to provide the relative weight for each variable based on its rank, which reflect its effect on safety. A database was created to record the rank of each variable. Then the number of times each variable was selected to be the first, the second, and so on was determined. Once this is defined, the total number of times a variable was selected to be number 1 in the rank is then multiplied by a value of 15 (since there were selected 15 significant variables, the scale was graduated from 0 to 15, with 15 representing the highest grade). This reflects the cumulative importance of the variable on safety based on experts' opinion. For example, the first variable V1; Rutting was selected "first" 9 times. This means that it was assigned a weight value of 135, which is the product of 9 and 15. The value of 135 represents the importance of rutting relative to other variables based on the expert opinions. The same is repeated for the number of times that V1 is selected to be second. Thus, it would gain additional weight depending on how many times it gets multiplied by 14 and so on for other ranks. Such calculation was repeated for all 15 variables. After completing the calculations for all variables, the sum of the values assigned for each variable for all ranks given to it was then calculated. Chapters 3 and 4 will provide more explanation and details about this step.

Task 9:

This step deals with the normalization of the relative weight or importance of each variable. To do so, two processes were employed. The first is dividing the total calculated weight for each variable as explained in the previous step by the highest weight (this means the value associated with the most important variable). For example if intersection type has the highest weight, then all other variables weight would be divided by the highest weight. This will insure that the value assigned for the most important variable is equal to unity, or one and the value assigned for each of the other variables is less than unity. Since the experts were asked in form 1 to assign a grade from 0 to 10 to each variable values, where 10 means the safest value, more mathematics had to be performed to make sure that the sum of all weights do not exceed 10. To ensure that this is the case, the calculated weight assigned for each variable had to be divided by the sum of the weights then the results multiplied by 10. This normalizes the calculated weights associated with each variable and ensures that a scale of 1 to 10 is observed. Chapters 3 and 4 will present more explanation and illustration on this analysis.

Task 10:

This task involved the creation of virtual intersections to be used for testing the developed algorithm. A computer program is developed using Visual Basic to create the different combinations of intersections out of the values included in the form (i.e. using one value for rutting with the rest of the variables values). Subsequently, the second value for rutting is used with the same values utilized previously and so on until

creating all possible combinations. Those combinations represent virtual intersections. The program then used the normalized variables weights, which have been calculated as explained in the previous step to calculate the intersection safety index ISI, which is assumed to be equal to the sum of all normalized weight associated with each variable value. Also, the program is used to calculate the intersection hazard index IHI ($100 - ISI$)).

Phase 4:

The fourth and final Phase of this research was carried out to calculate the safety Index using the data and information of the 48 intersections. Also, efforts were made to correlate the calculated Indices with the accident rates and the data obtained from the expert opinions. The following tasks formed the main contribution of this phase. Figure 2.5 shows these tasks.

Task 11:

The resulting (ISI) of step 10 as well as the input (the artificial intersection combinations) can then be used to train a NNTs program. NeuroShell predictor has been selected for training. Different methods and scenarios for training the NNTs are used. Also, in this step the NNTs is trained using the 48 intersections data as input and the accident rate on each intersection as output. Chapter 4 is presenting the training process for each training scenario in detail along with the outputs of each scenario.

Task 12:

The Visual Basic program developed in step 10 is used to calculate ISI for the real life intersections data collected in task 7 (48 intersections). Also, once the NNTs

program is trained, it can then be used easily to calculate ISI for real life data using the data collected in task 7 (this means the 48 Intersections characteristics data will be the input to the trained NNTs program and the output should be the Intersection Safety Index (ISI)). Once the ISI is calculated, the IHI can be calculated easily using equation 1.

$$IHI = 100 - ISI \quad (1)$$

Task 13:

Using statistical software, the calculated ISI's using both the statistical models (or the Visual Basic program) and the trained NNTs from step 12 are correlated.

Task 14:

This task is concerned with calibrating the developed safety index to ensure the quality of the proposed intersection safety index in predicting intersection safety condition. It involves screening the accident data collected in task 7 to select only intersection related accidents. Accident rates are then calculated (accidents per 10000 vehicles using the intersection). It also, involves correlating accident rates with the Intersection Safety Index calculated in tasks 12 and 13. Good correlation indicates that the proposed Intersection Safety Index can be used to evaluate safety conditions at intersections.

2.3 THE NEED FOR A SAFETY INDEX

Highway researchers are saving no efforts to improve the level and degree of highway safety. In 1991, it was suggested by Leonard to follow a systematic approach to developing a specific Intersection Hazard Index (5). This can be achieved by using one or more approaches. One approach is to prevent or reduce accident occurrence while the other is reducing accident severity. Preventing the occurrence of an accident is a very complex task. Reducing its severity on the other hand is more possible and may be the first step solution. This can be achieved in three stages:

- a) The first stage can be achieved by recognizing the highway sections at which accidents are most likely to occur then upgrading those locations in such a way as to give drivers time and space to recover.
- b) The second stage is to work with the driver to increase his/her experience through better training and education.
- c) The third stage is to improve the crash survivability through improving the vehicle's capability of absorbing most of the crash impacts.

Mechanical engineers and motor vehicle specialist are doing admirable effort to satisfy the third step. In the last 10 years, enormous improvements in crash survivability have been achieved.

Considering any signalized intersection unsafe based on accident occurrence is not the appropriate way of judging its safety (i.e., no one can be certain that an accident is due to inappropriate characteristics of the highway section). This is because the contributing factors associated with traffic accidents interact with each other, which make every aspect of the traffic system connected to one another. It was observed *"Many factors are associated with*

every traffic accident. The word cause has largely disappeared from the literature on safety, and for good reasons. For example, suppose that on a dark rainy morning a young man argues with his wife about the purchase of a sofa, leaves the house late for work in a rage, drives his poorly maintained car too fast on a badly-designed, poorly-lit curve. Suppose further that he skids, and is killed in a crash with a truck driven by an older driver. It is of little value to say that the death was caused by the car driver's youth or maleness, the truck driver's old age, the car's bad tires, the cost of sofa, emotional stress, rain, or other factors''

(5). This complexity necessitates the need for developing an evaluation tool to be utilized in evaluating signalized intersections based on the safety features they furnish. This tool should take into consideration most significant features that may have an effect on safety. Since no quantitative or qualitative measurements are currently available for safety evaluation, the development of a safety evaluation tool, namely safety index, relies on experts' opinions is an important step. It employs artificial intelligent techniques (AI) in developing a safety index algorithm for UAE highways. Chapter 4 presents the developed tool in more details. The fact that two sets of data, one is objective and considers actual measurements and characteristics while the other is based on subjective data representing expert opinions, were utilized to develop the Safety Index increases the confidence of adopting it. Furthermore, as will be shown the developed Index has excellent correlation with the rate of accidents.

2.4 DESCRIPTION OF THE NEURAL NETWORK PROGRAMME

Neural networks mimic the human brain for problem solving process, pattern classification and making predictions or forecasts. A neural network uses previous experiences or expert knowledge to solve examples to build a system of "neurons" that makes new decisions,

classifications, and forecasts. The artificial neural network (ANN) models have the unique capabilities to reconstruct, simply by learning from the real data of traffic accidents, the contribution by which each parameter must be weighed.

Neural networks look for patterns in training sets of data, learn these patterns, and develop the ability to correctly classify new patterns or to make forecasts and predictions. Neural networks excel at problem diagnosis, decision-making, prediction, and other problems where pattern recognition is important and precise computational answers are not required.

NeuroShell Predictor has been selected for developing and training of Neural Network Program utilizing the expert opinion data. The function of the program depends on the training of data and Network Structure. Neural networks solve two major classes of problems:

Prediction: The network estimates a number from a set of input values based upon patterns the network learned from the training set of data. The NeuroShell Predictor can forecast numeric amounts such as sales, prices, workload, level, cost, scores, speed, capacity, etc.

Classification: The network groups sets input values into categories based upon patterns the network learned from the training set of data. The NeuroShell Classifier solves this type of problem. Use the NeuroShell Classifier when the outputs are categories such as (cancer, benign), (buy, sell, hold), (acidic, neutral, alkaline), (highly qualified, qualified, unqualified), (winner, loser), (product 1, product 2,..., product N), (decision 1, decision 2, , decision N).

NeuroShell Predictor has been selected to develop an algorithm relationship between deduct points' values from highway experts and safety index. Subsequently, this network will be trained using the available input expert data with known values of highway safety index obtained from a specially written, Visual Basic Program which has been designed to calculate Safety Index (SI) using developed statistical relationship as will be explained in detail in chapter 4. As was discussed earlier, this study investigates only the accidents that occurred at

intersections and not on roads connecting between these intersections. For more clarity, one of the main thrusts of this thesis was to determine the most significant variables that govern the possibility of an accident occurring at an intersection. The thesis utilizes a database of accidents collected by the police of the City of Abu Dhabi. The data and information contained in the police reports were analyzed. The variables present at the site of the accident such as visibility, conditions of the road surface, type of accident, type of vehicles involved, description of drivers, and other geometrical parameters were thoroughly reviewed for each intersection.

2.5 CALIBRATION AND VERIFICATION

To calibrate and verify the results of the developed safety index (SI), 48 signalized intersections have been selected from Abu Dhabi City network. The selection process was based on CCTV camera coverage. Two sets of data were used in the calibration and verification process. The first set covered the intersection characteristics presented in the right column of figures 2.6 and 2.7 respectively. This data was collected from Roads and Traffic Department, Abu Dhabi Municipality. Detailed description of the data collected is presented in Chapter 3.

The second set was related to traffic accidents that occurred on each signalized intersection for three years (1999, 2000, 2001). A database program has been prepared and three years of hardcopy accident forms have been collected from the traffic police at the City of Abu Dhabi. The collected hard copies have been then entered to the database program. Results of applying the new developed intersection safety algorithm on 48 intersections are compared with calculated accident rates on the same intersections. In addition, the data for the

48 intersections were utilized to train the ANN model. The resulting relationship was used to predict safety index for a case of 1000 intersections simulating possible conditions in Abu Dhabi.

Figure 2.1: Different Phases of the Research Plan

Figure 2.2: Phase 1

Figure 2.3: Phase2

Figure 2.4: Phase 3

Figure 2.5: Phase 4

Table 2.1: Intersection Safety Index Selected Variables

No	Intersection Features	No	Intersection Features
Group A: Pavement Condition		13	All Red time (Sec)
1	Rutting	14	Traffic Signal Sequence
2	Corrugation	15	Traffic Signal Position
3	Bleeding	16	Cycle Length (sec)
Group B: Geometric Design Characteristics		17	Total No. of phases
4	Intersection Type	18	Green Wave Availability
5	Free right Turn Availability	Group D: Traffic Control Devices Condition	
6	Separate left Turn Lane	19	Advanced Warning Signs for pedestrian
7	Location of Pedestrian opening	20	Marking Condition
8	Intersection angle	Group E: Traffic Characteristics	
9	Storage area for pedestrian movement in the island	21	%Heavy Vehicles
10	Sector-Parking exit upstream within 50 m	22	% Taxi
11	Sector-Parking Entrance Down stream within 50 m	23	Pedestrian Density
Group C: Traffic Signal Characteristics		24	Posted Speed (Km/h)
12	Allowed Yellow Time (Sec.)	25	Level of Service (LOS)

Safety Questionnaire

Form 1

General information

Name	Job
Qualification	Driving Experience
Have you been involved in an accident before	Yes No

Example to show how to fill the form

No	Intersection Features	Condition				Comments
1	Rutting	N.A	Low	M	High	
	Safety Grade(Max=10)	10	10	5	3	

Signalized Intersection Features Measurements

No	Intersection Features	Condition				Comments
A	2.5.1 Pavement Condition					
1	Rutting	N.A	Low	M	High	
	Safety Grade(Max=10)					
2	Corrigration	N.A	Low	M	High	
	Safety Grade(Max=10)					
3	Bleeding	N.A	Low	M	High	
	Safety Grade(Max=10)					
B	2.5.2 Geometric Design Characteristics					
4	Intersection Type	Round-about	Signalized Round-about	Single point	Double point	
	Safety Grade(Max=10)					

No	Intersection Features	Condition				Comments
5	Free right Turn Availability.	N.A	One lane	Two L.		
	Safety Grade (Max=10)					
6	Separate left Turn L (S)	One	Two	Mixed		
	Safety Grade (Max=10)					
7	No. of Legs	3	4	> 4		
	Safety Grade (Max=10)					
8	Intersection angle	90	>90			
	Safety Grade (Max=10)					
9	Storage area for pedestrian movement in the island	Not Available	5m ²	>5m ²		
	Safety Grade (Max=10)					
10	Sector-Parking exit upstream within 50 m	One leg	Two legs	Three legs	Four legs	
	Safety Grade (Max=10)					
11	Sector-Parking Entrance Down stream within 50 m	One leg	Two legs	Three legs	Four legs	
	Safety Grade (Max=10)					

No	Intersection Features	Condition				Comments
C	Traffic signal characteristics					
12	Allowed Yellow Time(Sec.) Safety Grade(Max=10)	0-5	6-10	11-15		
13	All Red time (Sec)	1	2	3		
	Safety Grade (Max=10)					
14	Traffic signal Sequence	1	2	3	4	
	Safety Grade (Max=10)					
15	Traffic signal Position	Both Sides	Cantilever	Mixed		
	Safety Grade (Max=10)					
16	Cycle Length (sec)	60	90	120	140	
	Safety Grade (Max=10)					
17	Total No. Of phases	3	4	5	>5	
	Safety Grade (Max=10)					
18	Green wave availability	available	Not available			
	Safety Grade(Max=10)					
D	Traffic control Devices cond.					
19	Advanced Warning Signs for pedestrian	N.A.	Good	Fair	Poor	
	Safety Grade (Max=10)					

No	Intersection Features	Condition						Comments
20	Marking Condition	N.A.	Good		Fair		Poor	
	Safety Grade (Max=10)							
E	Traffic signal characteristics							
21	%Heavy Vehicles	<5	5-10		11-15		>15	
	Safety Grade (Max=10)							
22	% Taxi	<10	10-20		20-30		>30	
	Safety Grade (Max=10)							
23	Pedestrian Density	Low	Med		High			
	Safety Grade (Max=10)							
24	Posted Speed (kph)	30	45		60		>60	
	Safety Grade (Max=10)							
25	Level of Service (LOS)	A	B	C	D	E	F	
	Safety Grade (Max=10)							

Figure 2.6: Questionnaire Form1

- Please rank the most effective 15 variables on safety.

No	Intersection Features	Rank	Pts	Comments
1	Rutting			
2	Corrigation			
3	Bleeding			
4	Intersection Type			
5	Free right Turn Availability			
6	Separate left Turn Lane			
7	Location of Pedestrian opening			
8	Intersection angle			
9	Storage area for pedestrian movement in the island			
10	Sector-Parking exit upstream 50 m			
11	Sector-arkingEntranceDownstream 50 m			
12	Allowed Yellow Time(Sec.)			
13	All Red time(Sec)			
14	traffic signal Sequence			
15	traffic signal Position			
16	Cycle Length(sec)			
17	Total No. Of phases			
18	Green wave availability			
19	AdvancedWarning Signs pedestrian			
20	Marking Condition			
21	%Heavy Vehicles			
22	% Taxi			
23	Pedestrian Density			
24	Posted Speed (kph)			
25	Level of Service (LOS)			

Please write down any other comments you would like to add:-

Figure 2.7: Questionnaire Form 2

3 CHAPTER 3: DATA COLLECTION

3.1 INTRODUCTION

This chapter deals with the method and procedures followed for collecting, tabulating, screening and evaluating the various types of data required to develop and calibrate a safety index algorithm for Abu Dhabi signalized intersection. (as explained in Chapter 2). It was necessary that these procedures be planned and executed carefully, because of its importance in affecting the results.

Expert opinion's data was obtained on a scale of 1-10 for 25 selected signalized intersections features and their corresponding weights. The selection of the experts was made from Government organizations, consultants, and contractors involved in planning, design and construction of highways in United Arab Emirates (UAE). Relevant forms were sent to the experts with the request to fill-in the needed information and data.

Characteristics for 48 selected intersections that are covered by CCTV-system in Abu Dhabi city have also been collected. Those characteristics represent the 25 variables in the expert opinion's forms. It was important to collect real life intersections' data for properly calibrating the developed algorithm with a view to enhancing the developed safety index. Accident data at the selected 48 signalized intersections were obtained from the hard copy of the traffic police accident reports over a three years period. These data were also used for calibration of the safety index algorithm.

3.2 DATA COLLECTION PROCEDURE

Data collection procedure was planned in such a way so as to obtain maximum as well as reliable response from the experts within the scheduled time. Subsequent discussions with the experts revealed that certain features needed further clarifications so that the experts will be able to complete the data forms correctly.

3.2.1 Design of Experts Forms

In order to design clear and easily understandable forms, it was necessary, as a first step, to design a preliminary simplified data forms. These preliminary forms were distributed to ten experts in order to get their technical opinions and notes on the design and clarity of the forms shape, contents, sequence of data, etc. After analyzing the outcome of this preliminary step, the final refined data forms were established as shown in Chapter 2 (form 1& 2), Figures 2.6 and 2.7. The letters sent to the experts included explanation of the procedure to complete the forms as described in Appendix A.

3.2.2 Experts Selection

As explained in chapter 2, expert opinions were needed to collect necessary data about the influence of different signalized intersections features on safety with particular reference to signalized intersections in Abu Dhabi city. This data was obtained on a (0-10) point scale corresponding to 25 signalized Intersection features or conditions, that were identified as having the most significant impact on safety for Abu Dhabi signalized intersections.

Selection of highway experts was given due consideration. Their selection was based on their qualifications, relevant experience as well as the availability of sufficient number of

experts to provide sufficient database for statistical and logical analysis. These experts were selected from Government Departments, Consultants, Contractors and other professionals. To secure their cooperation and participation in this work, the related organizations were contacted and objective of this research, its methodology, and timeframe were discussed in sufficient details. Persistent efforts and continued discussions with those organizations ultimately helped to achieve favorable response and participation.

3.2.3 Expert Opinion Data

Expert opinion data include highway experts' opinions regarding influence on the level of safety, when selected signalized intersection parameters were varied. This data comprise point values representing level of safety with respect to 25 carefully selected variables (see Figures 2.6 in chapter 2). Data for establishing the respective weights of the fifteen most influential parameters affecting safety was obtained from the same experts on a separate form (see Figure 2.7 chapter 2). The two forms were distributed in early January 2002 to more than 100 experts in UAE. The particulars and addresses of experts were recorded; each expert was designated with an identification number for ease of future reference and contacts. The experts were asked to return the completed data forms within a period of one month. Consequently, the data collection process took more than two months. Personal contacts were made with government departments, consultants and contractors to seek their response and cooperation in this regard.

Expert opinion data collection procedures were planned in such a way so as to obtain maximum reliable response from the experts within the scheduled time. This procedure involved distribution of forms to organizations/experts, meetings and discussions with experts, and collection of completed data forms. The data forms were distributed rather personally or through fax transmission, personal meetings and discussions were held with representatives of

these organizations to explain the objectives of the research program, and to answer their questions/queries about the required details included in the data forms. Departments, Consultants, and Contractors were requested to issue these forms to eligible engineers (experts) under their control and return them after filling-in the required data. The selection of particular highway or traffic engineers (experts) within those organizations was left to the coordinating representatives, who were briefed about the criteria for their selection. The importance and urgency of returning the data forms was also explained to them.

The completed forms were received from experts either personally or through mail. They were then reviewed and screened. Forms with rational entries and without missing data were accepted for further analysis. All incomplete or unacceptable forms were screened out after review and were returned to the respective experts with clarification as what was required to complete or correct this data. Completed forms were received back and were reviewed again prior to acceptance.

3.3 GENERAL STATISTICS

The consolidated data entered from forms 1 and 2 was statistically analyzed. Statistical parameters (average, median, standard deviation, and variance) of the collected data were calculated. This statistical analysis is briefly discussed below. For forms 1 and 2 data, the ranges of these values indicate that the experts data is statistically consistent and valid for further study and development of safety index using artificial intelligence techniques. The average values of the scale, (which is reflecting the safety importance for all the features), show reasonable and expected trends. For example average point values for Rutting, Corrugation, Bleeding, Intersection type, were (9.78, 8.72, 5.30, 2.81), (9.77, 8.43, 5.18, 2.84), (9.79, 8.61, 5.51, 3.31), and (7.31, 8.01, 7.25, 5.85), respectively, (see Table 3.1).

The values of median for various features show a good correlation with their average values. For example the values of the Average and Median for four features: Rutting (High), Corrugation (High), Bleeding (High), and Intersection type (Double pt. intersection) are: (2.81, 3.00), (2.84, 3.00), (3.31, 3.00) and (5.85, 6.00), respectively. This indicates that the values of these statistical measures are well co-related with their average values. Standard deviation of experts' opinions for most of the features is less than 3.00; the variation in the values is reasonable and acceptable.

Figure 3.1 shows the number of times each variable, was picked by the experts. As expected the percentage of trucks, Intersection type and length of yellow time have the highest effect on safety (90, 88, 84 respectively) according to expert's opinion.

Examining the rank of the variables figures presented in Appendix B, shows that Intersection type has the highest rank (Rank 1). It was selected (33) times by experts to be the most common factor affecting safety. The allowed yellow time, all red time, and traffic signal sequence were also chosen (9,7,5) times, respectively. Also, it was found that free right turn, green wave availability, level of service, and separate left turn lane were classified by experts to have the least effect on safety. They were chosen (8, 8, 8, 7) times. Figures (3.2 and 3.3) show a sample of these graphs. For example, in Figure 3.2 the intersection type (variable No.4) was picked to be the No.1 33 times and second 11 times. On the other hand, the fifth variable which is right turn availability was ranked 1st three times, 2nd three times and 3rd only twice as shown in Figure 3.2.

3.4 SIGNALIZED INTERSECTIONS CHARACTERISTICS DATA

Data for signalized intersections condition related-parameters were compiled on separate forms. These data were obtained from available plans and designs of the particular signalized intersections, physical characteristics were also verified by site visits and inspections. Meetings were also held with the departments and consultants to explain the objectives of this research. Guidelines for filling the required information were sent to the experts to avoid any omissions. Subsequently, site inspections were made to verify the data provided by experts from the departments and consulting firms. Finally, data for the selected intersections was collected for final screening and tabulation. Table 3.2 shows the number associated with each of the 25 selected variables for signalized intersection safety index estimation, and the data describing the signalized intersections characteristics for the City of Abu Dhabi is summarized in Appendix B.

3.5 ACCIDENT DATA

In order to calibrate the safety index algorithm, which will be developed from experts' opinion data, it was necessary to have detailed accident data for the selected intersections for past years. Only data for 1999, 2000, and 2001 was available and used in this study. Abu Dhabi traffic police department developed a very detailed accident data collection form. Appendix A represents a sample of the accident data collection form. Several meetings have been conducted with representative from various sections in the traffic police department in order to collect the accident data in a softcopy format. However, it was concluded that extracting the accident data from the available Abu Dhabi traffic police department computerized database

would not be an easy task. Based on this finding a decision was made to develop a computer program, and to enter all the accident reports, which occurred in Abu Dhabi intersections during the past three years. The data were screened to only select accident data for the signalized intersections. It took one month for a team of three persons to enter more than 1100 injury accident reports (each accident report inc 95 fields).

Statistical analysis for the data was carried out and the number of accidents for each of the selected intersections, type of accident, number of injuries, distribution of these accidents during the day and during days of the week, months of the year, and drivers experience were recorded. Figure 3.4 through 3.9 show typical results.

It is obvious from these figures that most of these accidents were collision type, and most of them occurred during the morning or night hours. Figures 3.7 and 3.8 show that Monday is the day of the week, which has the highest percentage of accidents occurrence. Also, February and November for year 2001 appeared to have the highest percentage of accidents compared with other months of the year. Figure 3.9 shows that the higher the driving experiences the lesser the accidents committed. The data in Figure 3.4 showed that collision was the dominant mode of accidents at intersections. Also, it is interesting to note that while the number of accidents in 2001 was less than in 2000, it was still 20% higher than those in 1999. The increase may be explained by expansion and new improvements of the road networks in Abu Dhabi in 1999-2000. As a result of the sudden increase in number of accidents, the police Department issued a number of strict regulations and increased the number of their road patrols, which may explain the reduction, reported in 2001. Figure 3.5 shows the number of injuries reported during the years of the survey, 1999, 2000 and 2001. It is important to note that as the number of accidents increased the number of injured people also increased. Since the data was collected for the same intersections over the same period of

time, one can conclude that under the conditions observed in Abu Dhabi the utilization of the rate of accidents would in this case lead to the same conclusion as the use of the accident frequency.

The results shown in figure 3.6 showed that accidents are more likely to occur during the morning and late hours of the day. The data for year of 1999 showed that accidents were higher during the night when compared to those occurring during day hours. This observation may have to do with the changes described above.

Figures 3.7 suggested that accidents are higher on Saturdays and Mondays of the week. It should be noted that Saturday is the starting day of the working week in the City of Abu Dhabi while Thursday and Friday are the holidays. Figure 3.8 gives typical results for the monthly distribution of accidents over the study period. It should be noted that major events follow a lunar Calendar in UAE, which may help explain the data in that figure. Finally the accidents appear to have a very strong correlation with drivers' experience as shown in Figure 3.9. Also, the data in Figure 3.9 suggested a potential loss due to the fact that most of the accidents were reported to occur within the group with the younger age.

3.6 SUMMARY

This Chapter dealt with the data and results of the survey conducted during the course of this thesis. The first part identified a number of variables based on the interviews with selected number of highway experts. The results showed that out of a list of possible 25 variables 15 could play a major role in accidents occurrence at signalized intersections.

The second part of the data required for this investigation was carried out through actual measurements taken in the field. Forty eight intersections were selected and identified as the "candidates" for the study. The data included quantification for the variables used in the

experts' opinions survey. The third part of the data was based on gathering actual accidents information provided by Abu Dhabi Police Department. The data covers a period of three years from 1999 to 2001. The study was limited to 48 signalized intersections within the City of Abu Dhabi. The reported data along with the results of the interviews represent the main body of information and input necessary for the next phase.

Figure 3.1: Variables Selection Frequency

Figure 3.2: Intersection Type Variable No. 4

Figure 3.3: Free Right Turn Availability Variable No.5

Figure 3.4: Percentage of Accidents at AD City Signalized Intersections

Figure 3.5: Number of Injuries at Signalized Intersections in AD City

Figure 3.6: Percentage Of Accidents At AD City Signalized Intersections Per Time Of The Day

Figure 3.7: Percentage Of Accidents At AD City Signalized Intersections Per Day Of Week

Figure 3.8: Percentage Of Accidents At AD City Signalized Intersections Per Month Of Year

Figure 3.9: Percentage Of Accidents At AD City Signalized Intersections Per Driver

Table 3.1: Sample Statistical Data Analysis

	Rutting				Corrigration				Bleeding				Intersection Type			
	N.a	low	M	High	N.a	low	M	High	N.a	low	M	High	R.A.	SRA	Single Pt.Ints	Double Pt.Ints
Min	0.00	6.00	3.00	0.00	0.00	6.00	2.00	0.00	0.00	3.00	1.00	0.00	0.00	0.00	3.00	1.00
Med	10.00	9.00	5.00	3.00	10.00	8.00	5.00	3.00	10.00	9.00	5.00	3.00	8.00	8.00	7.00	6.00
Stdv	1.06	1.19	1.17	1.68	1.09	1.23	1.28	1.71	1.11	1.30	1.56	1.80	1.82	1.90	1.75	2.28
Var.	1.13	1.42	1.37	2.81	1.19	1.52	1.64	2.94	1.23	1.68	2.44	3.24	3.30	3.62	3.07	5.21
Max	10.00	10.00	9.00	10.00	10.00	10.00	9.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
average	9.78	8.72	5.30	2.81	9.77	8.43	5.18	2.84	9.79	8.61	5.51	3.31	7.31	8.01	7.25	5.85

Table 3.2: Variables and Its Associated Numbers

Number	Variable Name	Number	Variable Name
1	Rutting	13	All Red time(Sec)
2	Corrigation	14	traffic signal Sequence
3	Bleeding	15	traffic signal Position
4	Intersection Type	16	Cycle Length(sec)
5	Free right Turn Availability	17	Total No. Of phases
6	Separate left Turn Lane	18	Green wave availability
7	Location of Pedestrian opening	19	Advanced Warning Signs for pedestrian
8	Intersection angle	20	Marking Condition
9	Storage area for ped. movement in the island	21	%Heavy Vehicles
10	Sector-Parking exit upstream within 50 m	22	% Taxi
11	Sector-Parking Entrance Down stream within 50 m	23	Pedisttrain Density
12	Allowed Yellow Time(Sec.)	24	Posted Speed (kph)
25	Level of Service		

4 CHAPTER 4: INTERSECTION SAFETY INDEX MODEL DEVELOPMENT

4.1 INTRODUCTION

In this chapter a detailed description of the developed intersection safety index model is presented. As was mentioned earlier in Chapter 2, the model development process required four phases including 14 different tasks. Chapter 3 presented the tasks conducted up to and including step 7. This mainly covered one module of the overall development process, the data collection module. In this Chapter three other modules, the rest of the model development process, are explained in details. The first of these three modules deals with estimating the effect or contribution of each variable to the safety condition of a signalized intersection utilizing expert-opinion data. The second component is the programming and Neural Network Module. Finally, the last module is the Calibration module. Figure 4.1 represents the four model development process modules and the interrelationship between these modules. This Chapter concentrates on the second and the third modules. Chapter 5 focuses on the fourth module.

4.2 MODULE 2: ESTIMATING VARIABLES EFFECTS

To find the contribution of each of the 25 selected variables to the overall safety condition at signalized intersections, the collected expert-opinion data has been employed and the following steps have been conducted.

1. The experts were asked to define the most important 15 variables from a safety point of view. They were also asked to provide the relative weight for each variable based on its rank, reflecting its importance. A database was then created to record the rank each expert has given for each variable. Table 4.1 is an extract of the collected expert

opinion database, which shows the variables ranking. For time and economic constraints it was decided that using 25 variables will represent a very difficult task. Therefore, it was agreed that 15 variables will be a reasonable indicator and at the same time are within the resources available for the study.

2. The second step is to define the number of times each variable has been selected to be first, second, and so on. Once this is determined, the total number of times the variable has been selected to be number 1 in the rank is multiplied by a value of 15 (the value of 15 represents the maximum since experts have been asked to select the most effective 15 variables). This reflects the importance of the variable from the expert's point of view. For example, V_1 (rutting has been selected number 1 for 9 times). For example, if 9 is multiplied by 15 the result will be 135 and so on. The same is repeated for the number of times V_1 is selected to be the second where it is multiplied by 14. Table 4.2 shows the output of this step. The table has been extracted from the database.
3. The third step is to find the summation of the value assigned for each variable for all ranks given to it. The calculated values for V_1 through V_4 are shown in the last row of Table 4.2. Table 4.3 presents the summary of the calculated sum for each variable. Once the total has been calculated, the variable with the highest total should be identified and the value of such total should be utilized to normalize all variables, as will be explained in the next step.
4. To normalize the relative weight for each variable two different processes are employed. The first is dividing the total assigned value for each variable as presented in the previous table by the highest value. In the present case the highest is the value assigned for intersection type variable number 4 (1002). This will produce normalized values with a maximum value of 1 for variable 4. Table 4.4 shows the results of these

calculations. As it is shown in the table the highest value in the table now is 1 and the total sum is 13.09. To have it in a scale from 1 to 10, a simple transformation is required to ensure that the summation of all values in the table is equal to 10. This can easily be done by dividing each entry by 13.09 then multiply by 10. The results are presented in the last column in Table 4.4.

5. Once the normalized weights presented in Table 4.4 are calculated, the data from the questionnaire form 1, where each variable value was graded by the expert from zero to ten, can now be used to calculate, for each variable, the average limit value or level based on all experts. For example the average value given to variable 1 level 1 is 9.78. This value is then multiplied by the normalized weight for variable number 1 in Table 4.4 above. The result is the weighted safety grades as shown in table 4.5.

The last row in Table 4.5 represents the final safety grades and it will be used in the calculations for the 48 intersections. Table 4.6 shows some of the safety grades associated with the selected 48 intersections.

4.3 MODULE 3: PROGRAMMING AND NEURAL NETWORK

4.3.1 Artificial Intersections Creation

The first step in this module is concerned with using a computer program to create virtual intersections. The intersections were generated from assuming several combinations of different values for the 25 selected variables. They simulate intersections similar to those considered for intersection safety index estimation. Visual Basic has been used in developing the program. The main reason for creating these combinations is to use more intersections as an artificial data set to train the neural network program. Since generating all possible combinations using the 25 variables with 4 and 5 different levels for each variable will lead to

a very large number of intersections (24,300,000), it was decided to generate only 1,000 combinations. However, it should be noted that the written computer program could handle any required number of combinations. Appendix B contains the program source code of the developed program. The program was designed to create artificial different intersections as follows.

1. The program starts by reading the stored data from the "*Input*" file. This file consists of 5 different range-values for each one of the 25 variables. The program then declares integer variable, calls it "*I*" and initializes this variable to 1.
2. A random combination from the "*input*" file is created, considering the 1000 random combinations.
3. The combination is saved into a file called "*output*" file.
4. The process has to be repeated 1000 times.
5. Once the program finishes creating the required combinations, it shows a message and stop.

4.3.2 Intersection Safety Index Calculation

A special program has been designed and written to calculate intersection safety index for both the real life intersections as well as the 1000 artificial intersections. The program used the safety grade points presented in Table 4.5 as a look up table to estimate intersection safety index. Intersection safety index has been calculated using equation 4.1. The equation shows that the safety index of an intersection equal the summation of the grade points for the selected

25 variables. Also, the program has been used to calculate Intersection Hazardous Index using equation 4.2. The calculations have been conducted for both the real life signalized intersections (48 signalized intersections) and the 1000 artificial intersections. Table 4.8 shows the safety grade point for each variable, the intersection safety index (ISI), and the intersection hazardous index (IHI).

$$\text{Intersection safety Index} = \sum_{i=1}^{i=25} \text{Safety Grade Point} \quad (4.1)$$

$$\text{Intersection Hazardous Index} = 100 - \sum_{i=1}^{i=25} \text{safety Grade Point} \quad (4.2)$$

4.3.3 Training The Neural Network

This section presents the process followed to train the selected neural network program in order to use it later for predicting the intersection hazardous index. To train the selected neural network program, three different training data sets have been used. The first represents using the real life 48 intersections variable values and its associated calculated IHI as a training set. The trained network is then used to predict hazardous index (IHI) for the artificial intersections. In the second training process the same input variables used in the first training set have been used for training, however accident rates have been used as the associated output values. After training, the trained network can then be used to predict accident rates for the 1000 artificial intersections. In the third training process the input variables for the artificial intersections have been used for training along with its associated calculated IHIs. The trained model is then used to predict IHIs for the 48 real life intersections. In the following, a general discussion about the selected network capabilities is presented, followed by a presentation of the results of each training process.

A. NeuroShell Capabilities

“NeuroShell Predictor” was selected and trained. It is an intelligent program, which is capable of developing a relationship base between the inputs and outputs. After training, the program can be used to estimate the output values for any new data set. The model learning process has been employed for training NeuroShell. This aims at learning the patterns in the training data in order to make predictions. The exact process varies according to the selected training strategy. The NeuroShell Predictor allows a choice between two different training strategies, as follows:

1. *Neural*: Uses a neural net, which dynamically grows hidden neurons to build a model, which generalizes well, and trains fast. When applying the trained network to new data, the Neural Training Strategy may give a better result on “noisy data” that is somewhat dissimilar from the data used to train the network.
2. *Genetic*: The Genetic Training Strategy trains slowly. When applying the trained network to new data, the Genetic Training Strategy gets better results when the new data is similar to the training data. It also works better when the training data is sparse.

In this research, the Neural strategy has been utilized in training the program. The main reason for choosing this strategy is its ability to train the net faster. Figure 4.2 shows the start menu for the NeuroShell predictor.

Figure 4.3 shows one of the most important output screens in the NeuroShell predictor.

In the following text each item shown in this screen is explained:

Inputs: Lists the number of inputs for the model. This number is set when inputs and output are selected.

Output: Lists the column name of the predicted output variable.

Number of hidden neurons trained: Training the net by adding hidden neurons until the net is able to make good predictions. The displayed number is the total number of hidden neurons that have been added while the net is learning.

Optimal number of hidden neurons: This is the number of hidden neurons that best solve the prediction problem. This is the number of hidden neurons that will be used when applying the trained network to a data file.

R-squared: The value for R-squared ranges from 0 to 1. The closer the value is to 1, the better the net is able to make predictions. The net is not able to make good predictions if the value is near 0. Refer to R-Squared for details.

Average Error: This is the absolute value of the actual values minus the predicted values. This value will be highlighted, which indicates the objective of the network to minimize the average error.

Correlation Coefficient(r): This is a measure of how the actual and predicted values correlate to each other in terms of direction (i.e., when the actual value increases, the predicted value increase and vice versa). This is NOT a measure of magnitude. The values for r range from 0 to 1. The closer the correlation value is to 1, the more correlated are the actual and predicted values are.

Relative importance of inputs: Displays a list of inputs and a corresponding number, which indicates the importance of the variable in predicting the output. The higher the number, the more important that variable is in predicting the output. Selecting Importance of Inputs as one of the Graphic Screen options may also display the relative importance of inputs in a bar chart. The relative importance numbers range from 0 to 1, and they are "normalized" so that for all inputs they add up to approximately 1.

Therefore, one may think of these numbers as a percent contribution to the model of the respective inputs.

Mse: A statistical measure of the differences between the values of the outputs in the training set and the output values the network is predicting. This is the mean over all patterns in the file of the square of the actual value minus the predicted value, i.e., the mean of $\{(actual - predicted) / 2\}$. The errors are squared to penalize the larger errors and to cancel the effect of the positive and negative values of the differences.

Rmse: This is the square root of the Mse.

%Age in Range: This is the percent of network answers that are within the user-specified percentage of the actual answers used to train the network. The percentage is set in the Advanced Options menu (Options, Settings, Advanced Neural, Tolerance to compute percentage in range).

Percentage Complete: This value represents the percentage of the current Generation of individual sets of importance values evaluated by the network.

Generations: Displays the total number of generations that have been created since learning began.

Generations since last improvement: Displays the number of generations that have been created since an improvement in network performance. A threshold may be selected for maximum number of generations without improvement from the Settings screen. The lower the threshold, the shorter the training time.

Unpredictable Patterns: Displays the total number of patterns that the genetic method was unable to predict a value for. The Genetic method will never predict an output greater than

the greatest output with which it was trained. It will also never predict an output less than the smallest output with which it was trained.

When training a network, the following messages may be displayed on the screen; "No further training is possible unless more rows of different examples are provided" or "Training has stopped because model cannot be improved any more. Try to add more data rows." These messages may be displayed because the number of training rows relative to the number of inputs and hidden neurons that have been added is too small to permit further training without over fitting. The training algorithm has trained the net properly, but decided it didn't want to continue and perhaps over fit the data. The results are fine and may be used with confidence, however, if more rows can be obtained to train data, better model will be reached. But in this case 1000 combinations are taken which are more than enough to get a well trained network. The value, which has been selected, as the Genetic Optimization Goal will then be displayed. The selection of a graphics screen can be changed as learning progresses by clicking buttons. Figure 4.3 shows the relative importance of factors. Such output can be used to determine which factor has more contribution to intersection safety. Also, it tells the effects of the variables used relative to each other. Figure 4.4 demonstrates the network prediction capabilities. It shows the predicted outputs relative to the actual outputs (ISI or IHI) that have been used for the training. On the other hand, Figure 4.5 demonstrates the progress of the learning and training process. The progress of learning can be determined using the status signal, (green light indicates the network is learning. The yellow light means training has been interrupted. The red light indicates training is complete). Figure 4.6 presents the procedure, which has been followed to train the NeuroShell Predictor for calculating Safety Index. Clicking on the stop sign interrupts training. An option is available to save the net, and to load

the same later as an existing network to train a new data or to continue training the net if the Genetic Training Strategy is selected.

Figure 4.1: Safety Index Model Components

Figure 4.2: Neuroshell Predictor Program Start Menu

Figure 4.3: The Relative Importance Of Inputs

Figure 4.4: Actual Predicted Graphic Display

Figure 4.5: The Learning Graphic Display

Figure 4.6: The "Neuroshell Predictor" Flow Chart

Table 4.1: Samples Of Variables Ranks

Expert Number	Rutting	Corrugation	Bleeding	Intersection Type
1				8
2	14	8		15
3	1	2		
4				10
5				1
6				10
7				
8				1
9	6		14	
10	5	6	7	1
11	2	3	1	4
12	5	4	3	8

Table 4.2: Variables Weighting Ranks

Variable Rank	Weight	V1	V2	V3	V4
1	15	135	0	45	495
2	14	56	56	70	154
3	13	65	117	39	52
4	12	132	24	84	72
5	11	22	22	33	66
6	10	50	40	30	10
7	9	36	27	36	27
8	8	16	48	24	64
9	7	42	42	14	7
10	6	42	18	42	24
11	5	0	10	30	10
12	4	20	28	8	8
13	3	18	3	6	6
14	2	12	8	10	4
15	1	1	2	4	3
		647	445	475	1002

Table 4.3: Summation Of Values Assigned For Each For Each Variable

Variable Number	Calculated Sum
V ₄	1002
V ₁₂	755
V ₂₁	699
V ₁₄	657
V ₁	647
V ₁₃	619
V ₇	618
V ₈	603
V ₂₀	584
V ₂₄	575
V ₂₃	573
V ₁₅	501
V ₉	500
V ₁₉	491
V ₃	475
V ₆	475
V ₂₅	475
V ₂₂	454
V ₅	452
V ₂	445
V ₁₀	345
V ₁₆	335
V ₁₈	308
V ₁₇	277
V ₁₁	254

Table 4.4: Normalized Variables Weights

Variable Number	Calculated Sum	Weight	After normalization
v ₄	1002	1	0.8
v ₁₂	755	0.75	0.6
v ₂₁	699	0.69	0.5
v ₁₄	657	0.65	0.5
V ₁	647	0.64	0.5
V ₁₃	619	0.61	0.5
V ₇	618	0.61	0.5
V ₈	603	0.60	0.5
V ₂₀	584	0.58	0.4
V ₂₄	575	0.57	0.4
V ₂₃	573	0.57	0.4
V ₁₅	501	0.50	0.4
V ₉	500	0.49	0.4
V ₁₉	491	0.49	0.4
V ₃	475	0.47	0.4
V ₆	475	0.47	0.4
V ₂₅	475	0.47	0.4
V ₂₂	454	0.45	0.3
V ₅	452	0.45	0.3
V ₂	445	0.44	0.3
V ₁₀	345	0.34	0.3
V ₁₆	335	0.33	0.3
V ₁₈	308	0.31	0.2
V ₁₇	277	0.27	0.2
V ₁₁	254	0.25	0.2
	Summation	13.09	10

Table 4.5: Sample of the Safety Grades

Expert Number	Pavement Condition											
	Rutting				Corrigation				Bleeding			
	N.a	low	M	High	N.a	Low	M	High	N.a	low	M	High
1	10	9	5	2	10	6	4	2	10	9	5	3
2	10	9	6	3	10	8	4	2	10	9	7	5
3	10	6	4	2	10	7	5	2	10	8	6	4
4	10	10	5	3	10	8	5	3	10	8	5	3
Average	9.78	8.72	5.30	2.81	9.77	8.43	5.18	2.84	9.79	8.61	5.51	3.31
Weight	0.49	0.49	0.49	0.49	0.34	0.34	0.34	0.34	0.36	0.36	0.36	0.36
Safety Grade	4.79	4.27	2.60	1.38	3.32	2.87	1.76	0.97	3.52	3.10	1.98	1.19

Table 4.6: Safety Grade Values for the Selected 48 Intersections

Intersection Number	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆
41C	4.79	3.32	3.52	5.51	2.57	2.73
41B	4.79	3.32	3.52	5.51	2.57	1.78
41A	4.79	3.32	3.52	5.51	2.57	1.78
41	4.79	3.32	3.52	4.45	2.68	2.73
38C	4.79	3.32	3.52	5.51	2.57	1.78
39	4.27	3.32	3.10	5.51	2.68	3.07
38	4.27	3.32	3.10	5.51	2.68	3.07
12	4.79	3.32	3.52	5.51	2.68	3.07
9	4.27	3.32	3.52	5.51	2.68	3.07
11	4.27	3.32	3.52	5.51	2.68	3.07
11A	2.60	2.87	3.10	5.51	2.68	2.73
36	4.79	3.32	3.52	5.51	2.68	2.73
44	2.60	1.76	1.98	4.45	2.68	3.07
56	4.79	3.32	3.52	5.51	2.68	3.07

Table 4.7: Safety and Hazardous Indices Calculation

IP	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆	V ₇	V ₈	V ₉	V ₁₀	V ₁₁	V ₁₂	V ₁₃	V ₁₄	V ₁₅	V ₁₆	V ₁₇	V ₁₈	V ₁₉	V ₂₀	V ₂₁	V ₂₂	V ₂₃	V ₂₄	V ₂₅	ISI	IHI
41C	4.8	3.3	3.5	5.5	2.6	2.7	4.0	3.0	3.3	2.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	4.0	2.7	3.1	3.3	2.5	73.0	27.0
41B	4.8	3.3	3.5	5.5	2.6	1.8	4.0	3.0	1.3	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	4.0	2.7	3.1	3.3	2.1	68.7	31.3
41A	4.8	3.3	3.5	5.5	2.6	1.8	4.0	3.0	3.3	2.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	4.0	1.3	2.0	2.2	2.1	68.5	31.5
41	4.8	3.3	3.5	4.5	2.7	2.7	4.0	3.0	3.3	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	4.0	1.3	2.0	2.2	2.1	67.1	32.9
38C	4.8	3.3	3.5	5.5	2.6	1.8	4.0	4.2	3.3	2.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	4.0	1.3	2.0	3.3	2.5	71.3	28.7
39	4.3	3.3	3.1	5.5	2.7	3.1	3.5	4.2	3.3	2.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	4.0	1.3	2.0	2.2	2.9	70.5	29.5
38	4.3	3.3	3.1	5.5	2.7	3.1	3.5	4.2	3.3	1.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	4.0	1.3	2.0	3.3	2.9	70.6	29.4
12	4.8	3.3	3.5	5.5	2.7	3.1	4.0	3.0	3.3	1.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	1.3	2.0	3.3	1.7	70.3	29.7
9	4.3	3.3	3.5	5.5	2.7	3.1	3.5	4.2	2.6	2.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	1.3	2.0	2.2	1.2	69.1	30.9
11	4.3	3.3	3.5	5.5	2.7	3.1	3.5	4.2	2.6	2.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	1.3	2.0	3.3	1.7	70.9	29.1
11A	2.6	2.9	3.1	5.5	2.7	2.7	3.5	4.2	2.6	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	2.7	2.0	3.3	1.7	67.8	32.2
36	4.8	3.3	3.5	5.5	2.7	2.7	3.5	4.2	3.3	2.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	2.7	3.1	3.3	1.2	73.8	26.2
44	2.6	1.8	2.0	4.5	2.7	3.1	3.5	4.2	3.3	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	2.7	3.1	3.3	1.2	66.2	33.8
56	4.8	3.3	3.5	5.5	2.7	3.1	4.0	3.0	2.6	2.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	1.3	2.0	2.2	1.7	70.0	30.0
13	4.3	2.9	3.5	5.5	2.7	3.1	3.5	4.2	2.6	2.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	1.3	2.0	3.5	2.5	72.3	27.7
17	4.3	2.9	3.5	5.5	2.7	3.1	3.5	4.2	2.6	2.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	1.3	2.0	3.5	2.1	72.1	27.9
10	4.8	3.3	3.5	5.5	2.7	3.1	3.5	4.2	2.6	2.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	1.3	2.0	3.3	1.7	72.3	27.8
11C	4.8	3.3	3.5	5.5	2.7	1.8	4.0	4.2	2.6	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	1.3	2.0	3.3	1.7	69.1	30.9
35	4.8	3.3	3.5	5.5	2.7	3.1	3.5	4.2	2.6	1.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	2.1	2.0	3.3	1.7	71.2	28.8
44A	4.8	3.3	3.5	5.5	2.7	3.1	4.0	4.2	2.6	1.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	1.3	3.1	3.3	1.7	72.1	27.9
14	4.8	3.3	3.5	5.5	2.7	3.1	3.5	4.2	2.6	2.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	1.3	2.0	3.5	2.1	72.9	27.1
18	4.8	1.0	3.5	5.5	2.7	3.1	3.5	4.2	2.6	1.7	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	1.3	2.0	3.5	2.1	70.4	29.6
10A	2.6	1.0	3.1	5.5	2.7	3.1	3.5	4.2	2.6	1.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	1.3	2.0	3.3	1.2	65.9	34.1
35A	4.8	2.9	3.5	5.5	2.7	2.7	3.5	4.2	2.6	2.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	1.3	2.0	3.3	1.2	70.0	30.0
43A	2.6	1.0	3.5	5.5	2.7	2.7	3.5	4.2	2.6	1.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	2.1	2.0	3.3	1.2	65.9	34.1

IP	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆	V ₇	V ₈	V ₉	V ₁₀	V ₁₁	V ₁₂	V ₁₃	V ₁₄	V ₁₅	V ₁₆	V ₁₇	V ₁₈	V ₁₉	V ₂₀	V ₂₁	V ₂₂	V ₂₃	V ₂₄	V ₂₅	ISI	IHI
15	4.8	3.3	3.5	5.5	2.7	3.1	3.5	4.2	2.6	2.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	2.1	2.0	3.5	2.5	74.2	25.8
19.0	4.8	3.3	3.1	5.5	2.7	3.1	4.0	4.2	2.6	1.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	1.3	2.0	3.5	2.1	72.2	27.8
16.0	4.8	1.8	3.1	6.1	2.6	1.8	3.5	4.2	3.3	1.7	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	2.1	2.0	3.5	2.1	70.4	29.6
20.0	2.6	3.3	3.5	4.5	2.7	2.7	3.5	4.2	3.3	1.7	1.0	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	1.3	2.0	3.5	2.1	68.5	31.5
1.0	4.8	3.3	3.5	5.5	2.7	2.7	3.5	4.2	3.3	1.7	1.0	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	1.3	2.0	3.3	1.2	71.6	28.4
1E	4.8	3.3	3.5	4.5	2.7	2.7	3.5	4.2	2.6	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	2.1	2.0	3.3	1.2	69.7	30.3
43.0	4.8	3.3	3.5	5.5	2.7	3.1	3.5	4.2	3.3	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	2.1	2.0	3.3	1.2	70.8	29.2
47.0	4.3	3.3	3.1	5.5	2.7	3.1	3.5	4.2	2.6	2.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	2.1	2.0	3.3	1.7	71.0	29.0
49.0	4.8	3.3	3.5	5.5	2.7	3.1	3.5	4.2	2.6	2.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	2.1	2.0	3.3	1.2	71.7	28.3
49A	2.6	1.8	3.5	5.5	2.7	3.1	4.0	4.2	2.6	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	2.1	2.0	3.3	1.2	66.9	33.1
70.0	1.4	1.8	3.1	4.5	2.7	3.1	3.5	4.2	3.3	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	1.3	2.0	3.3	1.2	63.7	36.3
69.0	4.3	3.3	2.0	5.5	2.7	3.1	4.0	4.2	2.6	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	2.7	2.0	3.3	1.2	69.2	30.8
2.0	4.3	3.3	3.5	5.5	2.7	3.1	4.0	4.2	2.6	2.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	1.3	2.0	2.2	2.1	71.8	28.2
4.0	2.6	3.3	2.0	5.5	2.6	3.1	3.5	4.2	2.6	1.7	1.0	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	5.0	2.1	2.0	3.3	1.2	68.1	31.9
26.0	4.8	3.3	3.5	5.5	2.6	3.1	4.0	4.2	2.6	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	4.0	2.7	2.0	3.3	1.7	71.0	29.0
7A	4.3	3.3	3.5	5.5	2.7	2.7	4.0	4.2	2.6	1.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	4.0	2.7	2.0	2.2	2.1	70.0	30.0
5A	4.8	3.3	3.5	5.5	2.7	3.1	3.5	4.2	2.6	2.1	1.3	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	4.0	1.3	2.0	2.2	1.7	69.4	30.6
63.0	4.8	3.3	3.5	5.5	2.7	3.1	3.5	4.2	2.6	1.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	5.0	2.7	2.0	2.2	2.9	72.3	27.7
60B	4.8	3.3	3.5	5.5	2.7	3.1	4.0	4.2	2.6	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	5.0	2.7	2.0	3.3	2.9	73.3	26.7
118	4.8	3.3	3.5	5.5	2.7	3.1	3.5	4.2	2.6	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	5.0	2.7	2.0	3.3	2.5	72.4	27.6
57R	4.8	3.3	3.5	5.5	2.7	2.7	3.5	4.2	2.6	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	1.4	1.0	1.6	4.0	2.7	2.0	3.3	2.1	70.7	29.3
42P	4.8	3.3	3.5	5.5	2.7	3.1	3.5	4.2	2.6	1.1	1.5	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	1.3	2.0	3.3	2.1	71.0	29.1
135	4.8	3.3	3.5	4.5	2.7	3.1	3.5	4.2	3.3	1.1	0.9	4.1	2.7	4.2	3.0	2.0	1.7	2.1	1.0	1.6	4.0	1.3	2.0	3.3	2.1	70.0	30.0

5 CHAPTER 5: NEURAL NETWORKS RESULTS

5.1 THE CASE of 48 INTERSECTIONS (Case 1)

As indicated previously the data for the 48 intersections and its computed IHI are used for training the selected network. Figure 5.1 shows the relative weight of factors resulted in this stage. The results shown in the Figure indicate that variables 1 (rutting), 2 (corrugation) and 22 (percentage of taxies) are found to be the most contributing to intersection hazardous. On the other hand, the figure shows that variable 5 (free right turn availability) has the least effect on the Intersection Hazard Index. These results stand to reason. Rutting and other surface deformation within the intersection zone may cause problems with steering during early hours of the morning especially when the asphalt is wet. The effect of the taxi population on the accident or safety index can be explained by the fact that most of the taxi drivers in Abu Dhabi are from countries which Arabic language is not their mother tongue. Also, many of the drivers come from poor backgrounds with minimum levels of education. In contrast, the fact that free right turn contributes the least to the IHI is in agreement with engineering judgment. Right turns are known to cause the least amount of accidents due to the fact that they are usually made with care and after careful examination of the traffic flow.

Figure 5.2 shows the correlation between the predicted IHI by the trained network and the calculated values. Examining the figure, one will find that the trained network produces IHI that are very well correlated to the calculated IHI. The high correlation is indicated by the 45- degree straight-line relationship. This indicates that the trained model can be used to predict IHI with high degree of accuracy.

5.2 APPLICATION OF THE TRAINED NN MODEL (Case 2)

During this calibration case, the same input data used in case 1 has been reused in this case. The actual accident rates for the selected 48 intersections have been used as the output. The same procedure was then used to train the neural network. The main advantages of the selected network is its capabilities to screen the trained data set and remove the input variables that don't appear to have significant contribution to the output. Figure 5.3 presents the screen produced by the network, which test the variables to be removed by the network. According to the figure, the following variables have no significant contribution to accident rates:

- Variable 12 (Allowed Yellow Time)
- Variable 13 (All red time)
- Variable 14 (Traffic Signal Sequence)
- Variable 15 (traffic Signal Position)
- Variable 16 (Cycle Length)
- Variable 17 (Total Number of Phases)
- Variable 19 (Availability of Advanced Warning Signs for Pedestrian)

Similar to Figure 5.3, Figure 5.4 presents the relative importance of variables in predicting accident rates. It shows that variables 1 (rutting) and 5 (free right turn availability) have the highest contribution to accident rates. This is followed by variable 25 (intersection level of service). It also shows that variable 10 (sector parking exit upstream of the intersection) has very small contribution to accident rates. However, it is worth mentioning that these results

may be deceiving since it may be affected by the variability of the data (most of the intersections have similar characteristics). Also, one may argue that some of these variables are considered as part of other variables shown to be important in the analysis.

The network was able to produce very high correlation between the actual and predicted accident rates. Figure 5.5 shows an output screen that illustrates the general statistics resulted from the network. It shows that the Network can predict about 95% of the contributed factors.

5.3 THE CASE OF 1000 SIMULATED INTERSECTIONS (Case 3)

In this training case, the artificial 1000 intersections and their associated calculated IHI have been fed to the network for training. It is well known that using more data in training the network will improve the prediction capability of the trained network. This would make the trained network more reliable. Figure 5.6 shows the relative importance of the variables resulting from this training case. It can be seen that the results are consistent with the results obtained from case 1. As can be seen from Figure 5.6, the order of the first 5 variables is identical to that obtained from Figure 5.1 of case 1. Figures 5.7 and 5.8 demonstrate the prediction capability of the trained network. These results are very encouraging since they lend themselves to intersections conditions, which may exist either over a longer period of time or within a larger city.

5.4 USING THE TRAINED NEURAL NETWORK TO PREDICT HAZARD INDEX

The results of the three training cases presented in this Chapter produced three trained neural networks that can be easily used as engineering tool for prediction. It also, indicated that

training case three (3) is the most powerful case for predicting IHI. In this section the network trained in case three is used to predict IHI for the 48 selected urban signalized intersections. The values of 25 input variables shown in Table 4.8 have been entered to the trained neural network. The network used the hidden relationships between the input values and the output values resulting from the training process to estimate IHI for the real life 48 intersections. The learning procedure continued to train the program using 80 hidden neurons, in different steps. Various correlations between input parameters and output results can be examined to study the relative importance and significance of these factors and their importance on intersection safety. While the *NeuroShell Predictor* is used and as neurons are added to enhance this training process, the changes in the graphs for “relative importance of inputs”, and values of statistical parameters are observed. The relative importance of inputs is refined to more and more precision as the calculation progresses. The final results obtained at the end of calculations are shown in Figure 5.9. Also, the network produced results similar to what have been presented previously during the training process.

Figure 5.10 shows the relationship between the predicted intersection hazardous index IHI using the trained neural network program and the estimated IHI using equation 4.2. It shows that the trained network has been able to predict the IHI accurately.

Examining Figure 5.9 one may find that the relative importance of factors is similar to what has been found with the training case 3. The figure indicates that the most effective variables in IHI are in the following order:

- Variable 1 (Rutting)
- Variable 2 (corrugation)
- Variable 3 (Bleeding)

- Variable 9 (storage area for pedestrian)
- Variable 23 (Pedestrian Density)

These results are also in agreement with the results of the case 1, which shows that variables 1, 2, 3 and 9 are among the top 5 contributing ones. However, variable 23 was replaced by variable 22 in the later case.

5.5 SUMMARY

In this Chapter three cases were presented. The first case involved the examination of the ability of ANN to find the relationship between calculated IHI and actual measurements for the 48 intersections. The second case was to establish if there was correlation between the actual accident rates reported for the 48 intersections and their measured characteristics. Finally, the third case involved the use of the developed model to estimate the IHI for the artificial 1000 intersections. The results of these 3 scenarios were utilized to estimate the IHI for the 48 intersection and compare the predicted ones with the calculated values.

Figure 5.1: Relative Importance of Variable (Training Case 1)

Figure 5.2 Prediction Calibration

Figure 5.3 Selected Variables To Be Excluded

Figure 5.4: Relative Importance Of Variables In Predicting Accident Rates

R-squared	0.917739
Avg.error	0.001097
Correlation	0.958072
MSE	0.000002
RMSE	0.00141
% in range	0.0%

Figure 5.5: Network Statistics

Figure 5.6: Relative Importance Of Variables In Predicting IHI (Case 3)

Figure 5.7: Prediction Calibration (Case 3)

Best net statistics	
R-squared	0.999993
Avg. error	0.006317
Correlation	0.999997
MSE	0.000061
RMSE	0.007789
% in range	0.0%

Figure 5.8: Network Statistics (Case 3)

Figure 5.9: Relative Importance Of Signalized Intersection Variables In IHI

Figure 5.10: Predicted Vs Calculated Intersection Hazardous Indices For The Real Life Signalized Intersections

6 CHAPTER 6: MODEL CALIBRATION

6.1 INTRODUCTION

Model calibration is considered one of the most important steps in building any mathematical model. The calibration process usually aims at assuring the quality of the model outputs. This chapter is concerned with calibrating the developed intersection safety index to ensure its quality and enhance its capability in predicting intersection safety condition. The calibration process as presented in Figure 2.1 involves analyzing the collected accident data. Accident rates are then calculated (accidents per 10000 vehicles at the intersection). It also, involves correlating accident rates with the developed intersection hazardous index. Strong correlation indicates that the proposed Intersection hazardous Index can be used to evaluate safety conditions at intersections. Also, strong correlation will make it possible to predict accident rates at signalized intersection utilizing the calculated safety index. This will also, help in predicting accident occurrence. In The following sections the detailed calibration process is described. This is followed by presenting the methods used for the correlation and the results associated with each method.

6.2 THE CALIBRATION PROCESS

As shown in Figure 2.1, the calibration process involves the following steps:

1. Selecting existing signalized intersections to be used for model calibration.
2. Collecting two types of data. The first is the data needed for calculating accident rates and the second is the data required to run the developed model and calculate intersection safety index. As it is known, to calculate accident rates per 1000 vehicles passed through the intersection one would have to have the number of accidents

occurred at such intersection as well as the total traffic volume that passed through the intersection during the same period. Table 6.1 presents the number of accidents and the traffic volume that passed through each intersection. On the other hand, the data required to use the model and estimating the new developed intersection safety index was presented previously in Table 3.3.

3. SPSS version 7.52 for windows has been used to correlate accident rates and intersections hazard index using two different scenarios. Each scenario is presented in detail in the following sections.

6.3 CALIBRATION SCENARIO 1

In this scenario the calculated accident rate (AR) for the 48 selected signalized intersections is directly correlated with the estimated hazardous index for the same intersections. The results are given below.

$$\text{ACCIDENT RATE (AR)} = 1.19 \text{ IHI} \quad [6.1]$$

Multiple R	0.79884
R²	0.638
SE	26.9
F	67.015
T	8.186
N	48

Where

R²= Coefficient of Determination

SE = Standard Error

F = Goodness of Fit

T = Student test

N = Number of observations

The results of the statistical analysis given above suggested a strong correlation between the actual reported accident rates (AR) and the predicted Hazardous Index (IHI). This correlation is supported by the higher value of R approximately 80%. This implies that either variable can be used with confidence to predict the other one. Clearly, the value of this correlation is obvious since one can predict the rate of accidents using the characteristics of the intersections or one can use the IHI directly to estimate the accident rate at a given intersection.

6.4 CALIBRATION SCENARIO 2

To conduct such scenario, the Neural Network model has been trained using the selected 48 intersections characteristics data as an input and the previously calculated accident rates as an output. After training, the trained model has been used to predict accident rates for the 1000 artificial intersections (see Chapter 4 for more details). Then the predicted accident rates were correlated with the calculated hazard indices for the 1000 artificial intersections. The correlation results were found to be as follows:

$$IHI = 0.929 AR \quad [6.2]$$

Multiple R 0.84

R^2	0.704
SE	18.9
F	2378.8
T	48.77
N	1000

The above statistics is even much better than the results of the calibration scenario 1. This confirms that the developed hazardous index is a good representative for accident rates. The R value of 84% suggests that one may use accident rates confidently and easily to predict the hazardous index.

6.5 SUMMARY

The results presented and discussed in this Chapter confirmed the validity of the research methodology discussed and presented earlier in Chapter 2. The use of the statistical approach to develop a simple equation such as the one given in 6.1 or 6.2 is an important objective of this thesis. These equations can be utilized along the neural network model to estimate and evaluate specific scenario at certain intersection. Also, the use of the statistical analysis to calibrate the results obtained from the NN approach validate its application and possible use to predict accurately the IHI or the accident rates from actual measured characteristics of existing intersections. This results increased the confidence of using the developed model.

Table 6.1: Accident Rates at The Selected Signalized Intersections

Intersection Point	Yearly Traffic Volume	Number of Accidents	Accident Rate Per 10³ vehicles
41C	7665000	1	13.04631
41B	10613077	0	0
41A	12087115	0	0
41	10907885	0	0
38C	4422115	0	0
39	4716923	0	0
38	6190962	5	80.7629
12	16804038	1	5.95095
9	21226154	2	9.422338
11	20341731	10	49.16003
11A	19457308	4	20.55783
36	20046923	7	34.91808
44	19752115	1	5.062749
56	13561154	6	44.24402
13	7665000	10	13.04631
17	15035192	5	33.25531
10	17983269	9	50.04652
11C	14740385	4	27.13633
35	15919615	12	75.37871
44A	15330000	1	6.523157
14	11792308	4	33.92042
18	12971538	10	77.09186
10A	20636538	7	33.92042
35A	22995000	5	21.74386
43A	28891154	0	0
15	6485769	4	61.67349
19	9433846	2	21.20026
16	9139038	1	10.94207
20	14740385	7	47.48858
1	17393654	3	17.24767
1E	27711923	16	57.73688
43	31249615	3	9.600118

Intersection Point	Yearly Traffic Volume	Number of Accidents	Accident Rate Per 10³ vehicles
47	18278077	8	43.76828
49	25943077	7	26.98215
49A	24174231	4	16.54655
70	20636538	8	38.76619
69	18278077	0	0
2	12971538	1	7.709186
4	20341731	6	29.49602
26	11202692	0	0
7A	9433846	2	21.20026
5A	14740385	4	27.13633
63	4716923	2	42.40052
60B	5011731	3	59.85956
118	6780577	0	0
57R	11202692	1	8.926426
42P	13855962	4	28.86844
135	12381923	8	64.61032

7 CHAPTER 7: CONCLUSIONS AND REMARKS

7.1 INTRODUCTION

The main objectives of this investigation were to identify the main causes of the road accidents at urban intersections in the City of Abu Dhabi, to develop a Safety Index based on the opinions of traffic and highway experts and to determine whether there were a correlation between the developed safety indices and real life accident rates. The study utilized field data collected over the past 3 years in addition to two field surveys conducted in the year 2001. The first field survey involved the design and implementation of a survey dealing with the determination of expert's opinion regarding the influence and relative weight of specific variables on the occurrence of traffic accidents within the premises of urban intersections. One hundred experts were contacted and interviewed to complete this phase. The results of the interviews were utilized to develop a list of "weighed and ranked" variables with a total of 25 different variables. The list was then shortened to 15 final variables, which were ranked by the experts as most significant.

The second phase included the selection of 48 urban intersections in the City of Abu Dhabi. Actual data and measurements were collected at the site of each intersection. The data and measurement included features such as number of lanes, type of intersection, signal identification, surface conditions and distress severity, among other features. The data and information were used to establish a relationship between the objective measurements of the intersection and the rate of accidents at the same intersection. The technique of Neural Network was utilized and used throughout the investigation.

The third phase of the investigation dealt with examining the correlation that may exist between the objective measurements taken at the site of the intersection and the subjective results of the interviews. Establishing the relationship between the developed Safety Index and the subjective data collected based on the expert opinions completed this phase. The fourth and final Phase of the research dealt with the determination of the coefficient of correlation between the developed Safety Indices and the reported accident rates. The following sections discuss in more details the main conclusions and significant findings of the investigation. It is without a doubt a critical and significant step toward the development of a strategy to enhance the overall safety of travel on the road network of the UAE.

7.2 DETERMINATION OF MOST SIGNIFICANT FACTORS AFFECTING INTERSECTION'S SAFETY

The designed and implemented research plan succeeded to determine the most significant factors and variables governing the traffic safety at urban intersections in the City of Abu Dhabi. The type of intersection (V4), allowed yellow time (V12), percentage of heavy vehicles (V21), traffic signal sequence (V14), and rutting (V1) were the top 5 variables thought by the experts to be the most significant variables with respect to the safety at intersections. Clearly, the five variables cover geometric design aspects of the intersection, operational characteristics and surface conditions of the intersections. One can expect that understanding how these variables could affect safety would assist the traffic and highway engineers to make proper decisions to improve the safety and reduce the risk of accidents at the intersections.

7.3 EXPERT OPINION

One of the most important conclusions of the study performed in this thesis is the fact that the results obtained from the interviews lead to the same conclusions drawn from the application of the objective data. For example, when the analysis was carried out to rank the importance of the variables according to the opinion of the experts, the main causes according to the experts were the same shown to exist when the objective data was used.

Also, the thesis introduced a unique framework for developing intersection safety index. The suggested framework relies on the expert opinions and it employs statistical and Artificial Intelligent techniques.

7.4 SAFETY INDEX

For the first time in the United Arab Emirates a comprehensive study, which includes site visits, field interviews and actual measurements, was planned, designed and performed to develop safety indices suitable to UAE conditions. A new Index to assess the safety of traffic at urban intersections was developed. The Index correlates well with accident rates. In addition, the developed Index can be predicted using data based on the expert opinion or objective measurements of actual intersections. The index can be utilized to measure effects of treatments to improve safety at specific intersection.

7.5 UTILIZATION OF NEURAL NETWORK TECHNIQUES

The results and analysis presented throughout this study showed that the utilization of the advanced techniques known as Neural Network is a successful choice. The technique is easy to address problems associated with large data and the search for strong correlation. The NN techniques were used to establish a relationship between the data obtained from the experts and the data obtained from the selected 48 intersections. The qualities of the predictions were excellent. The use of the NN approach showed great flexibility in adopting different data sets such as the real measurements for the 48 intersections and the trained ones for the 1999 and 2000 accident rates. Also, the results of the NN models were confirmed when compared with those obtained by the conventional statistical methods. Finally, the developed models can be used for other intersections in the UAE since the main variables appear to be of similar characteristics within the Emirates.

7.6 FUTURE RESEARCH WORK

The results and conclusions presented in this thesis showed that indicators for safety of intersections could be predicted with higher degree of accuracy. Furthermore, the tools developed herein can be utilized and used to decide on future plans for enhancing accident situations at a given intersection. Clearly, the integration of the Intersection Safety Index, (ISI) to the overall safety of road network should result in improving the safety of traffic over most links and nodes of the network. This integration can be achieved by following similar approach with the road sections connecting between different intersections.

Another area for future consideration is the application of the same approach and methodology on other major Cities both in Developing as well as Developed Countries.

There is an urgent need to examine the validity of the developed approach on situations where traffic volumes are relatively high. The results of such a research should answer the question related to the use of accident rates or accident frequency.

Finally, the application of the finding and conclusions presented in this investigation to identify intersections with high risk to accidents may help cutting the number of fatalities and serious injuries, thus saving millions of lives and larger amounts of monies.

8 REFERENCES

1. National Highway Traffic Safety Administration (1999), Traffic Safety Facts 1998 (DOT HS 808 983), Washington, D.C., U.S. Department of Transportation.
2. Zeeger C. V., Stewart, R., and D. Reinfurt (1990), Effective Geometric Improvements for Safety Upgrading Horizontal Curves. Prepared for the Federal Highway Administration by the University of North Carolina.
3. Okamoto, H., and M. Koshi, (1989), The Method to cope with the Random Errors of Observed Accident Rates in Regression Analysis. Accident Analysis and Prevention, Vol. 21, pp. 317-332.
4. Shankar, V., Mannering, F., and W. Barfield, (1995). Effects of Roadway Geometrics and Environmental Factors on Rural Freeway Accident Frequencies. Accident Analysis and Prevention, Vol. 27 No.3, pp. 371-389.
5. Evens, Leonard. (1991), Traffic Safety and The Driver. Published by VanNostrand Reinhold.
6. Gothie , M. (2002), Could Adherence of a Road Surface be Used to Identify the Areas Where Maintenance is Needed? Bearing Capacity of Roads, Railway and Airfields, Proceedings Vol. 2, pp. 411-421.
7. Ben-Akiva, M., A. Ceder, L-h. Cheng, and C. M. Liss, (1999). A Methodology for Estimating Traffic Safety Improvements at Intersections. Journal of Advanced Transportation, Vol.33, No.3, pp.273-293
8. Paniati, J., and J. True, (1996). Transportation Research Board Circular 212: Interactive Highway Safety Design Model (IHSDM): Designing

- Highways With Safety in Mind, TRB, National Research Council, Washington, D.C., pp. 55-60.
9. Horst, R. V. D., (1988). Driver Decision Making at Traffic Signals, Transportation Research Record No. 1172, pp. 93 –97.
 10. Everett, C.C., and Paul M. Schonfeld (1991). Safety Belt Use and Highway Safety in Maryland. Transportation Research Record No. 1325, pp. 45-50
 11. Kim, K. (1991). Effects of Enforcement on Seat Belt use in Hawaii. Transportation Research Record No. 1325, pp. 51-56.
 12. Zhang, W-B., (1991). Engineering Design Concept For Intelligent Vehicle-Highway System Safety. Transportation Research Record No. 1318, pp.104-110.
 13. Almqvist, S., C. Hyden, and R. Risser. (1991). Use of Speed Limiters in Cars For Increased Safety and a Better Environment. Transport. Research Record No 1318, pp.34-39.
 14. Garber, N. J., and Raghavan Srinivasan, (1991). Characteristics of Accidents Involving Elderly Drivers at Intersections. Transport. Research Record No 1325, pp. 8-16.
 15. Craus, J., M. Livneh, and I Ishai (1991). Effect of Pavement and Shoulder Conditions on Highway Accidents. Transport. Research Record No 1318, pp 51-57.
 16. Goldstine, R., (1991). Influence of Road Width on Accident Rates by Traffic Volume. Transport. Research Record No 1318, pp. 64-69.

17. Persaud, B. and T. Nguen, (1998). Disaggregate Safety Performance Models for Signalized Intersections on Ontario Provincial Roads. *Transport. Research Record No 1635*, pp. 113-120.
18. Mountain, L., B. Fawaz, and D. Jarrett, (1996). Accident Prediction Models for Roads With Minor Junctions. *Accident Analysis and Prevention Vol. 28*, pp. 695-707.
19. Jovanis, P. P., and H. L. Chang, (1986). Modeling the Relationship of Accidents to Miles Traveled. *Journal of Transportation Research Vol. 106*, pp. 42-51.
20. Ben-Akiva, M., Ceder, A., Cheng, L., and Liss, M. (1988). Estimation of Intersection Traffic Safety Improvements. Final Report for the Massachusetts Department of Public Works, M.I.T, Center for Transportation Studies, Cambridge, MA.
21. Lau, M. Y-K., and Adolf D. May, JR., (1988). Injury Accident Prediction Models for Signalized Intersections. *Transportation Research Record No. 1172*, pp. 58-67.
22. A Policy on Geometric Design of Highways and Streets. AASHTO, Washington, D. C., 2002.
23. Turner, D. S., and C. W. Colson, (1988). Accident Data as a Tool for Highway Risk Management. *Transportation Research Record No. 1172*, pp. 11-22.
24. Holbrook, L. F., (1976). Prediction of Wet Surface Intersection Accidents From Weather and Skid Test Data. *Transportation Research Record No. 623*, pp. 29-39.

25. Gattis, J. L., (1992). Sight-distance Design for Curved Roadways with Tangential Intersections. Transportation Research Record No. 1356, pp. 20-27.
26. Bitzel, I.F. (1957). Accident Rates on German Expressways in Relation to Traffic Volumes and Geometric Design. Roads and Road Construction.
27. Cirillo, J. A. (1967). Interstate Accident Research-Study. Highway Research Record 188, pp. 1-7.
28. Glennon, J. C., Neuman, T.R., and Leisch, J.E., (1983). Safety and Operational Considerations for Design of Rural Highway Curves. FHWA, US. Department.
29. Glennon, J.C., Neuman, T.R, McHenery, R.R., and McHener, B.G., (1982). HVOSM Studies of Cross-Slope Breaks on Highway Curves. Report FHWA - RD - 82/054. FHWA, US Department of Transportation.
30. Glennon, J.C., (1987). Effect of Sight Distance on Highway Safety. State of the Art Report 6- Relationship between Safety and Key Highway Features. Transportation Research Board, National Research Council, Washington, DC.
31. Global Road Safety Partnership, 2001. Estimating Global Road Fatalities, 2001. A Special Study Carried out by TRL, London. U.K
32. Krammes, R. A, and Glascock, S. W., (1992). Geometric Inconsistencies and Accident Experience on Two-Lane Rural Highways in Transportation Research Record No.1356, TRB, National Research Council, Washington, D.C, pp. 1-10.

33. Bryson, D. A and Stone, J.R., (1987). Intersections advisor: An Expert System for Intersection Design in Transportation Research Record No.1145, TRB, National Research Council, Washington, D.C, pp. 48-53.
34. Accident Facts, 1986 Edition. National Safety Council, Chicago, Ill, 1987.
35. Road Safety Audit, (2002). Second Edition, ARRB Transport Research, Austria, 206 pages.
36. George Kanellaidis, (1999). Aspects of Road Safety Audits. Journal of Transportation Engineering, Vol. 125, No. 6, pp. 481-486.
37. Burke, L. I., and J. P. Ignizio, (1992). Neural Networks and Operation Research: an Overview. Computers and Operation Research, Vol. 19, No. $\frac{3}{4}$ Great Britain.
38. Dougherty, M. (1995). A Review of Neural Networks Applied to Transport. Transportation Research Vol. 3, No. 4, pp. 247-260.
39. Mussone, L. Ferrari, A. and Oneta, M (1999). An Analysis of Urban Collisions Using an Artificial Intelligence Model in Accident Analysis and Prevention Vol.31, pp. 705-718.
40. Hajeck, J.J. Chong, G.J. Hass, R.C.G., and Phang, W.A., (1987). Knowledge-Based Expert System Technology Can Benefit Pavement Maintenance in Transportation Research Record No.1145, TRB, National Research Council, Washington, D.C, pp. 37-47.
41. Mohamed, A.H.H., (1995). Development of Optimal Strategies for Bridge Management Systems, Ph.D. Thesis, Carleton University.
42. Miller, A, (1986). Expert systems: The Structure, History, and Future of Successful AI Applications. IEEE Potentials.

43. Simon Haykin, Neural Networks A Comprehensive Foundation, Second Edition, Prentice-Hall, Inc., New Jersey, 1999.
44. J.J. Hopfield, Neural Networks and Physical Systems with Emergent Collective Computational Abilities, Proc. Natl. Acad. Sci. USA, Vol. 79, 2554-2558, April 1982.
45. Kevin Swingler, Applying Neural Networks A Practical Guide, Academic Press Limited, 1996
46. Winston, P. H., Artificial Intelligence 3rd Edition, Addison Wesley, Reading, MA., 1992.
47. Gandhi, R.B.V. and Lytton, R.L. (1983) An improved Bridge Safety Index for Narrow Bridges. Research Report 233- 2F. Texas Transportation Institute, Texas A&M University, College Station.
48. Ivey, D. L., Olson, R.M., Walton, N. E., Weaver G. D., and Whitehurst, F. L. (1979) NCHRP Report 203: Safety at Narrow Bridge Sites. TRB, National Research Council, Washington, D.C.
49. Witkowski, J. M., (1992). Prioritizing Signalized Intersection Operational Deficiencies. Transportation Research Record No.1360, pp. 4-12.
50. Larson, L., and F. L. Mannering, (1997). Method for Prioritizing Intersections Improvements, Final Report, Washington State DOT. Washington.
51. Hauer, E., (1997). Observational Before-after Studies in Road Safety. Pergamon Publications.
52. Pfundt, K., (1969). Three Difficulties in the Comparison of Accident Rates. Accident Analysis Prevention Vol. 1, pp. 235-259.

- 53 Hakkert, A. S., M. Livneh, and D., Mahalel, (1976). Levels of Safety in Accident Studies-a Safety Index. ARRB Proceedings, Vol. 8, Part 5, pp.1-6. Australian Road Research Board.
- 54 Brundell-Freij, K., and L., Ekman, (1991). Flow and Safety. Paper 910006, Presented at the 70th Annual Meeting of the TRB, Washington D.C.
- 55 Hauer, E., (1993). Overview. In ITE, The Traffic Safety Toolbox; A Primer on Traffic Safety. ITE , Washington, D.C.
- 56 Hauer, E., (1995b). Exposure and Accident Rate. Traffic Engineering and Control, Vol.36, No. 3, pp. 131-138.
- 57 Ward, Richard E., R. W. Eck, and Abishai Polous, (1987). Developing an Intersection Hazard Index. Journal of Transportation Engineering, Vo. 113, No.2, pp. 211-215

9 APPENDICES

Appendix A

Appendix B

Appendix A

DEVELOPING A SAFETY EVALUATION ALGORITHM FOR SIGNALIZED INTERSECTIONS IN ABU DHABI (UAE) USING ARTIFICIAL INTELLIGENCE

Signalized Intersection Safety Evaluation Questionnaire Form

How to fill the attached form

1. The attached form consists of two parts.
2. Each form contains 25 variables thought to have an effect on safety (the same variables are repeated in both forms).
3. In the first form each variable has assigned different values. You are kindly requested to give a grade out of 10 points for each value where 10 represents the safest condition and zero represents the worst condition.
4. In the second form please rank the most effective 15 variables on the safety condition of a signalized intersection.
5. Once you ranked the variables please distribute a 100 points among the 15 most effective variables. You should make sure that the highest point is given to the variables you ranked as number 1 and the lowest point is given to the variable you ranked as number 15 in the previous step.
6. We expect that filling the form will need at least 2 hours and we appreciate your effort and help.
7. Please be informed that your opinion will help us in developing of the signalized intersection safety evaluation tool.

ATTEND: Hussain AL Harthei

Subject: Signalized Intersection Safety Evaluation Questionnaire Form

Dear Sir

Please find attached a copy of the signalized intersection safety evaluation questionnaire form, which has been designed to collect experts' opinions as part of the master thesis titled **"DEVELOPING A SAFETY EVALUATION ALGORITHM FOR SIGNALIZED INTERSECTIONS IN ABU DHABI (UAE) USING ARTIFICIAL INTELLIGENCE"**. You are kindly requested to fill the form following the attached instruction and return it back to the traffic engineering department, Abu-Dhabi traffic police.

Thank you for your help.

Yours Faithfully,

Hussain A. Al-Harthei
Traffic Engineering Section
Abu-Dhabi Traffic Police &
Graduate Student
Civil and Environmental Engineering Department
Carleton University, Ottawa, Canada

Safety Questionnaire

Form 1

General information

Name	Job
Qualification	Driving Experience
Have you been involved in an accident before	Yes No

Example to show how to fill the form

No	Intersection Features	Condition				Comments
1	Rutting	N.A	Low	M	High	
	Safety Grade(Max=10)	10	10	5	3	

Signalized Intersection Features Measurements

No	Intersection Features	Condition				Comments
A	Pavement Condition					
1	Rutting	N.A	Low	M	High	
	Safety Grade(Max=10)					
2	Corrigation	N.A	Low	M	High	
	Safety Grade(Max=10)					
3	Bleeding	N.A	Low	M	High	
	Safety Grade(Max=10)					
B	Geometric Design Characteristics					
4	Intersection Type	R.A	SRA	S.P.	D.P.	
	Safety Grade(Max=10)					
5	Free right Turn Availability.	N.A	One lane	Two L.		
	Safety Grade (Max=10)					

No	Intersection Features	Condition				Comments
6	Separate left Turn L (S)	One	Two	Mixed		
	Safety Grade (Max=10)					
7	No. of Legs	3	4	4	>4	
	Safety Grade (Max=10)					
8	Intersection angle	90°	>90°			
	Safety Grade (Max=10)					
9	Storage area for pedestrian movement in the island	Not Available	5m ²	>5m ²		
	Safety Grade (Max=10)					
10	Sector-Parking exit upstream within 50 m	One leg	Two legs	Three legs	Four legs	
	Safety Grade (Max=10)					
11	Sector-Parking Entrance Down stream within 50 m	One leg	Two legs	Three legs	Four legs	
	Safety Grade (Max=10)					
C Traffic signal characteristics						
12	Allowed Yellow Time(Sec.)	0-5	6-10	11-15		
	Safety Grade(Max=10)					
13	All Red time (Sec)	1	2	3		

No	Intersection Features	Condition				Comments
	Safety Grade (Max=10)					
14	Traffic signal Sequence	1	2	3	4	
	Safety Grade (Max=10)					
15	Traffic signal Position	Both Sides	Cantilever	Mixed		
	Safety Grade (Max=10)					
16	Cycle Length (sec)	60	90	120	140	
	Safety Grade (Max=10)					
17	Total No. Of phases	3	4	5	>5	
	Safety Grade (Max=10)					
18	Green wave availability	available	Not available			
	Safety Grade(Max=10)					
D Traffic control Devices cond.						
19	Advanced Warning Signs for pedestrian	N.A.	Good	Fair	Poor	
	Safety Grade (Max=10)					
20	Marking Condition	N.A.	Good	Fair	Poor	
	Safety Grade (Max=10)					
E Traffic signal characteristics						
21	%Heavy Vehicles	<5	5-10	11-15	>15	
	Safety Grade (Max=10)					
22	% Taxi	<10	10-20	20-30	>30	
	Safety Grade (Max=10)					

No	Intersection Features	Condition					Comments
23	Pedestrian Density	Low	Med	High			
	Safety Grade (Max=10)						
24	Posted Speed (kph)	30	45	60	>60		
	Safety Grade (Max=10)						
25	Level of Service (LOS)	A	B	C	D	E	F
	Safety Grade (Max=10)						

- Please rank the most effective 15 variables on safety.

No	Intersection Features	Rank	Pts	Comments
1	Rutting			
2	Corrigation			
3	Bleeding			
4	Intersection Type			
5	Free right Turn Availability			
6	Separate left Turn Lane			
7	Location of Pedestrian opening			
8	Intersection angle			
9	Storage area for pedestrian movement in the island			
10	Sector-Parking exit upstream 50 m			
11	Sector-arkingEntranceDownstream 50 m			
12	Allowed Yellow Time(Sec.)			
13	All Red time(Sec)			
14	traffic signal Sequence			
15	traffic signal Position			
16	Cycle Length(sec)			
17	Total No. Of phases			
18	Green wave availability			
19	AdvancedWarning Signs pedestrian			
20	Marking Condition			
21	%Heavy Vehicles			
22	% Taxi			
23	Pedestrian Density			
24	Posted Speed (kph)			
25	Level of Service (LOS)			

Please write down any other comments you would like to add:-

1-

2-

3-

4-

TRAFFIC SIGNAL SEQUENCE:

دولة الإمارات العربية المتحدة
وزارة الداخلية
الإدارة العامة لشرطة أبوظبي

مسلسل ٤١٣٩

رقم البلاغ

الرقم القضائي

شرطة المرور /

مركز / مخفر

تقرير حادث سير للاصابات فقط

مُتَعَمِّدٌ عَلى

* نوع الحادث: ١- صدم غير متحرك ٢- صدم أثناء الدوران ٣- صدم متتالي ٤- صدم متقابل ٥- صدم جانبي
٦- صدم عمودي ٧- صدم حيوان ٨- سقوط ٩- دهم انسان ١٠- تدهور ١١- احتراق

ساعة وقوع الحادث	يوم	شهر	سنة	١ (صباحا ٧ ظهرا ٣ عصرا ٤ مساء)	الاحداثيات
تاريخ وقوع الحادث	يوم	شهر	سنة	٢	
يوم وقوع الحادث	١- السبت ٢- الأحد ٣- الاثنين ٤- الثلاثاء ٥- الأربعاء ٦- الخميس ٧- الجمعة				

= مكان وقوع الحادث : اسم المنطقة اسم الشارع
رقم الشارع رقم التقاطع رقم العمود من إلى

* موقع الحادث بالقرب من : ١- مدرسة ٢- مسجد ٣- مستشفى ٤- هيئة حكومية ٥- منطقة تجارية ٦- محطة وقود
٧- حديقة ٨- منطقة سكنية ٩- طريق خارجي ١٠- نفق ١١- جسر ١٢- أخرى (حدد)

الاحوال الجوية في موقع الحادث

* المشاة في مكان الحادث : ١- في الطريق على خطوط عبور المشاة ٢- في مكان قريب من خطوط عبور المشاة
٣- لا توجد خطوط عبور للمشاة ٤- على الجزيرة الوسطية او الرصيف ٥- أخرى (حدد)

* تصنيف مكان وقوع الحادث : ١- دوار او ملتقى طرق ٢- طريق فردي ٣- طريق مزدوج ٤- خارج الطريق
٥- جسر ٦- موقف سيارات ٧- نفق

* تفاصيل ملتقى الطريق :

١- الحادث ليس على ملتقى الطريق او بحدود (٢٠) متر من الملتقى ٢- دوار ٣- ملتقى طريق عمودي
٤- ملتقى طريق نصف عمودي ٥- تقاطع طريق عمودي ٦- تقاطع طرق منحرف ٧- نتحة دوران
٨- تقاطع طرق متعددة ٩- تقاطع طرق من نوع أخرى

* الفاصل بين الشارحين : ١- فاصل حديدي ٢- فاصل خرساني ٣- فاصل رملي او زراعي ٤- رميف ٥- بدون فاصل

* المراقبة وتوفير العلامات المرورية :

١- اشارات ضوئية او توماتيكية ٢- اشارة قف ٣- خطوط قف ٤- اشارة افصح الطريق
٥- خطوط افصح الطريق ٦- مراقبة من قبل شرطي مرور او مختص ٧- بدون

* الاضاءة : ١- خلال ساعات النهار ٢- ليلا (الانارة الكافية) ٣- ليلا (الانارة ضعيفة) ٤- ليلا (بدون اضاءة)
* الطقس : ١- صحو ٢- ممطر ٣- عاصف ٤- مغبر ٥- ضباب ٦- غائم
* سطح الطريق : ١- جاف ٢- مبلل ٣- مغطى بالرمال ٤- مواد بتروليه او كيماويه
٥- يوجد مطبات ٦- غير معبد ٧- عوامل أخرى (حدد)

* حالات خاصة أخرى : ١- ليست هناك حالات خاصة ٢- الاشارات الضوئية معطلة كلياً ٣- الاشارات الضوئية معطلة جزئياً
٤- لوحات اشارات المرور مخفية عن النظر كلياً أو جزئياً ٥- علامات او شواخص الطريق غير موجودة
٦- الطريق تحت الإصلاح ٧- الخطوط الارضية غير واضحة او غير موجودة ٨- عوامل أخرى (حدد)

Att: Mr. Hussain Al Harathi

م ٢٢-٢٢-٢٢
٢٢٠٠

* الاضرار بالامتلاكات العامة :-

نوعها

رقم المركبة المتسببة

النتيجة : من الحادث :

أ- صفة المصاب :	١- سائق	٢- راكب	٣- مشاه	٤- غير معروف
ب- مكان وجوده :	١- المركبة رقم (١)	٢- المركبة رقم (٢)	٣- المركبة رقم (٣)	٤- المركبة رقم (٤)
ج- استخدام حزام الامان :	١- مستخدم	٢- غير مستخدم	٣- غير معروف	٤- غير معروف
د- كيفية نقل المصابين :	١- أسعاف	٢- سيارة شرطة	٣- سيارة مدنية	٤- طائرة عمودية
هـ- درجة الإصابة :	١- بسيطة	٢- متوسطة	٣- بليغة	٤- وفاة

م	اسم المصاب	الجنسية	العمر	درجة الإصابة	صفته	مكان وجوده	كيفية نقله	حزام الامان
١								
٢								
٣								
٤								
٥								
٦								
٧								
٨								
٩								
١٠								

النتيجة : وقوع الحادث :

١	عدم ترك مسافة كافية	١١	السوق بطيش وتهور
٢	عدم الالتزام بخط السير	١٢	التجاوز من مكان ممنوع
٣	عدم تقدير مستعملي الطرق	١٣	الوقوف المفاجئ
٤	عدم انصاف الطريق	١٤	الانحراف المفاجئ
٥	دخول الطريق دون التأكد من خلوه	١٥	الدخول في مكان ممنوع
٦	عدم اعطاء الاولوية لعبور المشاة	١٦	عدم الالمام بالقيادة / القيادة بدون رخصة سوق
٧	عبور الاشارة الضوئية الحمراء	١٧	انتقجار الاطوار
٨	الرجوع للخلف دون التأكد	١٨	تاثير تناول مسكر او مخدر
٩	السير عكس السير	١٩	عيوب في المركبة (حدد)
١٠	السرعة الزائدة	٢٠	اسباب اخرى (حدد)

شهود الحادث :

١. الاسم :	الجنسية :	العمر :	العنوان :
٢. الاسم :	الجنسية :	العمر :	العنوان :
٣. الاسم :	الجنسية :	العمر :	العنوان :

Appendix B

TABLE B-1: SIGNALIZED INTERSECTION CHARACTERISTICS DATA

Intersection Point (IP)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
41C	NA	NA	NA	S.PT	NA	2	3	>90	>5	1	NA	1	1	1	2	3	2	2	NA	FAIR	15%	15%	medium	60	C
41B	NA	NA	NA	S.PT	NA	MIX	3	>90	NA	NA	NA	1	1	1	2	3	2	2	NA	FAIR	15%	15%	medium	60	D
41A	NA	NA	NA	S.PT	NA	MIX	3	>90	>5	1	2	1	1	1	2	3	2	2	NA	FAIR	10%	20%	High	60/40	D
41	NA	NA	NA	D.PT	1	2	3	>90	>5	NA	NA	1	1	1	2	3	2	2	NA	FAIR	10%	20%	High	60/40	D
38C	NA	NA	NA	S.PT	NA	MIX	3	90	>5	1	2	1	1	1	2	3	2	2	NA	FAIR	5%	20%	High	60	C
39	L	NA	L	S.PT	1	1	4	90	>5	1	2	1	1	1	2	3	2	2	NA	FAIR	5%	20%	High	60/40	B
38	L	NA	L	S.PT	1	1	4	90	>5	NA	2	1	1	1	2	3	2	2	NA	FAIR	5%	20%	High	60	B
12	NA	NA	NA	S.PT	1	1	3	>90	>5	NA	2	1	1	1	2	3	2	1	NA	FAIR	10%	20%	High	60	E
9	L	NA	NA	S.PT	1	1	4	90	<5	1	2	1	1	1	2	3	2	1	NA	FAIR	10%	20%	High	60/45	F
11	L	NA	NA	S.PT	1	1	4	90	<5	1	1	1	1	1	2	3	2	1	NA	POOR	10%	20%	High	60	E
11A	M	L	L	S.PT	1	2	4	90	<5	NA	NA	1	1	1	2	3	2	1	NA	FAIR	10%	15%	High	60	E
36	NA	NA	NA	S.PT	1	2	4	90	>5	1	1	1	1	1	2	3	2	1	NA	FAIR	10%	15%	medium	60	F
44	M	M	M	D.PT	1	1	4	90	>5	NA	NA	1	1	1	2	3	2	1	NA	GOOD	10%	15%	medium	60	F
56	NA	NA	NA	S.PT	1	1	3	>90	<5	1	NA	1	1	1	2	3	2	1	NA	FAIR	5%	20%	High	60/45	E
13	L	L	NA	S.PT	1	1	4	90	<5	1	2	1	1	1	2	3	2	1	NA	FAIR	3%	30%	High	45	C
17	L	L	NA	S.PT	1	1	4	90	<5	1	1	1	1	1	2	3	2	1	NA	FAIR	3%	35%	High	45	D
10	NA	NA	NA	S.PT	1	1	4	90	<5	1	2	1	1	1	2	3	2	1	NA	FAIR	3%	35%	High	60	E
11C	NA	NA	NA	S.PT	1	MIX	3	90	<5	NA	NA	1	1	1	2	3	2	1	NA	FAIR	5%	30%	High	60	E
35	NA	NA	NA	S.PT	1	1	4	90	<5	NA	1	1	1	1	2	3	2	1	NA	FAIR	5%	25%	High	60	E
44A	NA	NA	NA	S.PT	1	1	3	90	<5	NA	1	1	1	1	2	3	2	1	NA	FAIR	5%	20%	medium	60	E
14	NA	NA	NA	S.PT	1	1	4	90	<5	1	2	1	1	1	2	3	2	1	NA	FAIR	3%	35%	High	45	D
18	NA	H	NA	S.PT	1	1	4	90	<5	2	1	1	1	1	2	3	2	1	NA	GOOD	3%	35%	High	45	D
10A	M	H	L	S.PT	1	1	4	90	<5	NA	2	1	1	1	2	3	2	1	NA	POOR	3%	35%	High	60	F
35A	NA	L	NA	S.PT	1	2	4	90	<5	1	2	1	1	1	2	3	2	1	NA	FAIR	5%	35%	High	60	F
43A	M	H	NA	S.PT	1	2	4	90	<5	NA	1	1	1	1	2	3	2	1	NA	FAIR	10%	25%	High	60	F
15	NA	NA	NA	S.PT	1	1	4	90	<5	1	1	1	1	1	2	3	2	1	NA	FAIR	3%	25%	High	45	C
19	NA	NA	L	S.PT	1	1	3	90	<5	NA	1	1	1	1	2	3	2	1	NA	POOR	3%	35%	High	45	D
16	NA	M	L	S.RA	NA	MIX	4	90	>5	2	1	1	1	1	2	3	2	1	NA	FAIR	5%	25%	High	45	D
20	M	NA	NA	D.PT	1	2	4	90	>5	2	3	1	1	1	2	3	2	1	NA	FAIR	5%	35%	High	45	D
1	NA	NA	NA	S.PT	1	2	4	90	>5	2	3	1	1	1	2	3	2	1	NA	GOOD	3%	35%	High	60	F
1E	NA	NA	NA	D.PT	1	2	4	90	<5	NA	NA	1	1	1	2	3	2	1	NA	GOOD	3%	25%	High	60	F
43	NA	NA	NA	S.PT	1	1	4	90	>5	NA	NA	1	1	1	2	3	2	1	NA	GOOD	5%	25%	High	60	F
47	L	NA	L	S.PT	1	1	4	90	<5	1	2	1	1	1	2	3	2	1	NA	FAIR	5%	25%	High	60	E
49	NA	NA	NA	S.PT	1	1	4	90	<5	1	1	1	1	1	2	3	2	1	NA	FAIR	5%	25%	High	60	F
49A	M	M	NA	S.PT	1	1	3	90	<5	NA	NA	1	1	1	2	3	2	1	NA	FAIR	10%	25%	High	60	F
70	H	M	L	D.PT	1	1	4	90	>5	NA	NA	1	1	1	2	3	2	1	NA	FAIR	5%	20%	High	60	F
69	L	NA	M	S.PT	1	1	3	90	<5	NA	NA	1	1	1	2	3	2	1	NA	GOOD	10%	15%	High	60	F
2	L	NA	NA	S.PT	1	1	3	90	<5	1	1	1	1	1	2	3	2	1	NA	FAIR	3%	30%	High	60/45	D
4	M	NA	M	S.PT	NA	1	4	90	<5	2	3	1	1	1	2	3	2	1	NA	FAIR	3%	25%	High	60	F
26	NA	NA	NA	S.PT	NA	1	3	90	<5	NA	NA	1	1	1	2	3	2	2	NA	FAIR	5%	15%	High	60	E
7A	L	NA	NA	S.PT	1	2	3	90	<5	NA	2	1	1	1	2	3	2	2	NA	FAIR	5%	15%	High	60/45	D
5A	NA	NA	NA	S.PT	1	1	4	90	<5	1	2	1	1	1	2	3	2	2	NA	FAIR	5%	20%	High	60/45	E

Intersection Point (IP)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
63	NA	NA	NA	S.PT	1	1	4	90	<5	NA	1	1	1	1	2	3	2	2	NA	FAIR	3%	15%	High	60/45	B
60B	NA	NA	NA	S.PT	1	1	3	90	<5	NA	NA	1	1	1	2	3	2	2	NA	FAIR	3%	15%	High	60	B
118	NA	NA	NA	S.PT	1	1	4	90	<5	NA	NA	1	1	1	2	3	2	2	NA	FAIR	3%	15%	High	60	C
57R	NA	NA	NA	S.PT	1	2	4	90	<5	NA	NA	1	1	1	2	3	2	2	NA	FAIR	5%	15%	High	60	D
42P	NA	NA	NA	S.PT	1	1	4	90	<5	NA	1	1	1	1	2	3	2	1	NA	FAIR	5%	20%	High	60	D
135	NA	NA	NA	D.PT	1	1	4	90	>5	NA	NA	1	1	1	2	3	2	1	NA	FAIR	5%	10%	High	60	D

**Rutting Rank
Variable No 1**

**Corrigation Rank
Variable No 2**

**Bleedomg Rank
Variable No 3**

**Intersection Type Rank
Variable No 4**

**Free right turn av.
Variable No 5**

**Sparate left Turn Lane(s)
Variable No 6**

**No. of legs
Variable No 7**

**Intersection angle
Variable No8**

Storage area for ped. Movement in the island
Variable No 9

Sector-Parking exit upstream within 50 m
Variable No 10

**Sector-parking Entrance Down stream within 50m
Variable No 11**

**Allowed Yellow Time Rank
Variable No 12**

All Red time(Sec)
Variable No 13

traffic signal Sequence
Variable No 14

traffic signal Postion
Variable No 15

Cycle Length(Sec)
Variable No16

**Advanced Warning Signs for pedestrian
Variable No19**

**Marking Condition
Variable No 20**

Percentage of Heavy Vehicles Rank
Variable No 21

%Taxi
Variable No 22

Level of service(LOS)
Variable No 25

Inputs

Hidden

Output

Visual Basic Source Code

- 1) **Data Entry Program** : this program was design to collect accident data from the accident forms , then was use to find statistics about the accident in different location and different situation

A snap shot about the program is given below

The source code is given below

```
Option Explicit
Public InsertNew As Boolean
Public Rs_accident As Recordset
Public Rs_Drivers As Recordset
Public Rs_Passengers As Recordset
Public Rs_People As Recordset
Public Rs_OtherCar As Recordset
Public CollectComboValues As Collection
Public AddRecord As Boolean

Private Sub Combo1_Click(Index As Integer)
Select Case Index
Case 28
If Combo1(28) = "خطأ أخرى هي" Then
Text4(3).Visible = True
```

End Sub

```
Private Sub DataGrid1_MouseMove(Button As Integer, Shift As Integer, X As Single, Y As Single)
On Error Resume Next
DataGrid1.ToolTipText = DataGrid1.Text
End Sub
```

```
Private Sub Form_Activate()
DitherBlue Me
Dim LblObject As Object
For Each LblObject In Me.Controls
If TypeOf LblObject Is Label Then LblObject.ZOrder 0
Next
End Sub
```

```
Private Sub Form_Load()
'open the connection with the server
'OpenConn
SendKeys"+^"
```

End Sub

```
Text4(3).SetFocus
Else
Text4(3).Visible = False
End If
```

```
Case 25
If Combo1(25) = "خطأ آخرى هي" Then
Text4(1).Visible = True
Text4(1).SetFocus
Else
Text4(1).Visible = False
End If
End Select
```

```
End Sub
```

```
Private Sub Command1_Click(Index As Integer)
On Error Resume Next
Dim CountCombo As Integer
Dim i As Integer
Select Case Index
```

```
Case 0
'to set all textfields to null and list to no select and combo to the default values
```

```
SetAndClearControls
AddRecord = True
InsertNew = True
DisplayCmd False
Text6.SetFocus
```

```
Case 1
If Text6 <> "" Then
i = MsgBox & "هل انت متأكد من حذف الملف رقم " & Text6, vbYesNo + vbCritical("حذف" ,
If i = vbYes Then
Db.Execute "delete from AccidentDetail where id=" & Text6
Db.Execute "delete from drivers where mainid=" & Text6
Db.Execute "delete from passengers where mainid=" & Text6
Db.Execute "delete from people where mainid=" & Text6
SetAndClearControls
```

```
End If
Else
MsgBox "يجب البحث أولاً" vbExclamation, "لا يوجد اي ملف للحذف",
End If
```

```
Case 2
DisplayCmd False
AddRecord = False
```

```
Case 3
If ErrorMsg(Text6, "", 2) = "يجب إدخال رقم الحادث", Then Exit Sub
If AddRecord = True Then
```

```
Rs_accident.MoveFirst
Rs_accident.Find "id=" & Text6.Text
```

```
If Rs_accident.EOF = False Then
MsgBox "هذا الرقم موجود من قبل"
Text6.SetFocus
Exit Sub
End If
```

```
End If
```

```
For CountCombo = 0 To 4
If ErrorMsg(Combo1(CountCombo), "", 2, Combo1(CountCombo).Tag (1, " غير صحيح " & Then Exit Sub
Next
```

```
If ErrorMsg(Text1(0), "", 2 (0, " يجب إدخال تعريف الموقع", Then Exit Sub
```

```
If ErrorMsg(Combo2(0 (0, "الجنسية", 0, " يجب ادخال الجنسية", Then Exit Sub
If ErrorMsg(Combo2(1 (1, "العمر", 0, " يجب ادخال العمر", Then Exit Sub
If ErrorMsg(Combo2(2 (0, "الجنس", 0, " يجب ادخال الجنس", Then Exit Sub
```

```
For CountCombo = 0 To 2
If ErrorMsg(Combo3(CountCombo), "", 0, Combo3(CountCombo).Tag (1, " غير صحيح " & Then Exit Sub
Next
```

```
For CountCombo = 0 To 2
If ErrorMsg(Combo4(CountCombo), "", 0, Combo4(CountCombo).Tag (1, " غير صحيح " & Then Exit Sub
Next
If ErrorMsg(Combo2(3 (0, " يجب اختيار جهة اصدار", 0, " جهة اصدار", Then Exit Sub
```

الفئة

```
If ErrorMsg(Combo1(11), "", 0 (1, " يجب اختيار الفئة", Then Exit Sub
If ErrorMsg(Combo1(11), Combo1(11), 0 (7, 1, 2, 7, " يجب اختيار الفئة ما بين 1 و 7", Then Exit Sub
If ErrorMsg(Combo1(13 (0, "الحالة التعليمية", 0, " يجب كتابة الحالة التعليمية", Then Exit Sub
If ErrorMsg(Combo1(14 (0, "حالة السائق", 0, " يجب كتابة حالة السائق", Then Exit Sub
If ErrorMsg(Combo1(15 (0, "حالات السكر للمتسبب", 0, " يجب كتابة حالات السكر للمتسبب", Then Exit Sub
If ErrorMsg(Combo1(16 (0, "التأمين", 0, " يجب كتابة التأمين", Then Exit Sub
If ErrorMsg(Combo1(12 (1, "السنة", 0, " يجب كتابة السنة", Then Exit Sub
If ErrorMsg(Combo2(4 (0, "جهة اصدار", 0, " يجب كتابة جهة اصدار", Then Exit Sub
If ErrorMsg(Combo2(5 (0, "نوع المركبة", 0, " يجب كتابة نوع المركبة", Then Exit Sub
If ErrorMsg(Combo2(6 (0, "نوع ناقل الحركة (الجيب)", 0, " يجب كتابة نوع ناقل الحركة (الجيب)", Then Exit Sub
If ErrorMsg(Combo1(17 (0, "نوع اللوحة", 0, " يجب كتابة نوع اللوحة", Then Exit Sub
If ErrorMsg(Combo2(7 (0, "لون المركبة", 0, " يجب كتابة لون المركبة", Then Exit Sub
If ErrorMsg(Combo5(0 (0, "صنف المركبة", 6, " يجب كتابة صنف المركبة", Then Exit Sub
If ErrorMsg(List4(1), "", 6 (4, " يجب كتابة صنف المركبة", Then Exit Sub
```

```
If ErrorMsg(List4(2), "", 6 (4, " يجب كتابة درجة الضرر", Then Exit Sub
```

```

'If ErrorMsg(Combo5(1 (0 " يجب كتابة درجة الضرر", 6, "درجة الضرر", Then Exit Sub
'If ErrorMsg(list4 (0 " يجب كتابة السبب الرئيسي للحدث", 6, "السبب الرئيسي للحدث", Then Exit Sub
'If ErrorMsg(Combo1(18 (0 " حزام الامان", 3, " يجب كتابة حزام الامان", Then Exit Sub
'If ErrorMsg(Combo1(22 (0 " الفاصل بين الشارعين", 3, " يجب كتابة الفاصل بين الشارعين", Then Exit Sub
'If ErrorMsg(Combo1(19 (0 " عدد المحاور", 3, " يجب كتابة عدد المحاور", Then Exit Sub

```

```

'If ErrorMsg(Combo1(23 (0 " العلامات المرورية", 3, " يجب كتابة العلامات المرورية", Then Exit Sub
If ErrorMsg(Combo1(20 (0 " اسم الطريق", 4, " يجب كتابة اسم الطريق", Then Exit Sub
If ErrorMsg(Combo1(24 (0 " تصنيف مكان وقوع الحادث", 4, " يجب كتابة تصنيف مكان وقوع الحادث", Then Exit Sub
If ErrorMsg(Combo1(26 (0 " تفاصيل ملتقى الطرق", 4, " يجب كتابة تفاصيل ملتقى الطرق", Then Exit Sub
If ErrorMsg(Combo1(21 (1 " حدود السرعة على الشارع", 4, " يجب كتابة حدود السرعة على الشارع", Then Exit Sub
'If ErrorMsg(Combo1(28 (0 " اخطاء الركاب", 4, " يجب كتابة اخطاء الركاب", Then Exit Sub
'If ErrorMsg(Combo1(27 (0 " وسائل عبور المشاة", 4, " يجب كتابة وسائل عبور المشاة", Then Exit Sub
If ErrorMsg(Combo1(25 (0 " اخطاء المشاة", 4, " يجب كتابة اخطاء المشاة", Then Exit Sub
If ErrorMsg(Combo1(29 (0 " الاضاءة", 4, " يجب كتابة الاضاءة", Then Exit Sub
If ErrorMsg(Combo1(30 (0 " الطلقس", 4, " يجب كتابة الطلقس", Then Exit Sub
If ErrorMsg(Text3, "", 0 (3 " يجب كتابة عيوب المركبة", Then Exit Sub

```

```

If ErrorMsg(Text4(3), "", 0 (3 " يجب كتابة اخطاء الركاب", Then Exit Sub

```

```

If ErrorMsg(Text4(1), "", 0 (3 " يجب كتابة اخطاء المشاه", Then Exit Sub

```

```

If ErrorMsg(Text4(2), "", 0 (3 " يجب كتابة سطح الطريق", Then Exit Sub

```

```

If ErrorMsg(Text4(4), "", 0 (3 " يجب كتابة الحالات الخاصة", Then Exit Sub

```

```

If ErrorMsg(Text5, "", 0 (3 " يجب كتابة السبب الرئيسي للحدث", Then Exit Sub

```

```

If ErrorMsg(List2, "", 0 (4 " يجب كتابة المراقبة والاشارات المرورية", Then Exit Sub
If ErrorMsg(List3(1), "", 0 (4 " يجب كتابة سطح الطريق", Then Exit Sub
If ErrorMsg(List3(0), "", 0 (4 " يجب كتابة حالات خاصة اخري", Then Exit Sub
If ErrorMsg(List1(2), "", 0 (4 " يجب كتابة الاجزاء المتضررة", Then Exit Sub
If ErrorMsg(List4(0), "", 0 (4 " يجب كتابة السبب الرئيسي للحدث", Then Exit Sub
If ErrorMsg(List1(1), "", 0 (4 " يجب كتابة العيوب في المركبة", Then Exit Sub
If CheckDate(Combo1(0), Combo1(1), Combo1(2 (2 " التاريخ غير صحيح", Then Exit Sub
If CheckDate(Combo3(0), Combo3(1), Combo3(2 (0 " التاريخ غير صحيح", Then Exit Sub
If CheckDate(Combo4(0), Combo4(1), Combo4(2 (0 " التاريخ غير صحيح", Then Exit Sub

```

```

'add information
If AddRecord = True Then
Rs_accident.AddNew
End If

```


With Rs_accident

```
.Fields("id") = Text6
.Fields("injury") = WhichOneIsSelected(Option1, 2(
.Fields("atype") = WhichOneIsSelected(Option2, 7(
.Fields("adate") = CDate(Combo1(0) & "/" & Combo1(1) & "/" & Combo1(2)((
.Fields("atime") = Combo1(3) & ":" & Combo1(4(
.Fields("timing") = WhichOneIsSelected(Option3, 3(
.Fields("day") = WhichOneIsSelected(Option4, 6(
.Fields("location") = WhichOneIsSelected(Option5, 13(
.Fields("nearby") = WhichOneIsSelected(Option6, 24(
.Fields("AccidentLocation") = WhichOneIsSelected(Option9, 2(
.Fields("peopleinroad") = WhichOneIsSelected(Option10, 7(
.Fields("belt") = Combo1(18(
.Fields("intersectionbetweenroads") = Combo1(22(
.Fields("numberofaxes") = Combo1(19(
.Fields("trafficsignals") = Combo1(23(
.Fields("tayerscondition") = WhichOneIsSelected(Option8, 2(
.Fields("glassblack") = WhichOneIsSelected(Option7, 1(
.Fields("nationality") = Combo2(0(
.Fields("age") = Combo2(1(
.Fields("gender") = Combo2(2(
.Fields("licenceissuedate") = CDate(Combo3(0) & "/" & Combo3(1) & "/" & Combo3(2)((
.Fields("licenceexpiredate") = CDate(Combo4(0) & "/" & Combo4(1) & "/" & Combo4(2)((
.Fields("placeissue") = Combo2(3(
.Fields("licencetype") = Combo1(11(
.Fields("licenceTypeoption") = WhichOneIsSelected(Option11, 2(

.Fields("educationallevel") = Combo1(13(
.Fields("drivercondition") = Combo1(14(
.Fields("drinkingcondition") = Combo1(15(
.Fields("otherdrivermistake") = Text2
.Fields("insurance") = Combo1(16(
.Fields("model") = Combo1(12(
.Fields("insuranceissueplace") = Combo2(4(
.Fields("cartype") = Combo2(5(
.Fields("roadtype") = Combo2(6(
.Fields("numberplatetype") = Combo1(17(
.Fields("carproblem") = CheckSelectedItemOnList(List1(1), Text3(
.Fields("carcolor") = Combo2(7(
.Fields("othercartype") = Combo5(0(
'passing text6 just to avoid error
.Fields("othercartype") = CheckSelectedItemOnList(List4(1), Text6(
'Combo5(0(
.Fields("damagepart") = CheckSelectedItemOnList(List1(2), Text6(
.Fields("damagecondition") = Combo5(1(
.Fields("damagecondition") = CheckSelectedItemOnList(List4(2), Text6(
```

```

.Fields("maincause") = CheckSelectedItemOnList(List4(0), Text5(
.Fields("roadnameduringaccident") = Combo1(20(
.Fields("accidentplacetype") = Combo1(24(
.Fields("roadnoduringaccident") = Text4(0(
.Fields("roaddetail") = Combo1(26(
.Fields("speedlimit") = Combo1(21(
.Fields("trafficsignalavailable") = CheckSelectedItemOnList(List2, Text6(
.Fields("light") = Combo1(29(
.Fields("roadsurface") = CheckSelectedItemOnList(List3(1), Text4(2((
.Fields("specialcases") = CheckSelectedItemOnList(List3(0), Text4(4((

```

```

If Text4(1).Visible = True Then
.Fields("passengermistake") = Text4(3(
Else
.Fields("passengermistake") = Combo1(28(
End If
.Fields("passengerwakingfacilities") = Combo1(27(
If Text4(1).Visible = True Then
.Fields("walkermistake") = Text4(1(
Else
.Fields("walkermistake") = Combo1(25(
End If
.Fields("weather") = Combo1(30(

```

```

For i = 0 To 6
.Fields(i + 8) = Text1(i(
Next

```

```

.UpdateBatch adAffectCurrent
End With

```

```

DisplayCmd True

```

```

Case 4

```

```

Me.Rs_accident.CancelUpdate
DisplayCmd True

```

```

End Select
End Sub

```

```

Private Sub DataGrid1_GotFocus(Index As Integer(
Dim i As Integer
If Index = 3 Then

```

```
DataGrid1(3).Col = 1
If InsertNew Then
Db.Execute "insertintothecar"
InsertNew = False
End If
```

```
For i = 0 To 5
DataGrid1(3).Row = i
DataGrid1(3).Text = Text6
Next
End If
End Sub
```

```
Private Sub DataGrid1_LostFocus(Index As Integer)
'If Index = 2 Then
'SSTab1.Tab = 4
'Combo1(20).SetFocus
'End If
End Sub
```

```
Private Sub DataGrid1_OnAddNew(Index As Integer)

DataGrid1(Index).Col = 1
DataGrid1(Index).Text = Text6

End Sub
```

```
Private Sub Form_Activate()
Set General_Form = FrmAccident
SSTab1.Tab = 2
End Sub
```

```
Private Sub Form_Load()
Dim Obj As Object
Set Rs_accident = New Recordset
Rs_accident.Open "SELECT * FROM ACCIDENTDETAIL ", Db, adOpenDynamic, adLockOptimistic
Set CollectComboValues = New Collection
For Each Obj In Me
If TypeOf Obj Is ComboBox Then
CollectComboValues.Add Obj.Text
End If
Next
```

```
Set Rs_Drivers = New Recordset
Rs_Drivers.Open "SELECT * FROM drivers ", Db, adOpenDynamic, adLockOptimistic
```

```
Set Rs_Passengers = New Recordset
Rs_Passengers.Open "SELECT * FROM passengers ", Db, adOpenDynamic, adLockOptimistic
```

```
Set Rs_People = New Recordset
Rs_People.Open "SELECT * FROM people ", Db, adOpenDynamic, adLockOptimistic
```

```
Set Rs_OtherCar = New Recordset
Rs_OtherCar.Open "select * from OtherCar", Db, adOpenDynamic, adLockOptimistic
```

```
Set DataGrid1(3).DataSource = Rs_OtherCar
Set DataGrid1(0).DataSource = Rs_Drivers
Set DataGrid1(1).DataSource = Rs_Passengers
Set DataGrid1(2).DataSource = Rs_People
'this to clear the grid information
GetGridInformation
```

```
End Sub
```

```
Private Sub DisplayCmd(Res As Boolean)
Command1(0).Visible = Res
Command1(1).Visible = Res
Command1(2).Visible = Res
Command1(3).Visible = Not Res
Command1(4).Visible = Not Res
```

```
End Sub
```

```
Function ErrorMsg(Obj As Object, objval As String, Tablocation As Integer, ErrMsg As String, TypeErr
As Integer, Optional min As Integer, Optional max As Integer) As Boolean
Dim i, j As Integer
Select Case TypeErr
Case 0
If Obj.Text = objval Then
MsgBox ErrMsg
Obj.SetFocus
SSTab1.Tab = Tablocation
ErrorMsg = True
End If
```

```
Case 1
```

```
If Not IsNumeric(Obj) Then
MsgBox ErrMsg
Obj.SetFocus
SSTab1.Tab = Tablocation
ErrorMsg = True
```

```
End If
```

```
Case 2
```

```
If objval < min Or objval > max Then
MsgBox ErrMsg
Obj.SetFocus
SSTab1.Tab = Tablocation
```

```
ErrorMsg = True  
End If
```

Case 3

```
If Obj.Visible And Obj = "" Then  
MsgBox ErrMsg  
Obj.SetFocus  
SSTab1.Tab = Obj.Tag  
ErrorMsg = True  
End If
```

Case 4

```
j = 0  
For i = 0 To Obj.ListCount - 1  
If Obj.Selected(i) = True Then  
j = j + 1  
Exit For  
End If
```

Next

```
If j = 0 Then  
MsgBox ErrMsg  
Obj.SetFocus  
SSTab1.Tab = Obj.Tag  
ErrorMsg = True  
End If
```

```
End Select  
End Function
```

```
Private Sub Frame4_DragDrop(Index As Integer, Source As Control, X As Single, Y As Single)  
  
End Sub
```

```
Private Sub List1_Click(Index As Integer)  
Select Case Index  
Case 1  
CheckList List1(1,2,"لايجوز اختيار اكثر من خيران",Text3, 1  
Case 2  
CheckList List1(2,6,"لايجوز اختيار اكثر من 6 خيرات",Text3, 0
```

```
End Select
```

End Sub

```
Private Sub CheckList(Obj As Object, ErrMsg As String, MaxSelect As Integer, ShowText As Object,
ShowOrNot As Integer)
Dim i, j As Integer
j = 0
For i = 0 To Obj.ListCount - 1
If Obj.Selected(i) = True Then
j = j + 1
If j > MaxSelect Then
MsgBox ErrMsg
Obj.Selected(i) = False
Exit For
End If
End If
Next
If ShowOrNot = 1 Then
If Obj.Selected(Obj.ListCount - 1) Then
ShowText.Visible = True
ShowText.SetFocus
Else
ShowText.Visible = False
End If
End If
End Sub
```

```
Private Sub List1__LostFocus(Index As Integer)
If Index = 1 Then
SSTab1.Tab = 6
DataGrid1(3).SetFocus
End If
End Sub
```

```
Private Sub List2_Click()
CheckList List2, 3, "لايجوز اختيار اكثر من 3 خيارات", Text2, 0
```

End Sub

```
Private Sub List3_Click(Index As Integer)
Select Case Index
Case 0
CheckList List3(0, 2, "لايجوز اختيار اكثر من 3 خيارات", Text4(4), 1
Case 1
CheckList List3(1, 4, "لايجوز اختيار اكثر من 4 خيارات", Text4(2), 1
End Select
```

End Sub

```
Private Function WhichOneIsSelected(Obj As Object, NumberOfOption As Integer) As Integer
```

```

Dim i As Integer
For i = 0 To NumberOfOption
If Obj(i).Value = -1 Then
WhichOneIsSelected = i
Exit Function
End If
Next
End Function

```

```

Private Function CheckDate(Obj1 As Object, Obj2 As Object, Obj3 As Object, ErrMsg As String,
Tablocation As Integer) As Boolean
Dim TempDate As String
TempDate = Obj1 & "/" & Obj2 & "/" & Obj3

```

```

If Not IsDate(TempDate) Then
MsgBox ErrMsg
Obj1.SetFocus
SSTab1.Tab = Tablocation
CheckDate = True
End If
End Function

```

```

Private Sub SetAndClearControls()
Dim Obj As Object
Dim j, i As Integer
j = 1
For Each Obj In Me
If TypeOf Obj Is ComboBox Then
Obj.Text = CollectComboValues.Item(j)
j = j + 1
ElseIf TypeOf Obj Is TextBox Then
Obj.Text = ""
ElseIf TypeOf Obj Is ListBox Then
For i = 0 To Obj.ListCount - 1
Obj.Selected(i) = False
Next
End If
Next
GetGridInformation
End Sub

```

```

Public Sub GetInformation()
Dim i As Integer
SetAndClearControls
With Rs_accident

Text6 = .Fields("id("
Option1(.Fields("injury")).Value = -1
'this is to get the grid information
GetGridInformation

```

```

Option2(.Fields("atype")).Value = -1

Combo1(0) = Mid(.Fields("adate"), 1, 2(
Combo1(1) = Mid(.Fields("adate"), 4, 2(
Combo1(2) = Mid(.Fields("adate"), 7(

Combo1(3) = Mid(.Fields("atime"), 1, InStr(1, .Fields("atime"), ":") - 1(
Combo1(4) = Mid(.Fields("atime"), InStr(1, .Fields("atime"), ":") + 1(
Option3(.Fields("timing")).Value = -1
Option4(.Fields("day")).Value = -1
Option5(.Fields("location")).Value = -1
Option6(.Fields("nearby")).Value = -1
Option9(.Fields("AccidentLocation")).Value = -1
Option10(.Fields("peopleinroad")).Value = -1
Combo1(18) = .Fields("belt("
Combo1(22) = .Fields("intersectionbetweenroads("
Combo1(19) = .Fields("numberofaxes("
Combo1(23) = .Fields("trafficsignals("
Option8(.Fields("tayerscondition")).Value = -1
Option7(.Fields("glassblack")).Value = -1
Combo2(0) = .Fields("nationality("
Combo2(1) = .Fields("age("
Combo2(2) = .Fields("gender("
.Fields("licenceissuedate") = CDate(Combo3(0) & "/" & Combo3(1) & "/" & Combo3(2)((
Combo3(0) = Mid(.Fields("licenceissuedate"), 1, 2(
Combo3(1) = Mid(.Fields("licenceissuedate"), 4, 2(
Combo3(2) = Mid(.Fields("licenceissuedate"), 7(
.Fields("licenceexpiredate") = CDate(Combo4(0) & "/" & Combo4(1) & "/" & Combo4(2)((
Combo4(0) = Mid(.Fields("licenceexpiredate"), 1, 2(
Combo4(1) = Mid(.Fields("licenceexpiredate"), 4, 2(
Combo4(2) = Mid(.Fields("licenceexpiredate"), 7(

Combo2(3) = .Fields("placeissue("
Combo1(11) = .Fields("licencetype("

Option11(.Fields("licenceTypeoption")).Value = -1

Combo1(13) = .Fields("educationallevel("
Combo1(14) = .Fields("drivercondition("
Combo1(15) = .Fields("drinkingcondition("
Text2 = .Fields("otherdrivermistake("
Combo1(16) = .Fields("insurance("
Combo1(12) = .Fields("model("
Combo2(4) = .Fields("insuranceissueplace("
Combo2(5) = .Fields("cartype("
Combo2(6) = .Fields("roadtype("
Combo1(17) = .Fields("numberplatetype("
SetListValues List1(1), .Fields("carproblem"), Text3
Combo2(7) = .Fields("carcolor("

```



```

'Combo5(0) = .Fields("othercartype("

SetListValues List4(1), .Fields("othercartype"), Text6

SetListValues List1(2), .Fields("damagepart"), Text6
' Combo5(1) = .Fields("damagecondition("
SetListValues List4(2), .Fields("damagecondition"), Text6

SetListValues List4(0), .Fields("maincause"), Text5
Combo1(20) = .Fields("roadnameduringaccident("
Combo1(24) = .Fields("accidentplacetype("
Text4(0) = .Fields("roadnoduringaccident("
Combo1(26) = .Fields("roaddetail("
Combo1(21) = .Fields("speedlimit("
SetListValues List2, .Fields("trafficsignalavailable"), Text6
Combo1(29) = .Fields("light("
SetListValues List3(1), .Fields("roadsurface"), Text4(2(
SetListValues List3(0), .Fields("specialcases"), Text4(4(
Combo1(28) = .Fields("passengermistake("
Combo1(27) = .Fields("passengerwakingfacilities("
Combo1(25) = .Fields("walkermistake("
Combo1(30) = .Fields("weather("

```

```

For i = 0 To 6
    Text1(i) = .Fields(i + 8(
Next

```

```

End With
End Sub

```

```

Private Function CheckSelectedItemOnList(Obj As Object, Optional ObjText As Object) As String
Dim i As Integer
Dim j As String
j"" =
For i = 0 To Obj.ListCount - 1
If Obj.Selected(i) = True Then
j = j + CStr(i", " + (
End If
Next
If ObjText <> Text6 Then
If ObjText.Visible Then
CheckSelectedItemOnList = j + ObjText.Text
Else
CheckSelectedItemOnList = j
End If
Else
CheckSelectedItemOnList = j
End If

```

End Function

```
Private Sub SetListValues(Obj As Object, listValues As String, ObjText As Object)
Dim i, j As Integer
Dim ivalue As String
i = 1
j = InStr(i, listValues(",", " ,
While (i < j(
ivalue = Mid(listValues, i, j - i(
Obj.Selected(Int(ivalue)) = True
i = j + 1
j = InStr(i, listValues(",", " ,
Wend

If Right(listValues, 1) <> "," Then
ObjText = Mid(listValues, i(
End If
```

End Sub

```
Private Sub GetGridInformation()
Rs_OtherCar.Requery
If Text6 = "" Then
Rs_Drivers.Filter = "mainid = -1"
Rs_Passengers.Filter = "mainid= -1"
Rs_People.Filter = "mainid= -1"
Rs_OtherCar.Filter = "mainid= 1"
Else
Rs_Drivers.Filter = "mainid = " & Text6
Rs_Passengers.Filter = "mainid=" & Text6
Rs_People.Filter = "mainid=" & Text6
Rs_OtherCar.Filter = "mainid=" & Text6
End If
```

```
DataGrid1(0).Refresh
DataGrid1(1).Refresh
DataGrid1(2).Refresh
DataGrid1(3).Refresh
```

End Sub

```
Private Sub List3_LostFocus(Index As Integer)
If Index = 0 Then
SSTab1.Tab = 3
Combo1(18).SetFocus
End If
End Sub
```

```
Private Sub List4_Click(Index As Integer)
```

```
Select Case Index
Case 0
CheckLList List4(0,7," خيرات 7",Text5, 1
Case 1
CheckLList List4(1,4," خيرات 4",Text6, 0

Case 2
CheckLList List4(2,4," خيرات 4",Text6, 0
End Select

End Sub
```

```
Private Sub List4_LostFocus(Index As Integer)
If Index = 0 Then
SSTab1.Tab = 5
DataGrid1(0).SetFocus
End If
End Sub
```

```
Private Sub Text1_LostFocus(Index As Integer)
If Index = 6 Then
SSTab1.Tab = 1
Option6(0).SetFocus
End If

End Sub
```

- 2) **Accident Model** this program is use to predict the accident rate and the safety index of a given road by given its parameters

As snap shot of the program is given below

Variable	Values
Rutting	NA
Corrigation	NA
Bleeding	NA
Intersection type	R.A.
Free Right turn Availability	NA
Separate left turn lane	1
No Of Legs	3
Intersection Angle	90
Storage area for	NA
Sector Parking exit upstream	1
Sector parking entrance	1
Allowed Yellow Time(sec)	1
All Red Time(sec)	1
Traffic Signal Sequence	1
Traffic Signal Position	1
Cycle Length(sec)	1
Total No Of Phases	1
Green wave availability	NA
Advanced warning signs for	NA
Marking Condition	0.05
%Heavy Vehicles	0.5
%Taxi	low
	30

The source code is given below

Option Explicit

Public RowCount As Integer

Public MakeSelect As Boolean

```
Private Sub Command1_Click(Index As Integer)
```

```
Dim i As Integer
```

```
Dim sum As Double
```

```
sum = 0
```

```
For i = 0 To 24
```

```
sum = sum + bValue(i + 1, IIf(Combo1(i).ListIndex = -1, 2, Combo1(i).ListIndex + 2)((
```

```
Next
```

```
MsgBox "The Signalized Safety index for the above data is " & Format((100 - sum), "###.##"), , "S.S.I".
```

```
End Sub
```

```
Private Sub Form_Activate()
```

```
DitherRed Me
```

End Sub

```
Private Sub Form_Load()
Dim Irow, Icount, i, j As Integer
Dim ReadingFromTxt As String
Dim RowCount As Integer
Open App.Path & "\\Variable.txt" For Input As #1

Dim txtobj As Excel.Workbook
Irow = 1
MSFlexGrid1.Row = 0
MSFlexGrid1.Col = 1
MSFlexGrid1.Text = "Values"
MSFlexGrid1.Col = 0
MSFlexGrid1.ColWidth(0) = 3000
MSFlexGrid1.ColWidth(1) = 3000
Combo1(0).Left = MSFlexGrid1.Left + 3040
Combo1(0).Width = 3000
MSFlexGrid1.Text = "Variable"
While Not EOF(1)
MSFlexGrid1.Rows = Irow + 1
MSFlexGrid1.Row = Irow
Input #1, ReadingFromTxt
MSFlexGrid1.Text = ReadingFromTxt
Irow = Irow + 1
Wend
Close #1
RowCount = Irow
'Text1.Height = MSFlexGrid1.RowHeight(0)
MSFlexGrid1.ColAlignment(1) = 0
MakeSelect = True

Combo1(0).ZOrder (0)
For RowCount = 1 To 24
Load Combo1(RowCount)
Combo1(RowCount).Visible = True
Combo1(RowCount).Top = Combo1(RowCount - 1).Top + Combo1(RowCount - 1).Height + 16
Combo1(RowCount).ZOrder (0)
Next

Set txtobj = GetObject(App.Path & "\\variable.xls")

txtobj.Application.Visible = True
txtobj.Parent.Windows(1).Visible = True
txtobj.Application.Sheets("Vairable").Select
For i = 1 To 25
aValue(i, 1) = txtobj.Application.ActiveSheet.Range("a" & i)
aValue(i, 2) = txtobj.Application.ActiveSheet.Range("b" & i)
aValue(i, 3) = txtobj.Application.ActiveSheet.Range("c" & i)
aValue(i, 4) = txtobj.Application.ActiveSheet.Range("d" & i)
aValue(i, 5) = txtobj.Application.ActiveSheet.Range("e" & i)
aValue(i, 6) = txtobj.Application.ActiveSheet.Range("f" & i)
aValue(i, 7) = txtobj.Application.ActiveSheet.Range("g" & i)
```

Next

```
txtobj.Application.Sheets("Values").Select
For i = 1 To 25
bValue(i, 1) = txtobj.Application.ActiveSheet.Range("a" & i(
bValue(i, 2) = txtobj.Application.ActiveSheet.Range("b" & i(
bValue(i, 3) = txtobj.Application.ActiveSheet.Range("c" & i(
bValue(i, 4) = txtobj.Application.ActiveSheet.Range("d" & i(
bValue(i, 5) = txtobj.Application.ActiveSheet.Range("e" & i(
bValue(i, 6) = txtobj.Application.ActiveSheet.Range("f" & i(
bValue(i, 7) = txtobj.Application.ActiveSheet.Range("g" & i(
Next
```

```
txtobj.Parent.Windows(1).Visible = False
txtobj.Close 0
```

```
Set txtobj = Nothing
```

```
For i = 0 To 24
For j = 2 To aValue(i + 1, 1) + 1
Combo1(i).AddItem aValue(i + 1, j(
Next
Combo1(i).Text = Combo1(i).List(0(
Next
```

```
frmDiplomatic.Show
Combo1(0).SetFocus
```

```
End Sub
```

```
Private Sub Form_Unload(Cancel As Integer)
Dim RowCount As Integer
For RowCount = 1 To 24
Unload Combo1(RowCount(
Next
End Sub
```

3) Data Enquiry Program : to given statistical information about intersection

snap shot is given below

The screenshot shows a software application window titled "Signalized Safety Index - [ابحث عن حادث]". The window has a menu bar with "File" and a toolbar with standard window controls. The main area contains a search form with the following fields and controls:

- Location: A text input field.
- Direction: A dropdown menu with "الكل" (All) selected.
- Time: A dropdown menu with "الكل" (All) selected.
- Vehicle Type: A dropdown menu with "الكل" (All) selected.
- Accident Type: A dropdown menu with "الكل" (All) selected.
- Buttons: "الخروج" (Exit), "الطباعة" (Print), and "البحث" (Search).

Below the search form is a table with the following columns:

accname	locationid	location	etime	adate	vtimind	madate	vdsw	vatvpe	id	Accident
[The table body is mostly blank, suggesting no data is currently displayed or it is obscured by a watermark.]										

the Source code

Option Explicit

```
Public Rs_Find As Recordset  
Private sqlString(20) As String
```

```
Public SqlQuery As String
```

```
Private Sub cmdCancel_Click()  
Me.Hide  
End Sub
```

```
Private Sub CmdFind_Click()  
'On Error Resume Next  
Dim Icount As Integer  
Set Rs_Find = New Recordset
```

For Icount = 0 To 15

sqlString(Icount) = (
Next

If txtfields(0) <> "" Then sqlString(0) = " id=" & txtfields(0)
If txtfields(1) <> "" Then sqlString(1) = " ip LIKE '%" & txtfields(1) & "
If txtfields(2) <> "" Then sqlString(2) = " year(adate)=" & txtfields(2) & "
If Combo1.Text "الكل" <> Then sqlString(3) = " Injury =" & Combo1.ListIndex
If Combo2.Text "الكل" <> Then sqlString(4) = " atype =" & Combo2.ListIndex
If Combo3.Text "الكل" <> Then sqlString(5) = " timing =" & Combo3.ListIndex
If Combo4.Text "الكل" <> Then sqlString(6) = " day =" & Combo4.ListIndex
If Combo5.Text "الكل" <> Then sqlString(7) = " location =" & Combo5.ListIndex

'If txtfields(5) <> "" Then sqlString(4) = " note LIKE '%" & txtfields(5) & "
'If Combo1 "الجهة الوارد اليها" <> Then sqlString(5) = " letter_in =" & Combo1 & "
' If txtfields(5) <> "" Then sqlString(6) = " note LIKE '%" & txtfields(4) & "

For Icount = 0 To 14

If sqlString(Icount) <> "" Then sqlString(15) = sqlString(15) + sqlString(Icount) + " and"
Next

If sqlString(15) <> "" Then

sqlString(15) = Left(sqlString(15), Len(sqlString(15)) - 5(

SqlQuery = sqlString(15(

Rs_Find.Open "select * from qAccidentDetail where " & sqlString(15), DbConn, adOpenForwardOnly,
adLockOptimistic

Else

Rs_Find.Open "select * from qAccidentDetail", DbConn, adOpenForwardOnly, adLockOptimistic

End If

If Not (Rs_Find.EOF And Rs_Find.BOF) Then

Select Case Rs_Find.RecordCount

Case 1

MsgBox "لقد حصلنا على حادث واحدة"

' Command1.Enabled = True

Case 2

MsgBox "لقد حصلنا على حدثان"

' Command1.Enabled = True

Case Else

MsgBox & " رسائل " Rs_Find.RecordCount " لقد حصلنا على "

' Command1.Enabled = True

End Select

'call the funtion to find the information about the out going letter

Else

MsgBox "لايوجد اي رسالة بهذه التفاصيل"

End If

Set DataGrid1.DataSource = Rs_Find

DataGrid1.Refresh


```

'DataGrid1.Columns(0).Caption"رقم الوارد" =
'DataGrid1.Columns(1).Caption"رقم الرسالة" =
'DataGrid1.Columns(2).Caption"التاريخ" =
'DataGrid1.Columns(3).Caption"من" =
'DataGrid1.Columns(3).Width = 150
'DataGrid1.Columns(4).Caption"الى" =
'DataGrid1.Columns(4).Width = 150
'DataGrid1.Columns(5).Caption"الموضوع" =
'DataGrid1.Columns(5).Width = 150
'DataGrid1.Columns(6).Caption"الملاحظة" =
'DataGrid1.Columns(6).Width = 3500
'DataGrid1.Columns(6).WrapText = True

```

```

'Rs_Find.Close
End Sub

```

```

Private Sub Command1_Click()
Dim Icount As Integer
CrystalReport1.Connect = "DSN = server;UID = letter_in_out;PWD = letter_in_out";
If IsDate(txtfields(2)) And IsDate(txtfields(6)) Then
sqlString(2) = " letter_date>=to_date('" & CDate(txtfields(2)) & "','dd/mm/yyyy') and
letter_date<=to_date('" & CDate(txtfields(6)) & "','dd/mm/yyyy" ('
sqlString(6) = (
For Icount = 0 To 5
If sqlString(Icount) <> "" Then sqlString(6) = sqlString(6) + sqlString(Icount) + " and"
Next

sqlString(6) = Left(sqlString(6), Len(sqlString(6)) - 5(
SqlQuery = sqlString(6(
End If
CrystalReport1.SqlQuery = "SELECT v_all_embassy.* From V_all_EMBASSY where " & SqlQuery

```

```

CrystalReport1.PrintReport
'ID, LOCATION_ID, NAME, LETTER_NO, LETTER_DATE, SUBJECT, NOTE,LETTER_IN
'where " & SqlQuery" &
'Order By LETTER_IN ASC,LOCATION_ID ASC
Command1.Enabled = False
End Sub

```

```

Private Sub DataGrid1_Click()
On Error Resume Next
Dim Temp As String
Dim i As Integer
txtfields(4) = Rs_Find.Fields(6(
For i = 1 To Len(txtfields(4)) Step 80
Temp = Temp + Mid(txtfields(4), i, 80) + Chr(13) + Chr(10(
Next
txtfields(4) = Temp

```