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Evaluation of the Effectiveness of Speed Cameras on Road Safety in the Emirate of Abu Dhabi Roads

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ABSTRACT

The problem of road safety in the Emirate of Abu Dhabi is eminent. According road crash data from the Ministry of Interior, from 1999 to 2007 the averaged percentage of deaths due to road crashes in the Emirate of Abu Dhabi was 42 percent of the whole UAE. The high death rate due to road crashes has enormous economic and financial loss to the Emirate. The previous research on road safety in the UAE reported that the aberrant driving behavior is one of the major causes for road crashes in the UAE. The aberrant driving behavior includes careless driving, speeding, tailgating, flashing, and disregarding traffic regulations. To control the aberrant driving behavior, and consequently, improve the road safety, a number of strategies have been implemented in the UAE over the last several years. One of the strategies has been to increase traffic surveillance by installing speed cameras. Speed cameras have been recognized as an effective measure in improving the road safety in many countries including UK, USA, Canada, Australia, and European countries.

The aim of this study was to evaluate the effectiveness of speed cameras in reducing road crashes on some selected roads in the Emirate of Abu Dhabi. The road crash data of six years (from 2002 to 2007) was collected from the Road Traffic Safety department in the Emirate of Abu Dhabi. Using the before and after with comparison group methodology, the data was analyzed to assess the effectiveness of speed cameras. The study found that the speed cameras have been effective in reducing the crashes as well as severity of crashes along the selected roads. However, in order to realize maximum benefits of speed management strategies along these roads, the study recommends: 1) increasing the number of speed cameras. 2) Using other mechanism of traffic surveillance such as regular police patrol as this would help in detecting various types of traffic violations that cannot be detected by speed cameras such as: sudden deviation, wrong overtaking, following too close to the vehicle in front and tailgating etc...

In addition, it is recommended that in order to enhance the effectiveness of speed cameras on these roads and the entire road network in the Emirate of Abu Dhabi, the following actions could be taken;

1. Appraising current road safety performance through high-level strategic review;
2. Adopting a far-reaching road safety vision or goal for the longer term;
3. Analysing what could be achieved in the shorter term;

4. Agreeing targets and ensuring accountability across the road safety partnership;
5. Setting Safety Performance Indicators (SPI);
6. Continuous monitoring of targeted and other safety performance indicators;
7. Establishing the effectiveness of specific road safety measures by carrying out before and after studies; and
8. Reviewing and updating of policies and measures with re-distribution of resources towards more cost-effective measures; identifying delays in implementation requiring corrective action.

DEDICATION

To my beloved Parents, Brothers and Sisters.

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Finally, I would like to acknowledge the inputs of those who assisted me in one way or the other towards the final realization of the goals of the entire masters program.

Once again, thanks to you all, I couldn't have done it alone!

DECLARATION

The undersigned certifies that he has read and hereby recommends for acceptance by the United Arab Emirates University a dissertation entitled: ***Evaluation of the Effectiveness of Speed Cameras on Road Safety in the Emirate of Abu Dhabi Roads,*** in partial fulfilment of the requirements for the award of a Masters degree in Civil Engineering.

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Dr. Arif Mehmood

(Supervisor)

Date: June 23, 2009

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Chapter 1: Introduction

1.1 Background Information

Road safety is a major concern in the United Arab Emirates (UAE). According to the Ministry of Interior, throughout the UAE more than 1,000 people died, and about 12,000 injured due to road crashes in 2007 (Road Traffic Accident Statistical Annual Report, 1999 to 2007). These deaths represent an increase of 20 percent on the previous year. The road crash fatality rates in the UAE and other Gulf countries are comparatively higher than those of the developed countries with comparable vehicle ownership levels (Jadaan et al., 1992).

The high death rates associated with road crashes have enormous economic and financial loss to a country. According to the International Road Federation Report (2006) on road safety, in 2006 the financial loss due to road crashes was about Dhs 4 Billion (1.6 percent of the UAE's Gross National Product). Acknowledging the magnitude of road crashes burden, any efforts aimed at the reduction in death rate associated with road crashes would therefore have a substantial economic and financial savings to the UAE.

The previous research on road safety in the UAE (for example, Bener, 1992, 2001; Bener et al, 1994; Abdalla, 2002; Mehmood, 2009) reported that driver behaviour is one of the major contributory factors of road crashes in the UAE and other Gulf countries along side roadway, vehicular and environmental factors.

To control driver behaviours, and consequently, to improve the road safety, a number of strategies have been implemented in the UAE over the last several years. These strategies for example, include introducing tough penalties for violating traffic laws, and installing speed detecting cameras on various roads. The tough penalties for violating traffic laws include hefty amount of fine for violations and in some cases charging "Black Points" to drivers for violating traffic laws. On March 01, 2008 a new law of demerit points system was introduced in the UAE. With this new law if a driver accumulates 24 points in a year, his/her driving license will be confiscated for six months and his or her vehicle for a month. In addition to introducing tough penalties on traffic rules violators, a number of speed detecting cameras has been increased to monitor violations of traffic rules.

Installation of speed cameras started in 1991 (Abdalla, 2002). There are two types of speed cameras, i.e. one is fixed and the other one is mobile. The fixed speed cameras are installed along the major roads in the UAE that uses the photo radar technique in which the camera takes the picture of vehicle violating the prescribed speed limit. Due to cultural norms in the UAE, in the Emirate of Abu Dhabi the cameras are positioned to take the pictures from the back of the vehicle. In addition, speed gun radars are currently used on some roads by traffic police to monitor violations of speed limits. Currently the roads equipped with the fixed speed cameras include the main freeways and primary arterials, for example, Abu Dhabi - Al Ain Road, Abu Dhabi - Dubai Road, Abu Dhabi - Swehaan Road, Al Salaam and Arabian Gulf Roads in Abu Dhabi.

The effectiveness of speed cameras in improving the road safety on these roads is not well known. It is observed that drivers slow down close to the surveillance area and speed up when they move away from it (Mehmood, 2009). Ali et al., reported in Webster, (2000) that speed cameras have not had the desirable effects on the speeding behaviour of drivers in the oil rich nations of the Middle East. However, speed cameras have been recognized as an effective measure in improving the road safety in many countries including UK, USA, Australia, and Europe (OECD, 2003; Gains et al., 2004; Elvik and Vaa, 2004; Goldenbeld et al., 2005; OECD, 2006).

1.2 Objective and Scope

The primary objective of this research is to evaluate the impact of speed cameras on road safety in the Emirate of Abu Dhabi. The Emirate of Abu Dhabi is one of the seven emirates that constitute the UAE. Abu Dhabi is the largest emirate by area (86 % of the total land area of the UAE), and the second largest by population, after Dubai.

To achieve the objective of this research, the main tasks carried out included:

1. A collection of the time series data of road crashes for the Emirate of Abu Dhabi
2. Obtaining the information of speed cameras installed in the Emirate of Abu Dhabi. The information included the time of installation and the locations of speed cameras.
3. A literature review on various methods applied to evaluate the effectiveness of road safety measures.
4. An evaluation the effectiveness of speed cameras on road safety using a method: "Before and After Study with Comparison Group"

1.3 Thesis Outline

This thesis is organized in five chapters. Chapter 2 describes the literature review on speed cameras and methods for evaluating effectiveness of measures. Chapter 3 provides the details of data collection. Analysis of data is discussed in Chapter 4. The conclusions and directions for future research work are presented in the last chapter.

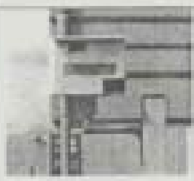
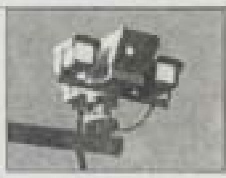
Chapter 2: Literature Review

This chapter is divided into three sections. The first section provides a general overview of the speed cameras employed in detection of speed violations. The second section describes the effectiveness of using speed cameras to improve the road safety in different countries. The statistical methods applied to evaluate the effectiveness of various road safety measures are discussed in the third section.

2.1 Speed Cameras

There are various types of speed cameras employed in different countries to detect the violations of speed limits. These types include GATSO, SPECS, Dash Mounted radar, Mobile Speed Camera, Hand-held laser. The pictures of these cameras are shown in the Table 1.

Table 1: Example of various cameras to detect speed violations

				
GATSO Speed Camera	SPECS Speed Camera	Dashboard Mounted radar	Mobile Speed Camera	Hand-held laser speed gun

In UK, the most commonly used speed cameras are GATSO, and SPECS. Whereas these two types of speed cameras use the infrared technology to record the speed of vehicle, the former uses the film while the later employs the digital technology. The GATSO speed camera capture the spot speed of vehicles within the speed zone while the SPECS camera works in pairs and calculates the average speed of a vehicle over a distance from one camera to another.

The laser speed gun employs the principle of reflection time of light, which estimates the round-trip time for light to strike a car and reflect back. Light waves from a laser speed gun travels faster than sound – about 300,000,000 metres per second. A laser speed gun shoots a very short burst of infrared laser light and then waits for it to reflect off the vehicle. The officer has to aim the laser speed gun at a specific target therefore the officer will only target vehicles he deems to be travelling at speeds over the posted speed limits. The mobile speed camera and dashboard mounted radar are vehicle in built technologies that signals the driver when a certain speed limit is exceeded.

2.2 Effectiveness of Speed Cameras

The use of speed cameras has been recognized as an effective measure in improving the road safety in many countries. For example, Elvik and Vaa (2004) reported that, based on a meta-analysis of studies related to evaluating the impact of speed cameras on road safety, in the period 1984-1996, speed cameras helped to reduce the total number of all road crashes by 19 percent in USA. Other studies show very similar results (see Goldenbeld et al., 2005), and a few studies show even larger effects. For example, in Australia, a very intensive speed enforcement program contributed to a 41 percent reduction in fatal[1] road crashes. Similarly, in the UK, Gains et al. (2004) estimated a 42 percent reduction in fatalities or seriously injured casualties in response to the national safety camera program. Furthermore, a report by the OECD (2003) pointed out a 50 percent reduction in road crash fatalities in Europe, and 22 percent in New South Wales.

Similar evidence of the effectiveness of cameras in reducing speeding is found in Washington, D.C. where speeding violations dropped from 25.5 percent to 2.2 percent (District of Columbia, 2006). Other evidence of the effectiveness of speed cameras is reported in New South Wales (Anderson and Edgar, 2003), in British Columbia (Chen et al., 2002), and in New Zealand (Keall et al., 2001, 2002). An evaluation of a hidden speed camera program in New Zealand by Keall et al. (2002) concluded that hidden cameras were significantly more effective at broadly deterring speeding than were visible cameras, but that both mobile and fixed cameras were effective in reducing speed violations.

[1] Road crashes that result into instant death or death within the first 30 days of hospitalisation

Wilson et al. (2006), reviewed studies related to evaluating impact of speed camera on road safety, and noted that in these studies after the implementation of speed enforcement program there were reductions ranging from 14 to 72 percent in all crashes, 8 to 46 percent for fatal crashes and 40 to 45 percent for crashes involving serious injuries.

Pilkington and Kinra (2005) reviewed 14 speed camera studies and concluded that speed cameras are an effective intervention in reducing road traffic collisions and related casualties. Newstead and Cameron (2003) evaluated the crash effect of the speed camera in Queensland and reported that Queensland speed camera program produced a reduction in fatal crashes of around 45 percent in areas within 2 Km of speed camera sites. A study in the Netherlands evaluated the effects of Automated Speed Enforcement (ASE) when combined with variable message sign warnings. This study found that average speeds were reduced by 5 km/hr and the 85th percentile speeds were reduced by 8 km/hr. The percent of vehicles speeding declined by 27 percent after the system was installed (Shankar and Manerring, 1996).

Canada and Australia have both used automated speed enforcement. In Ontario, a one year ASE pilot program reduced the number of vehicles exceeding the speed limit by 50 percent. The number of vehicles traveling at more than 40 km/hr over the speed limit was reduced by 74 percent. Similarly, in Australia, the percent of traffic exceeding the speed threshold for enforcement fell from 10.8 percent to 2.4 percent after the ASE system was implemented (Edwards, 2001). In Canada the use of speed cameras was found to be associated with a 9% reduction in crashes and a 2.8 km/h fall in mean speeds at sites where the units were located (Chen, Meckle, and Wilson, 2002).
Jones et al., (2008) assessed the impact of crash and casualty numbers in correspondence to the introduction of mobile speed cameras in the rural county of Norfolk, England. They studied 29 camera sites, and reported that the deployment of mobile speed cameras is an effective Tool to reduce road traffic casualties in areas where high crash rates have been associated with excessive vehicle speeds.

2. 3 Methods to Evaluate the Effectiveness of Road Safety Measures

Over the past several decades, various methods have been developed to estimate the effectiveness of countermeasures in transportation studies. In this section different methods applied to measure effectiveness of road safety measures are discussed. These methods are:

- Before and After Models
  - Simple Before-and-After Model
  - Before-and-After with weights
  - Before-and-After with comparison or control group
- Crash Reduction Factor
- Collision Modification Factor
- Cross-Sectional Models
- Empirical Bayesian Method (EBM)
- Propensity Score Method (PSM)

In this study, the before and after with comparison group and the crash reduction factor methods have been used to evaluate the effectiveness of speed cameras on the selected study roads. The next section provides a brief discussion of these methods.

2.3.1 Before and After Models

Before-after models have been widely used to estimate the effects of countermeasure in road safety studies. The approach analyzes the sites with only one or more improvements, while other characteristics are remained the same. In before and after models, the effect of a given countermeasure is determined by comparing predicted or observed number of crashes after the countermeasure is introduced to the number of crasehs had there been no countermeasure (Hauer 1997, Persaud 2001). There are three types of before-after models have been commonly cited in the literature.

These are:

a) Simple Before and After method

b) Before-and-After with Weights

c) Before-and-After with Control or Comparison Group

a) Simple Before-and-After Method

In a simple before-and-after method, the safety effect of a countermeasure is determined by the difference in the number of crashes occurring before the improvement with those occurring after. For example, while evaluating the effect of speed cameras on crashes at road sections, the crash experience before a camera is installed is compared with the crash experience after the camera is installed. The assumption in this study design is that the crash frequency in the after period would have been the same as the before period if the camera had not been installed. When the crashes are quantified for the before-and-after periods, the crashes in the two periods must be compared, and differences in the two quantities of crashes calculated in order to determine the direction of change. In this method, it is assumed that if nothing has changed, the crash experience before improvement is a good estimate of what would have happened in the after period without the improvement. The safety effect of a measure or crash reduction factor (CRF) in simple before and after method is determined by following equation.

$$CRF = 1 - \frac{N_A}{N_B}$$

Where,

N_B	=	Number of observed crashes at a treated site before (or without any measure)
N_A	=	Number of observed crashes at a treated site after (or with any measure)

According to above equation when N_A is greater than N_B, the CRF will be negative that will imply that treatment or implemented measure is ineffective to reduce the number of crashes.

The simple before-and-after methodology is attractive because it allows a comparison to be performed without having to consider variations between locations (Persaud, 2001). It requires few road sections and less effort than the other before-and-after study designs. However, there are some well-documented potential drawbacks to using a simple before-and-after evaluation, which should be considered because they may affect the confidence of the findings of the evaluation.

b) Before-and-After With Weights

When before/after data are available from two or more treatment locations, those data may often be combined to produce one overall estimate of treatment effect. If the treatment locations have similar characteristics and can be appropriately combined, this will provide more accuracy and precision in the analysis of the effectiveness of speed cameras. Griffin (1989) has developed a weighting scheme that estimates the overall treatment effect based on the weighted average of the estimated effects at each location. The before and after method with weighting scheme does not address temporal effects nor regression to the-mean problem (Persaud, 2001).

c) Before-and-After with Comparison Group

Researchers have developed the before-and-after method with comparison group to solve the problems associated with simple before and after method (Mountain et al., 1992, Hauer, 1997). A comparison group refers to a group of control sites selected as being similar enough to the treatment sites in traffic volume and geographic characteristics. In this method, crash data at the comparison group are used to estimate crashes that would have occurred at the treated sites if the treatment had not been made. This method can potentially produce more accurate estimates than a simple before-and-after method. Its strength increases as the similarity between treated and comparison sites increases (Mountain et al., 1992).

The before-and-after with comparison group method is based on two fundamental assumptions (Hauer, 1997):

1. The factors that affected safety have changed in the same way from the before period to after the improvement period at both treatment and comparison groups, and
2. The changes in the various factors influence the safety of treatment and comparison groups in the same manner.

These assumptions imply that the change in the number of crashes before and after the implementation of countermeasures in the treated sites, if the treatment had not been improved, would have been in the same proportion as that for the comparison group.

A before and after with comparison group methodology involves a paired comparison of crashes and traffic laws violations data taken twice at a selected site, once before a countermeasure and once after a countermeasure (Hauer, 1997). The measurements at the treated sites are then compared with those of the comparison sites. The treatment and comparison sites should exhibit similar roadway and traffic characteristics. The crash experience before the treatment is compared with the crash experience after treatment. This crash experience is compared with the same before-and-after periods in the comparison group.

In literature, various formulas have been proposed to estimate effectiveness of a measure in the before-and-after study with comparison group method. Most commonly used formula is as follows (Pendleton, 1991 and 1996; Griffin, 1982, Haur, 1997, 1999):

CRF = OR - 1

Where,

CRF = Crash Reduction Factor

OR = Odds Ratio, a ratio between odds of before and after crashes in comparison group to odds of before and after crashes in treatment group

Odds Ratio can be calculated as follows:

OR = [(A/B) / (C/D)]

Where,

A = Before crash counts for comparison road

B = After crash counts for comparison road

C = Before crash counts for target road

D = After crash counts for target road

Effectiveness of a treatment would depend on CRF, for example a negative value of CRF would indicate that treatment is effective in improving the road safety, otherwise treatment is ineffective (i.e. no reduction in number of road crashes due to treatment).

The 95 % confidence interval (CI) of odds ratio can be estimated by following formula:

Upper limit of 95% CI of (OR) = $e^{[\ln(OR) + 1.96(1/A + 1/B + 1/C + 1/D)^{\wedge}0.5]}$

Lower limit of 95% CI of (OR) = $e^{[\ln(OR) - 1.96(1/A + 1/B + 1/C + 1/D)^{\wedge}0.5]}$

2.4 Shortcomings of Before and After Methodology

It known to be that simple before and after method can lead to inaccurate and potentially misleading conclusions because the method is known to subject to the following problems (Elvik 1997, Persaud, 2001):

1. Regression-to-the-mean (RTM)
2. Crash migration
3. Maturation

2.4.1 Regression to the Mean (RTM)

One of the major problems associated with the before-after model is regression-to-the-mean (RTM) bias. This refers to the situation where safety countermeasures are normally applied to those sites with a high number of observed crashes. The subsequent reduction in crashes following the countermeasure is then assigned fully to the countermeasure effect. However, given the random nature of crashes, the frequency of crashes is more likely to drop from previous high levels notwithstanding the introduction of countermeasures. As noted by Council et al. (1980), the average crash frequency approaches to the mean over the long term in spite of high frequencies of crashes in certain years. This phenomenon is commonly referred to Regression-to-the-Mean (RTM) bias.

The problem has been known for many years and is perhaps the most frequently cited problem associated with before-and-after studies (Council et al., 1980). The researchers (Park and Saccomanno 2007, Pendleton 1991) described RTM bias is a form of treatment selection bias, arising when the classical statistical assumption of random sampling is violated. The phenomenon is a principle stating that of related observations, and selecting those where the first observation is either higher or lower than the average, the expected value of the second is closer to the long term and/or population mean than the observed value of the first. It means that there is a tendency to consider that if the first observation taken is above the average (or below the average), the second will always move towards the population average. When safety analysts estimate countermeasure effects via a before-and-after model without properly taking into account RTM bias, they may not observe an actual effect of countermeasures. In simple terms, the crash reduction effects could be wrongly attributed to the countermeasure, where much of the effect could be due to RTM.

2.4.2 Crash Migration

The second problem the simple before and after method is crash migration that can be geographic and non-geographic. Geographic migration is a transfer of crashes from a treated site to surrounding locations as a result of the treatment. For example, when a particular highway curve is improved, crashes at that curve may decrease, but crashes at the next curve may increase. Non-geographic migration, on the other hand, involves a shift across severity levels and/or crash types due to a treatment. For example, installing light poles can reduce nighttime crashes, but may increase fixed-object crashes, which may also increase the overall crash severity (Pendleton, 1992).

The problem of crash migration has been known for many years. Boyle and Wright (1984) first drew attention to the problem. Since then a number of researchers have tried to demonstrate that crash migration exists and can be observed. When crash migration occurs, crashes may be observed to decline at treatment sites, they may increase elsewhere. Accordingly, it was suggested that the evaluation of safety improvement should be based on crash data collected over many sites rather than simply at the treated site itself. This allows changes in the number of crashes for the expanded site locations to reflect both the treatment effect at the treated sites and the crash migration effect at the surrounding sites (Mountain and Fawaz, 1989).

2.4.3 Maturation

The maturation problem refers to change in crashes due to temporal changes such as traffic flow, road geometry, vehicle improvement, traffic laws, etc. (Council et al., 1980). Evaluation of a treatment at locations must consider crash trends to obtain accurate results. For example, if a treatment at selected sites shows a change in crash numbers or rates between before and after periods, it is possible that this change was due to the implemented countermeasure; however, it might also be an extension of a continuing decreasing trend that had been occurring for years. If this crash trend had not been realized, it might be concluded that the observed decrease in crash numbers or rates in the after period was simply due to the countermeasures. While this could be the case, another alternative cause of this decrease could simply be the continuing decrease in crash counts resulting from the combination of many other factors (Council et al., 1980).

In spite of these problems with the simple before-and-after method, this method has been widely used (Hauer, 1997). The reasons to justify application of simple before and after method are as follows.

1. Simple before and after method has been widely used in the evaluation of highway improvements.
2. It is known that the regression-to-the-mean effect is not significant and does not greatly affect the results of the analysis.

3. Selected sites usually have a long high crash history; thus, sites with short-term increase in crashes are excluded.

Chapter 3: Data Collection

This chapter provides details of the data collected for this research. The data collection includes information about speed cameras installed on various roads in the Emirate of Abu Dhabi, and time series data of road crashes in the Emirate of Abu Dhabi. The data is obtained from the Ministry of Interior (MOI), Abu Dhabi.

3.1 Study Location

Figure 1 shows the geographical location of the Emirate of Abu Dhabi.

Figure 1: Geographical location of the Emirate of Abu Dhabi.

The problem of road safety in the Emirate of Abu Dhabi is eminent. According to MOI data, from 1999 to 2007 the averaged percentage of deaths due to road crashes in the Emirate of Abu Dhabi was 42 percent of the UAE (Figure 2).

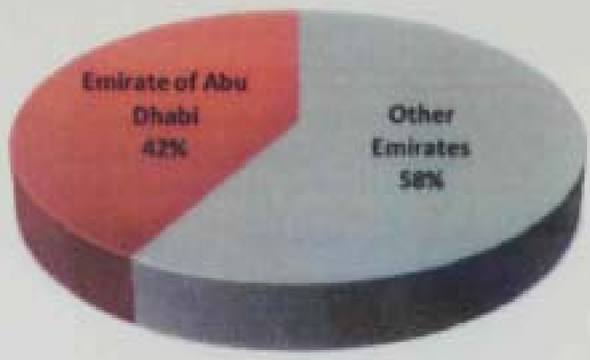


Figure 2: Averaged percentage of deaths due to road crashes in the Emirate of Abu Dhabi,
(Source: UAE Ministry of Interior data (1999 to 2007)

Figure 2 shows the total number of crashes occurred in the Emirate of Abu Dhabi from 1998 to 2007. As shown in this figure the recent trend indicates an increase of 70 percent from year 2005 to 2007. Similarly, the recent trend of fatal crashes in the Emirate of Abu Dhabi indicates an increase of 20 percent (Figures 3 and 4).

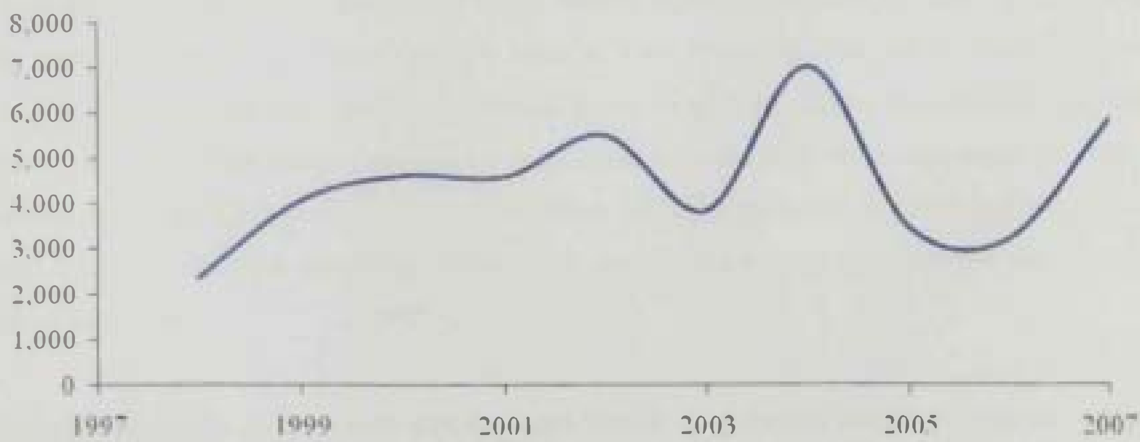


Figure 3: Total number of crashes in the Emirate of Abu Dhabi

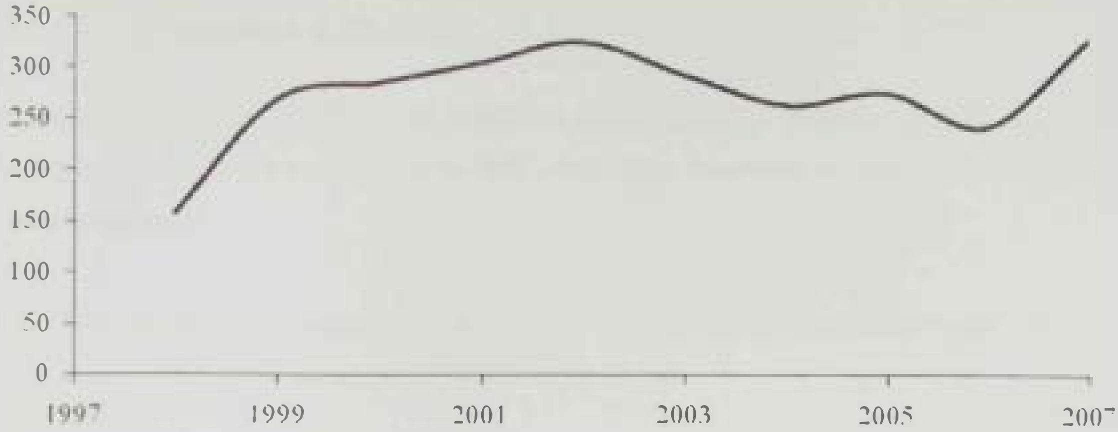


Figure 4: Total number of fatal crashes in the Emirate of Abu Dhabi

The ten-year crashes data analysis showed that the Emirate is experiencing an increasing number of road traffic accidents. This can be attributed to a number of reasons. The prominent amongst them is related to the high motorization levels due to the economic boom that has been experienced over the past ten years. Many people have the purchasing power due to surplus income. The cost of maintaining and operating cars is relatively low in the country with unit fuel costs costing relatively low as compared to other highly motorized countries in the world. Car ownership levels have risen immensely as the culture of many people in the country is more of a car dependent society as many families have at least two cars. The public transport system coupled with unfavourable weather conditions is not so well developed to enhance modal shift. Many cars imply that many new drivers have been licensed with little experience or with no knowledge of the UAE roads. Another factor that might be attributed to the rising trends in the road crashes is the road conditions. Some roads sections encourage speeding and other reckless driver behaviours.

Even though traffic enforcement and fines are levied on violators, there has been no adequate road safety education and campaigns to spread the information on the dangers of road accidents. Furthermore, many drivers even know the exact locations of speed cameras and thus manipulate their speeds while passing such locations then continue to drive at speeds above the posted speed limits.

3.2 Roads Considered in this Study

The choice of the study sections were identified and reviewed as potential evaluation sites. Two categories of sites were considered for this study. The treatment or improved sections were defined as follows:

1. Sections which had speed cameras initially but where their number has been increased.
2. Sections where speed cameras have been installed.

The comparison sections considered were sections without speed cameras, with the exception of Andreassen (1995) where other treated sections (sections which had initial speed cameras) served as a comparison group.

The criteria for selecting the comparison sites were based on matching as closely as possible the geometric, volume, and speed characteristics of the experimental sites. Sites were selected based on the following criteria:

1. Generally, long sections of more than 5 km in length were selected as short segments typically have very few accidents per year.
2. Sections where major maintenance or minor safety improvements, had not been implemented.
3. Study sections were selected to represent a wide range of geographic and rural and urban conditions.
4. Study sections were selected to provide a good mixture of typical locations where speed limits were either raised or lowered in response to changing land use and/or traffic demand.

Since road crash rates are a function of the functional hierarchy of the roads, different sections of two roads classes, i.e., freeways and primary arterials were considered for the study. A total of 7 study sections were selected and included in the data collection effort described in the early stages. Table 2 presents the distribution of the sites by name, road type, area, and speed limit and Figure 5 provides an illustration of the study sections within the Emirate of Abu Dhabi Road network.

Table 2: Characteristics of roads considered in this study

Road Name	Type of Road	Number of Lanes in each direction	Length (Km)	Area	Speed Limit Before 2005	Speed[2] Limit After 2005
Abu Dhabi – Al Ain	Freeway	3	110	Rural	120 km/h	120[3] km/h
Abu Dhabi – Dubai	Freeway	4	80	Rural	120 km/h	120 km/h
Abu Dhabi – Sweehan	Freeway	3	111	Rural	120 km/h	120 km/h
Abu Dhabi – Tarief	Freeway	3	111	Rural	120 km/h	120 km/h
Al Salaam	Primary Arterial	3	15	Urban	60 km/h	60 km/h
Arabian Gulf	Primary Arterial	3	15	Urban	60 km/h	60 km/h
Eastern Ring	Primary Arterials	3	12	Urban	60 km/h	60 km/h

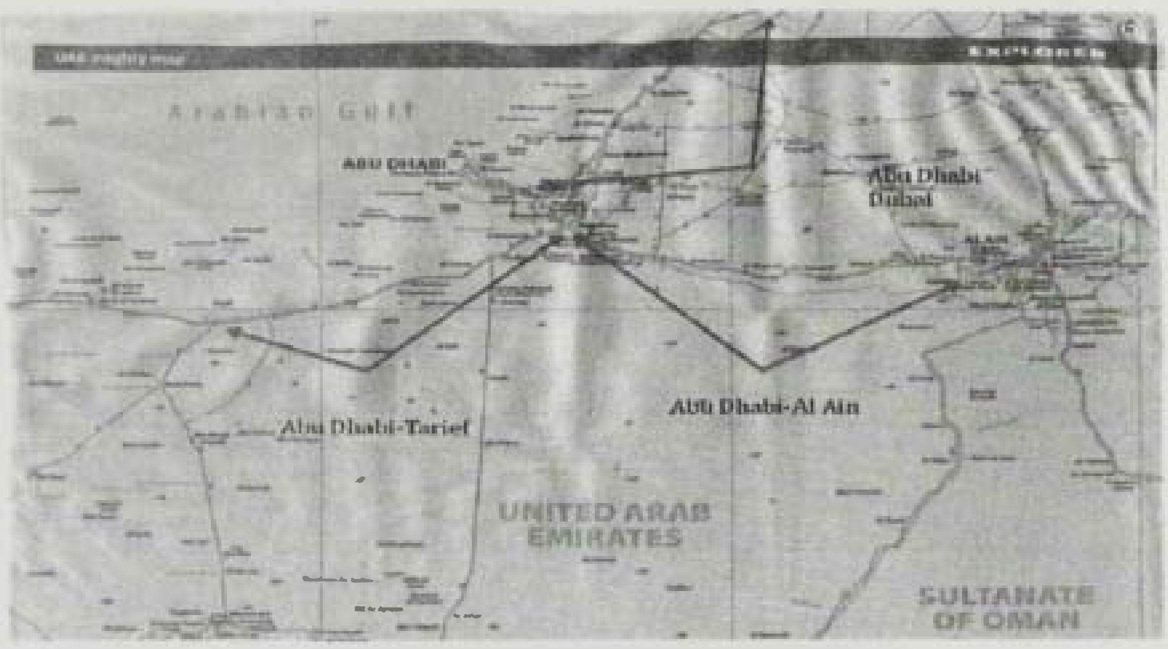


Figure 5: Locations of some roads considered in this study

[2] Speed limit in this case denoted to the posted speed limit which have been same during the study period
[3] Speed limits have been changed to 160 km/hr in the Emirate of Abu Dhabi freeways in 2005

3.3 Time series road crash data

Road crashes data for 2002 through 2007 were extracted from the computerized files from the Traffic Police department. The data included crash type, crash cause, degree of injury (fatal, serious, moderate and slight), type of crashes, time and date of crash, week day, driver's attributes such as age, nationality, and gender.

The original data was in Arabic language (sample of data shown in Figure 6) that was translated into English (sample of data shown in Figure 7).

Figure 6: Sample of data in Arabic language

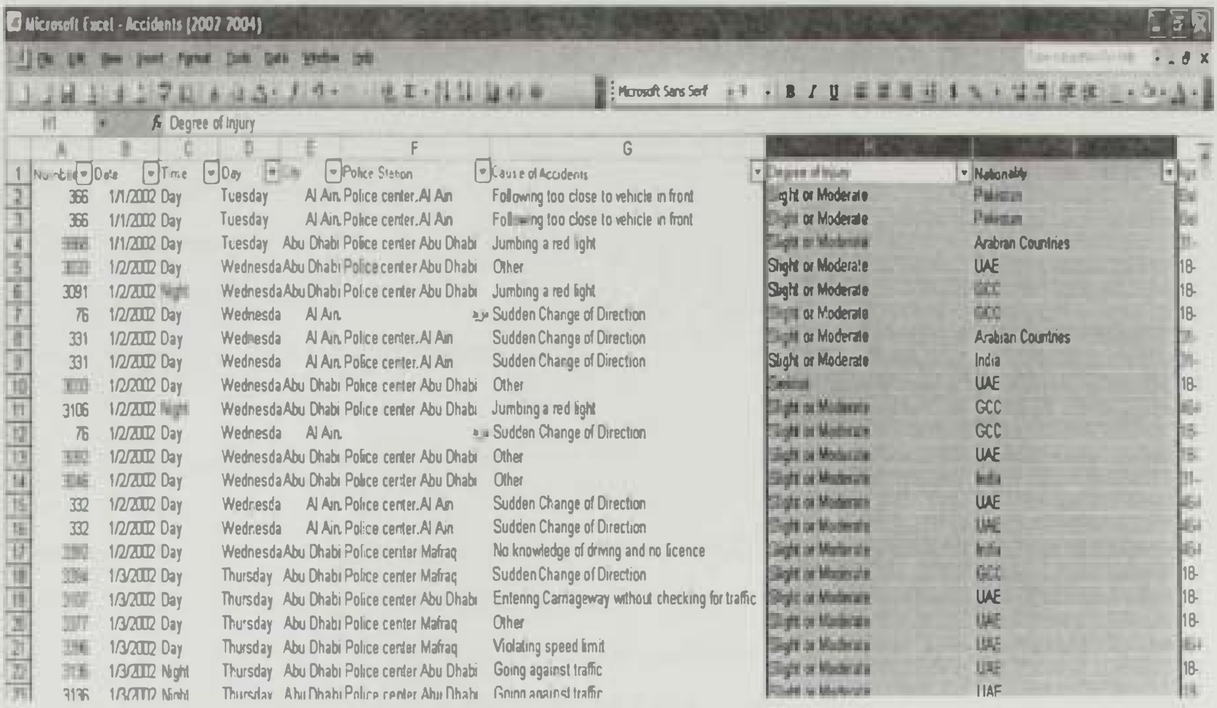


Figure 7: Sample of data translated into English language

Chapter 4: Data Analysis and Discussion

Detailed analysis of the road crash data is described in this chapter. The analysis of data is divided into three sections:

- Trend analysis
- Simple before and after
- Before and after with comparison group

4.1 Trend Analysis

Trend analysis is an informal before-and-after evaluation. In trend analysis changes in crash statistics as a function of time were investigated for various roads in the Emirate of Abu Dhabi. Currently speed cameras are functional on roads including Abu Dhabi – Al Ain Road, Abu Dhabi – Dubai Road, Abu Dhabi – Sweehan, Al Salaam, and Arabian Gulf. Even though Abu Dhabi – Tarief and Eastern Ring Roads do not have speed cameras, they have been included as comparison group roads.

The information about incremental increase in the installation of speed cameras was not available; the only information obtained from the MOI was number of speed cameras installed before and after 2005. This information is presented in Table 3.

Table 3: Installation of speed cameras on various roads in the Emirate of Abu Dhabi

Road Name	Number of Speed Cameras	
	Before 2005	After 2005
Abu Dhabi – Al Ain	5	15
Abu Dhabi – Dubai	6	18
Abu Dhabi – Sweehan	0	11
Abu Dhabi – Tarief	0	0
Al Salaam	1	2
Arabian Gulf	1	3
Eastern Ring	0	0

Figures 8 to 14 show the trends of the total number of crashes from 2002 to 2007 for selected roads in the Emirate of Abu Dhabi. In general, most recent trends on all roads except Arabian

Gulf and Al Salam road, indicates that the number of crashes is increasing. The rate of increase in the number of crashes for roads, Abu Dhabi – Al Ain, Abu Dhabi – Sweehan Road, and Abu Dhabi – Dubai is alarming. Although, number of cameras installed on these roads increased substantially, for example, on Al Ain - Abu Dhabi and Abu Dhabi – Dubai road number of cameras increased three times from 5 to 15, and 6 to 18 respectively.

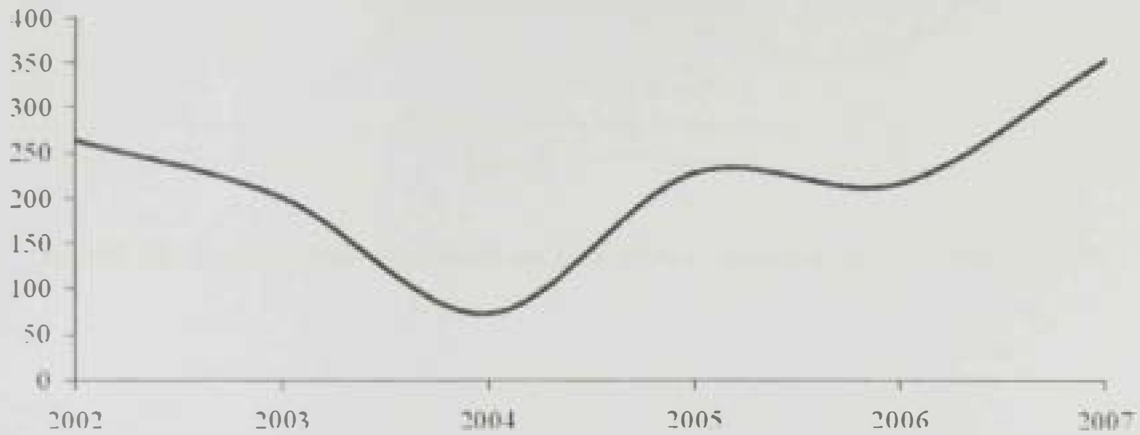


Figure 8: Total number of crashes on Abu Dhabi – Al Ain Road (2002 to 2007)

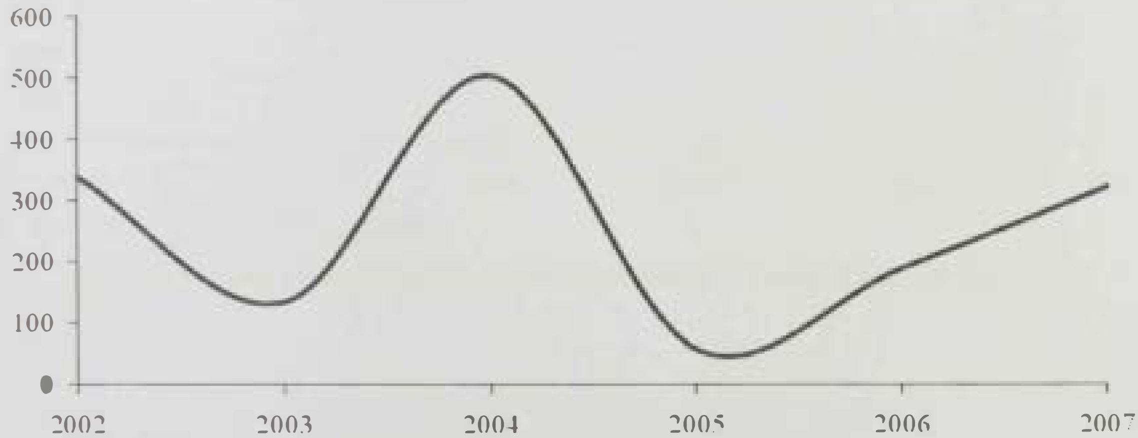


Figure 9: Total number of crashes on Abu Dhabi – Dubai Road (2002 to 2007)

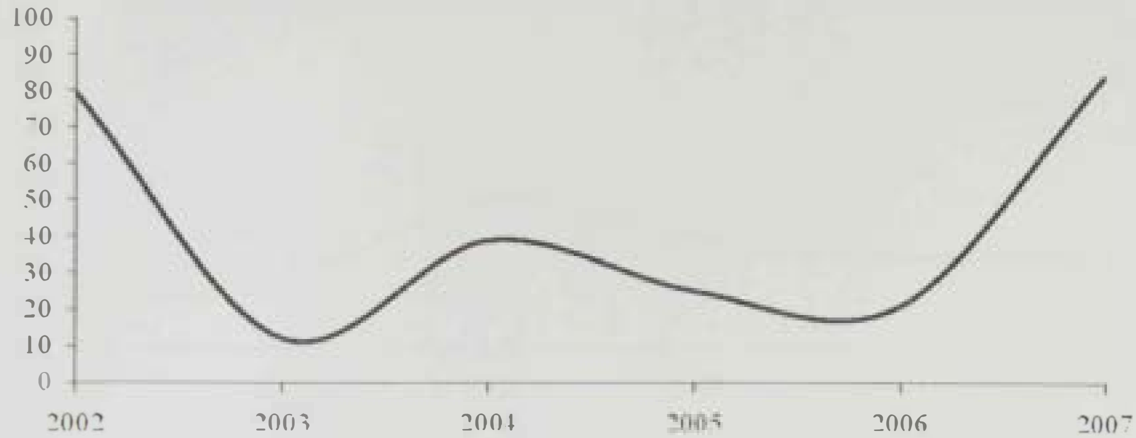


Figure 10: Total number of crashes on Abu Dhabi – Sweehan Road (2002 to 2007)

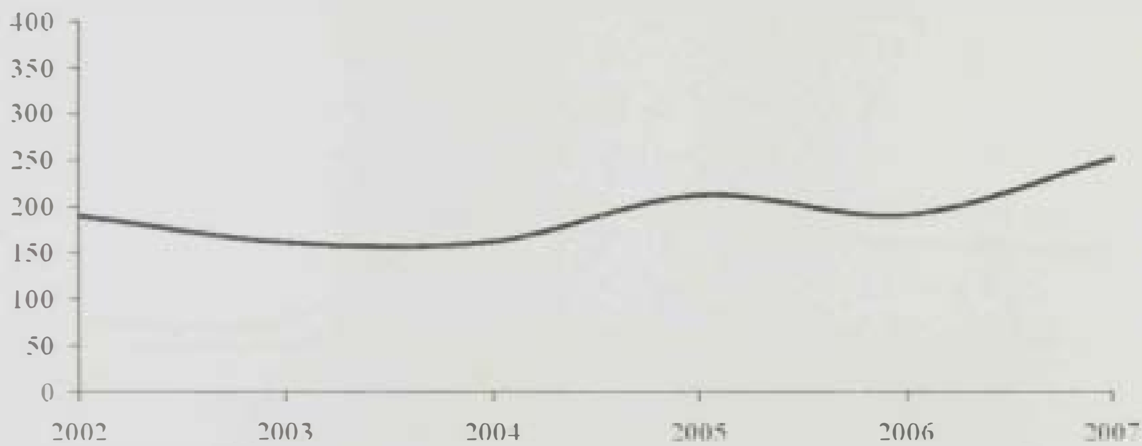


Figure 11: Total number of crashes on Abu Dhabi – Tarief Road (2002 to 2007)

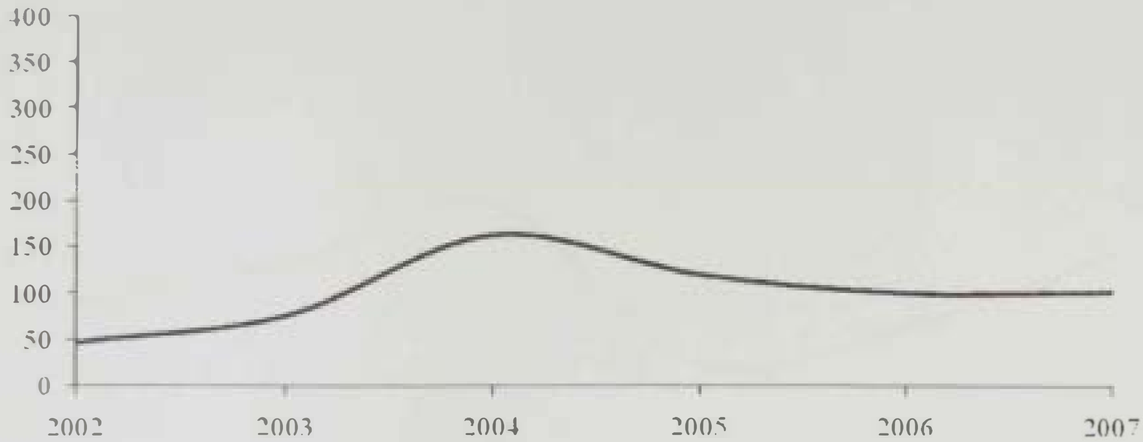


Figure 12: Total number of crashes on Al Salam Road (2002 to 2007)

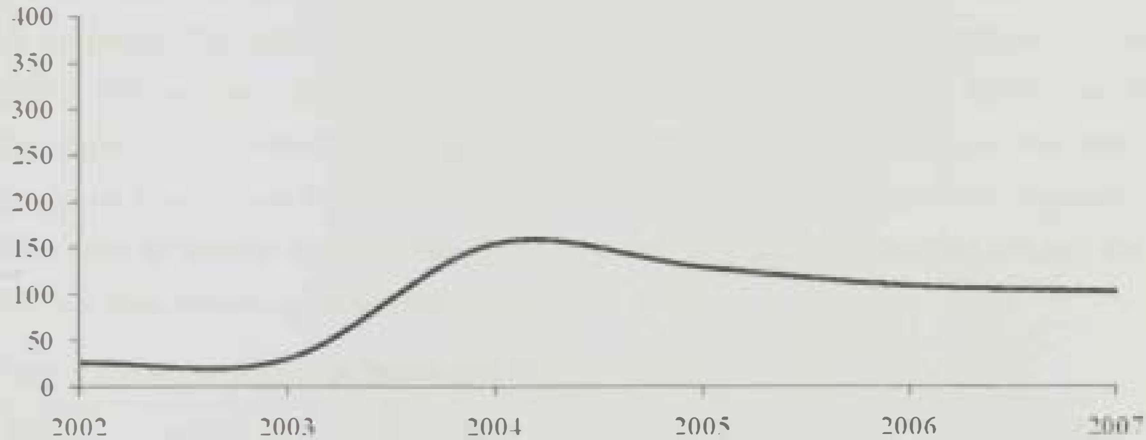


Figure 13: Total number of crashes on Arabian Gulf Road (2002 to 2007)

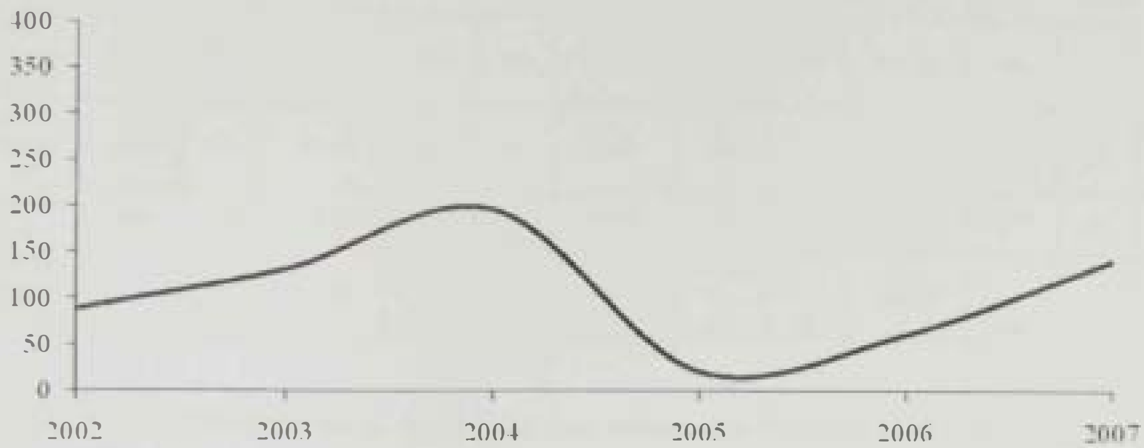


Figure 14: Total number of crashes on Eastern Ring Road (2002 to 2007)

4.2 Simple Before and After Method

In simple before and after method, the three year before and three year after of 2005 crash data was compared. The years from 2002 to 2004 is considered as before countermeasure and from 2005 to 2007 as after countermeasure period. Figures 4.8 and 4.9 present before and after comparison of total crashes, and crashes by severity level on Abu Dhabi – Al Ain road. Similar comparison is carried out for other roads, figures of other roads are provided in the Appendix A. The crashes by severity include types of crashes based on degree of injury and damage. These types are, fatal, serious, moderate and slight.

Table 4: Summary of simple before and after method

Road Name	Total crashes			Fatal crashes			Serious crashes			Moderate & Slight crashes		
	Before	After	%Change	Before	After	%Change	Before	After	%Change	Before	After	%Change
Abu Dhabi – Al Ain	540	802	48.52	47	75	59.57	49	64	30.61	444	663	49.32
Abu Dhabi - Dubai	312	122	-60.90	29	17	-41.38	23	9	-60.87	260	96	-63.08
Abu Dhabi-Swehan	130	207	59.23	17	29	70.59	9	40	344.44	104	138	32.69

Table 5: Summary of simple before and after method (continue)

Road Name	Total crashes			Fatal crashes			Serious crashes			Moderate & Slight crashes		
Abu Dhabi - Tarief	222	657	195.95	169	72	-57.40	13	65	400.00	190	520	173.68
Al Salam road	284	101	-64.44	6	6	0.00	14	13	-7.14	264	82	-68.94
Arabian Gulf	213	108	-49.30	6	8	33.33	10	9	-10.00	197	91	-53.81
Eastern Ring Road	443	238	-46.28	9	5	-44.44	20	13	-35.00	414	220	-46.86

Table 4 presents the summary of before and after comparison for total, fatal, serious, moderate and slight crashes. As shown in this table, the total number of crashes increased on the following roads: Abu Dhabi – Al Ain (48%), Abu Dhabi – Swehan (59%), and Abu Dhabi –Tarief (195%). And the total number of crashes decreased on the following roads Abu Dhabi – Dubai (- 60%), Al Salam Road (- 64%), Arabian Gulf (- 49%), and Eastern Ring Road (- 46%).

The observed changes in the crashes on these roads during before and after period could be due to changes in multiple factors including installation of speed camera, traffic volume, driver awareness, and road attributes etc. To evaluate effectiveness of speed camera attributed to changes in road crashes in the next section "before and after with comparison method" is applied. As discussed in the Chapter 2, before and after with comparison method solves problems associated with the simple before and after method.

4.3 Before and After with Comparison Road

The details of this method (before and after with comparison road) are discussed in chapter 2. In this method, the before and after crash experience of the target road is compared with before and after crash experience of a comparison road. The target road refers to a road where effect of speed camera on reducing crashes is to be determined. The comparison road refers to a road that has characteristics (such as speed limit, number of lanes, and road classification etc.) similar to the target road.

As mentioned in chapter 2, in this method it is assumed that the factors that affect road safety have changed in the same way from before to after period for both target and comparison roads, and that the influence of changes in various factors on road safety is same for both roads. These assumptions imply that the change in the number of crashes before and after the installation of speed cameras at target road, if the cameras had not been installed, would have been in the same proportion as that for the comparison road. That is, without the installation of the cameras, the two roads would be expected to have similar crash experiences in the after period. The strength of the study is directly proportional to how similar the target road with comparison road (Hauer, 1997).

4.3.1 Treatments Types

The selected target and comparison roads for this study are given in Table 5. As shown in this table, freeway roads are compared with freeways, and primary arterial with primary arterial, all possible combinations of comparing roads is considered to assess the effect of speed cameras on reducing crashes.

Table 6: Target and comparison roads

Target Road	Comparison Road	Treatment Types
Abu Dhabi-Al Ain Road	Abu Dhabi-Tarief Road	Installing speed cameras
Abu Dhabi-Sweehan Road	Abu Dhabi-Tarief Road	Installing speed cameras
Abu Dhabi-Dubai Road	Abu Dhabi-Tarief Road	Installing speed cameras
Abu Dhabi-Dubai Road	Abu Dhabi-Al Ain Road	Increasing the number of speed cameras
Abu Dhabi-Al Ain Road	Abu Dhabi-Sweehan Road	Increasing the number of speed cameras
Abu Dhabi-Dubai Road	Abu Dhabi-Sweehan Road	Increasing the number of speed cameras
Arabian Gulf Road	Eastern Ring Road	Installing speed cameras
Salam Road	Eastern Ring Road	Installing speed cameras
Salam Road	Arabian Gulf Road	Increasing the number of speed cameras

4.3.2 Analysis Formulation

The Crash Reduction Factors (CRF) is used to estimate the expected reduction in crashes that may have occurred during a given period as a result of installing speed camera. As described in Chapter 2, the formula used to estimate CRF is as follows (Pendleton, 1991 and 1996; Griffin, 1982, Haur, 1997, 1999):

CRF = OR - 1

Where,

CRF = Crash Reduction Factor

OR = Odds Ratio, a ratio between odds of before and after crashes in comparison road to odds of before and after crashes in target road

Odds Ratio can be calculated as follows:

OR = [(A/B) / (C/D)]

Where,

A = Before crash counts for comparison road

B = After crash counts for comparison road

C = Before crash counts for target road

D = After crash counts for target road

Effectiveness of speed camera would depend on CRF, for example a negative value of CRF would indicate that speed camera is effective in improving the road safety otherwise, speed camera is ineffective (i.e. no reduction in number of road crashes due to speed cameras).

4.4 Analysis Results

The results of the analysis of the speed cameras are presented under the following headings:

1. Total Crashes by Road type,
2. Nationality
3. Age group
4. Time of the day
5. Gender
6. Vehicle type

4.4.1 Effectiveness of Speed Cameras by Total Crashes

The analysis was done for all the roads under crash outcome categories consisting of total, fatal, serious, and moderate crashes. The results are presented in Table 6.

In general, these results indicate that for all roads speed cameras are effective in reducing the total crashes as well as crashes by severity level.

When Abu Dhabi – Al Ain Road is compared with Abu Dhabi-Sweehan Road, it is found that speed cameras on Abu Dhabi – Al Ain road are effective relative to Abu Dhabi-Sweehan Road for reducing all types of crashes. The length of these two roads is almost same, but number of speed cameras on Abu Dhabi – Al Ain road is more than cameras on Abu Dhabi-Sweehan Road. This implies increasing the number of speed cameras increases their effectiveness in reducing crashes. Similarly, before and after comparison of other roads also indicate that speed cameras are effective in reducing the crashes. While comparing Abu Dhabi-Al Ain Road and Abu Dhabi-Dubai Road with Abu Dhabi-Tarief Road, in both cases it is found that speed cameras are effective.

As shown in Table 6, installation of speed cameras on primary arterial roads also shows a reduction in crashes, for examples roads monitored by speed cameras like Arabian Gulf Road, Al Salam roads has relatively less increase in crashes than Eastern ring road where no camera is installed.

Even the number of speed cameras is more in the Arabian Gulf road, the results showed less effectiveness of speed cameras in this road comparing with Al Salam road. The reason could be related to difference in road and variation in traffic volume. Also crash migration problem could be appear in the parallel roads in the network

Table 7: Summary of before and after with comparison method

Target Road	Comparison Road	Total		Fatal		Serious		Moderate	
		CRF	Outcome	CRF	Outcome	CRF	Outcome	CRF	Outcome
Abu Dhabi-Dubai Road	Abu Dhabi-Al Ain Road	-0.74	Speed camera is Effective	-0.63	Speed camera is Effective	-0.7	Speed camera is Effective	-0.75	Speed camera is Effective
Abu Dhabi-Al Ain Road	Abu Dhabi-Sweehan Road	-0.07	Speed camera is Effective	-0.06	Speed camera is Effective	-0.71	Speed camera is Effective	0.13	Speed camera is ineffective
Abu Dhabi-Al Ain Road	Abu Dhabi-Tarief Road	-0.5	Speed camera is Effective	-0.58	Speed camera is Effective	-0.74	Speed camera is Effective	-0.45	Speed camera is Effective
Abu Dhabi-Dubai Road	Abu Dhabi-Sweehan Road	-0.75	Speed camera is Effective	-0.66	Speed camera is Effective	-0.91	Speed camera is Effective	-0.72	Speed camera is Effective
Abu Dhabi-Dubai Road	Abu Dhabi-Tarief Road	-0.87	Speed camera is Effective	-0.85	Speed camera is Effective	-0.92	Speed camera is Effective	-0.87	Speed camera is Effective
Abu Dhabi-Sweehan Road	Abu Dhabi-Tarief Road	-0.46	Speed camera is Effective	-0.55	Speed camera is Effective	-0.11	Speed camera is Effective	-0.52	Speed camera is Effective
Al Salam Road	Arabian Gulf Road	-0.3	Speed camera is Effective	-0.25	Speed camera is Effective	0.03	Speed camera is ineffective	-0.33	Speed camera is Effective
Arabian Gulf Road	Eastern Ring Road	-0.06	Speed camera is Effective	1.4	Speed camera is ineffective	0.38	Speed camera is ineffective	-0.13	Speed camera is Effective
Al Salam Road	Eastern Ring Road	-0.34	Speed camera is Effective	0.8	Speed camera is ineffective	0.43	Speed camera is ineffective	-0.42	Speed camera is Effective

4.4.2 Effectiveness of Speed Cameras by Nationality

The results of analysis by nationality are presented in Table 7. In general, the results indicate that for all the roads, the speed cameras are effective in controlling crashes. However, the effectiveness differs depending on the type of treatment.

The overall outcome shows speed cameras are more effective for "other" nationality group. The "other" refers to nationalities including USA, Europe, Australia, and Canada. The effectiveness of speed cameras is less effective for nationalities such as Pakistan, Bangladesh and India.

Table 8: Summary of before and after with comparison group results by nationality

Abu Dhabi-Al Ain Road and Abu Dhabi-Tarief Road							
Total	A = Before crash counts for comparison road	B = After crash counts for comparison road	C = Before crash counts for target road	D = After crash counts for target road	Odds Ratio	Crash factor	Remarks
UAE	55	118	209	245	0.55	-0.45	Effective
Pakistan, Bangladesh and India	61	187	115	285	0.81	-0.19	Effective
GCC other than UAE	58	137	49	92	0.79	-0.21	Effective
Arabian Countries other than GCC	30	161	76	111	0.27	-0.73	Effective
Asian Countries	4	18	15	36	0.53	-0.47	Effective
Others	14	37	76	33	0.16	-0.84	Effective
Abu Dhabi-Dubai Road and Abu Dhabi-Tarief Road							
UAE	55	118	66	50	0.35	-0.65	Effective
Pakistan, Bangladesh and India	61	187	117	28	0.08	-0.92	Effective
GCC other than UAE	58	137	48	11	0.10	-0.90	Effective
Arabian Countries other than GCC	30	161	62	15	0.05	-0.95	Effective
Asian Countries	4	18	3	9	0.67	-0.33	Effective
Others	14	37	16	9	0.21	-0.79	Effective

Table 9: Summary of before and after with comparison group results by nationality (Continue)

Arabian Gulf Road and Eastern Ring Road							
Total	A = Before crash counts for comparison road	B = After crash counts for comparison road	C = Before crash counts for target road	D = After crash counts for target road	Odds Ratio	Crash factor	Remarks
UAE	120	43	62	11	0.50	-0.50	Effective
Pakistan, Bangladesh and India	85	86	104	23	0.22	-0.78	Effective
GCC other than UAE	28	11	14	4	0.73	-0.27	Effective
Arabian Countries other than GCC	106	48	73	32	0.97	-0.03	Effective
Asian Countries	16	27	10	10	0.59	-0.41	Effective
Others	88	23	21	21	3.83	2.83	Ineffective
Al Salam Road and Eastern Ring Road							
UAE	120	43	62	11	0.50	-0.50	Effective
Pakistan, Bangladesh and India	85	86	104	23	0.22	-0.78	Effective
GCC other than UAE	28	11	14	4	0.73	-0.27	Effective
Arabian Countries other than GCC	106	48	73	32	0.97	-0.03	Effective
Asian Countries	16	27	10	10	0.59	-0.41	Effective
Others	88	23	21	21	3.83	2.83	Ineffective

4.4.3 Effectiveness of Speed Cameras by Age Group

The results of analysis by nationality are presented in Table 8. In age groups, it appears that the speed cameras are most effective for age group below 18 years, and less effective for age group above 60. This may be due to less number of crashes for age group above 60 compared to the other age groups. Its clear from the table below that speed cameras are more effective on controlling crashes for age groups below 18 years and from 18-30 years contrary to what people think that old people are more affected by speed cameras

Table 10: Summary of before and after with comparison group results by age group

Total	A = Before crash counts for comparison road	B = After crash counts for comparison road	C = Before crash counts for target road	D = After crash counts for target road	Odds Ratio	Crash factor	Remarks
Abu Dhabi-Al Ain Road and Abu Dhabi-Tarief Road							
Below 18	2	133	39	90	0.03	-0.97	Effective
18-30	80	234	284	348	0.42	-0.58	Effective
31-45	110	204	180	246	0.74	-0.26	Effective
46-60	27	75	36	106	1.06	0.06	Ineffective
Above 60	3	12	1	12	3.00	2.00	Ineffective
Abu Dhabi-Dubai Road and Abu Dhabi-Tarief Road							
Below 18	2	133	7	8	0.02	-0.98	Effective
18-30	80	234	163	59	0.12	-0.88	Effective
31-45	110	204	110	36	0.18	-0.82	Effective
46-60	27	75	29	16	0.20	-0.80	Effective
Above 60	3	12	3	3	0.25	-0.75	Effective
Arabian Gulf Road and Eastern Ring Road							
Below 18	33	18	28	13	0.92	-0.08	Effective
18-30	198	94	81	51	0.76	-0.24	Effective
31-45	143	85	70	27	0.49	-0.51	Effective
46-60	61	38	33	15	0.59	-0.41	Effective
Above 60	8	3	1	2	2.67	1.67	Ineffective
Al Salam Road and Eastern Ring Road							
Below 18	33	18	26	13	0.85	-0.15	Effective
18-30	198	94	105	38	1.33	0.33	Ineffective
31-45	143	85	109	32	0.65	-0.35	Effective
46-60	61	38	41	15	0.73	-0.27	Effective
Above 60	8	3	3	3	5.33	4.33	Ineffective

4.4.4 Effectiveness of Speed Cameras by Time of the Day

As shown in Table 9, it appears that speed cameras are effective during both day and night. In most of the cases speed cameras are effective during night more than daytime. The reasons could be because drivers don't tend to speed during the night time.

Table 11: Summary of before and after with comparison group results by time of the day

Abu Dhabi-Al Ain Road and Abu Dhabi-Tarief Road							
Total	A = Before crash counts for comparison road	B = After crash counts for comparison road	C = Before crash counts for target road	D = After crash counts for target road	Odds Ratio	Crash factor	Remarks
Day	185	456	337	553	0.67	-0.33	Effective
Night	37	202	203	249	0.22	-0.78	Effective
Abu Dhabi-Dubai Road and Abu Dhabi-Tarief Road							
Day	185	456	253	74	0.12	-0.88	Effective
Night	37	202	59	48	0.15	-0.85	Effective
Arabian Gulf Road and Eastern Ring Road							
Day	326	174	108	78	1.35	0.35	Ineffective
Night	117	64	105	30	0.52	-0.48	Effective
Al Salam Road and Eastern Ring Road							
Day	326	174	189	49	0.66	1.61	Effective
Night	117	64	95	52	0.69	-0.51	Inffective

4.4.5 Effectiveness of Speed Cameras by Gender

In gender, the speed cameras show effective for male and ineffective for female drivers. The reason might be attributed to fewer female drivers on the road. The culture on this country doesn't allow female to drive but the number of female drivers increased in the last few years.

Table 12: Summary of before and after with comparison group results by gender

Total	A = Before crash counts for comparison road	B = After crash counts for comparison road	C = Before crash counts for target road	D = After crash counts for target road	Odds Ratio	Crash factor	Remarks
Abu Dhabi-Al Ain Road and Abu Dhabi-Tarief Road							
Male	195	632	476	688	0.45	-0.55	Effective
Female	27	26	64	114	1.85	0.85	Ineffective
Abu Dhabi-Dubai Road and Abu Dhabi-Tarief Road							
Male	195	632	231	113	0.15	-0.85	Effective
Female	27	26	81	9	0.12	-0.88	Effective
Arabian Gulf Road and Eastern Ring Road							
Male	405	219	185	74	0.74	-0.26	Effective
Female	38	19	28	34	2.43	1.43	Ineffective
Al Salam Road and Eastern Ring Road							
Male	405	219	232	83	0.66	-0.34	Effective
Female	38	19	52	18	0.69	-0.31	Effective

4.4.6 Effectiveness of Speed Cameras by Vehicle Type

Table 11 presents results of the effectiveness of speed cameras by vehicle type. The results show that speed cameras are more effective in controlling crashes for sedan and SUVs vehicle type more than light trucks. It is known that crashes severity increase either by weight of vehicle or speed. The effectiveness of speed cameras are less when the posted speed limit is designed to monitor light vehicles.

Table 13: Summary of before and after with comparison group results by vehicle type

Total	A = Before crash counts for comparison road	B = After crash counts for comparison road	C = Before crash counts for target road	D = After crash counts for target road	Odds Ratio	Crash factor	Remarks
Abu Dhabi-Al Ain Road and Abu Dhabi-Tarief Road							
Motorbike	1	2	2	5	1.25	0.25	Ineffective
Sedans	60	273	221	369	0.37	-0.63	Effective
SUVs (4x4)	73	306	254	285	0.27	-0.73	Effective
Light Truck	45	44	42	62	1.51	0.51	Ineffective
Others	44	33	21	81	5.14	4.14	Ineffective
Abu Dhabi-Dubai Road and Abu Dhabi-Tarief Road							
Motorbike	0	2	7	2	0.00	-1.00	Effective
Sedans	60	273	105	42	0.09	-0.91	Effective
SUVs (4x4)	73	306	104	43	0.10	-0.90	Effective
Light Truck	45	44	54	24	0.45	-0.55	Effective
Others	44	33	42	11	0.35	-0.65	Effective
Arabian Gulf Road and Eastern Ring Road							
Motorbike	5	6	4	3	0.63	-0.38	Effective
Sedans	182	94	78	44	1.09	0.09	Ineffective
SUVs (4x4)	133	80	71	43	1.01	0.01	Ineffective
Light Truck	85	20	32	16	2.13	1.13	Ineffective
Others	38	38	28	2	0.07	-0.93	Effective
Al Salam Road and Eastern Ring Road							
Motorbike	5	6	5	1	0.17	-0.83	Effective
Sedans	182	94	119	44	0.72	-0.28	Effective
SUVs (4x4)	133	80	91	39	0.71	-0.29	Effective
Light Truck	85	20	28	15	2.28	1.28	Ineffective
Others	38	38	41	3	0.07	-0.93	Effective

Chapter 5: Findings and Recommendations

5.1 Introduction

This chapter discusses the findings from the previous Chapter against the available academic literature. The discussion is organised under crash trends in the emirate of Abu Dhabi, the role of speed and crashes, the effectiveness of speeds cameras and the study limitations.

5.2 Effectiveness of Speed Cameras

The analysis showed that speed cameras are effective in controlling all types of crashes. The following discussion presents an insight into the factors as observed in the analysis.

The analysis showed that speed cameras have significant effects along the freeways more than primary arterials. Speed cameras on highly motorized roads (i.e. with high ADT) do experience a phenomenon referred to as a natural tendency of crashes increment. As the number of vehicles increase, so does the number of crashes. In essence even when there are countermeasures on the road, then the number of crashes will increase. This phenomenon is referred to as the tendency of crashes to increase. However, when there is publicity and driver education and awareness of road safety, irrespective of the number of speed cameras installed, there is tendency of crashes to decrease. Based on this phenomenon, the effective of speed cameras on the study roads cannot be solely attributed to the speed cameras installation or increment.

In this study, three driver parameters were considered. Driver nationality which is related to education, age and gender were considered. These parameters affect the compliance of speed limit on the road. The analysis showed that speed cameras are effective for male and ineffective for female drivers. The reason might be attributed to fewer female drivers on the road. The culture on this country doesn't allow female to drive but the number of female drivers increased in the last few years.

On the other hand, the analysis of effectiveness of drivers by nationality showed that the speed cameras are more effective for "other" nationality group. The "other" refers to nationalities including USA, Europe, Australia, and Canada. The effectiveness of speed cameras are less effective for nationalities such as Pakistan, Bangladesh and India.

In age groups, the results revealed that the speed cameras are most effective for age group below 18 years, and less effective for age group above 60. This may be due to less number of crashes for age group above 60 compared to the other age groups.

The results also showed that speed cameras are more effective in controlling crashes for sedan and SUVs vehicle type more than light trucks. It is known that crashes severity increase either by weight of vehicle or speed. The effectiveness of speed cameras are less when the posted speed limit is designed to monitor light vehicles.

5.3 Findings Summary

In this study effectiveness of speed cameras to reduce crashes in the Emirate of Abu Dhabi was investigated. The total crash counts, and crashes by severity level on six freeway roads and three primary arterial was analyzed. The six freeways considered are: 1) Abu Dhabi – Al Ain Road, 2) Abu Dhabi – Dubai Road, 3) Abu Dhabi – Sweehan, and 4) Abu Dhabi – Tarief and three primary arterials are: 1) Al Salaam, 2) Arabian Gulf and 3) Eastern Ring Road. Trends in total crashes and their severities were examined graphically, and comparisons were made between before and after periods. Three years (2002 to 2004) was considered as before and three years (2005 to 2007) was considered as after period. Before and after with comparison method was applied to assess the effectiveness of speed cameras. In addition, effectiveness of speed cameras was also investigated for various factors including drivers' nationality, drivers' age, day or night time, vehicle types, and gender of drivers.

Based on results, the main conclusions that can be drawn from this study is that it appears speed cameras were effective in reducing the crashes as well as severity of crashes in the Emirate of Abu Dhabi. This finding is consistent with the findings of many studies that supported effectiveness of speed cameras in different countries. The findings of this study can be summarized as follows:

1. In general, it appears that speed cameras helped in reducing the total crashes as well as crashes by severity level on freeways and primary arterial roads in the Emirate of Abu Dhabi.
2. On some roads it is found that speed cameras were not effective for drivers of age groups 46 and above, female drivers, drivers of motorbike and light trucks.
3. The increase in the number of cameras on Abu Dhabi – Al Ain road could help in reducing crashes.
4. Currently, there is no speed camera on Abu Dhabi – Tarief road where crashes has an increasing trend. Similarly, there is no camera on Eastern ring road where every year increase in number of crashes is more than previous year.

However, despite the effectiveness of speed cameras, the data shows that the number of crashes on many of these roads is still increasing. It can be concluded, on one hand that crashes might have increased more than the current counts if speed cameras were not installed. As identified in this study, some group of drivers are insensitive to speed camera, their behaviour is not affected by speed cameras.

5.4 Study Limitations

The results of this study can be considered accurate with some degree of confidence and a viable foundation for a more detailed study that can give a policy direction on the regarding decisions for the installation or increasing the number of speed cameras along particular road sections. However, there are a number of notable limitations of the study. These include the following;

1. The analysis has assumed that the posted speed limit enforcement has not been changed along the study area sections.
2. The study has assumed uniformity in AADT along the study road sections on the basis that these roads are currently saturated and have more or less a uniform traffic flow characteristics over the study period.

3. The study sections have different types of speed cameras with varied optical strengths and thus it is difficult to determine which speed camera types are effective than the others.
4. The natural tendency of crashes increment or decrement on the study area road sections and thus the decrease or increase of crashes cannot be attributed to speed cameras only.
5. It is difficult to isolate the impacts of speed cameras alone on car crashes, as there are road signs, warnings that in essence do the same. For instance, the warning sign, road controlled by radar can be effective even without speed cameras installed.
6. That many motorists especially commuter drivers have the knowledge of the exact locations of speed cameras so in many cases they manipulate them.
7. The analysis of primary arterials roads is limited by the crash migration phenomenon where an installation of speed cameras along a road section might lead to crash migrating to the other adjacent and parallel road sections.
8. It is difficult to monitor the performance of speed cameras when there number is changed without a good justification.

5.5 Recommendations

The overall aim of this research was to evaluate the effectiveness of speed cameras in controlling crashes in the Emirate of Abu Dhabi roads. The study has found out that even though that the magnitude of road crashes in the Emirate of Abu Dhabi is appreciated and the concerned authorities have begun to seriously address the issue of road safety within the Emirate of Abu Dhabi, they are still faced with enormous challenges and deficiencies within their road safety management practice and countermeasures.

The Speed cameras are monitored speed violations only while driver behaviour affected by different factors including: sudden change of direction, following too close to the vehicle in front, and wrong overtaking etc.

A package of countermeasures could be a good solution for the road safety problem in the Emirate of Abu Dhabi. Speed enforcement is one of the elements of an integrated speed management approach. Speed enforcement gains in effectiveness if it is targeted towards prioritized roads, situations and times. Speed cameras enforcement should be used for a large concentration of traffic crashes at high-volume traffic locations. Physical policing can be a good alternative to safety camera enforcement when crashes are scattered, and provided operations are randomized and applied to a large part of the network. To increase its effectiveness, speed enforcement must be supported by setting safe and credible speed limits, by publicity, by legislation facilitating effective enforcement, and by appropriate sanctions. Speed enforcement operations gain in effectiveness if they have specified objectives and success criteria, and are monitored in terms of both process and product. Cooperation and partnerships between police, local authorities and data experts provide the best guarantee for problem-oriented, outcome-focused and evidence-based speed policing operations.

The driver must know, always and everywhere, what the speed limit is. The conventional way is to use consistent roadside signing and road markings. In-vehicle systems to inform drivers about the speed limit in force are likely to be introduced progressively.

The first three measures assume that the unintentional speed violations are an exception. Drivers who still exceed the speed limit do so intentionally. Police enforcement should remain necessary to control and punish that group of drivers.

Quantitative targets represent the road safety results which a country or jurisdiction wishes to achieve over a given time frame is also important. A country's focus on results and how they are to be achieved by system-wide intervention and effective institutional management is at the core of an effective national road safety management system and national road safety strategy. Countries have become more ambitious over time in their choice of long term goals and interim quantitative targets with implications for the interventions selected and their delivery by institutions across the road safety partnership. Targets for final outcomes (long and interim targets to reduce deaths and injuries) are used widely in many countries in national, regional and local road safety strategies and programmes. Targets should be set for intermediate outcomes (decreases in mean speeds, increases in seat belt use) and institutional delivery outputs (numbers of random breath tests, speed checks) which allow closer management of the range of interventions needed to achieve final outcome targets.

In the latest evolution of the road safety management system, key institutional management functions provide the foundation for system-wide interventions to achieve a range of results expressed as different types of quantitative targets. Targets provide the focus for the national road safety strategy and the level of their ambition drive decisions about coordination needs, legislative needs, funding and resource allocation, promotion needs, monitoring and evaluation, as well as research, development and knowledge transfer. Current good practice involves a combination of top down long term goals as well as bottom up interim targets (usually of 7-10 year duration), which are soundly related to interventions, their likely effectiveness in the national road safety strategy and the quality of their delivery. Result focus is the overarching function of lead agency management for road safety which defines the country's level of ambition for road safety and takes into account the interventions and institutional arrangements which need to be put in place in order to realize it. The process should involve:

1. Appraising current road safety performance through high-level strategic review;
2. Adopting a far-reaching road safety vision or goal for the longer term;
3. Analysing what could be achieved in the shorter term;
4. Agreeing targets and ensuring accountability across the road safety partnership;
5. Setting Safety Performance Indicators (SPI);
6. Continuous monitoring of targeted and other safety performance indicators;
7. Establishing the effectiveness of specific road safety measures by carrying out before and after studies; and
8. Reviewing and updating of policies and measures with re-distribution of resources towards more cost-effective measures; identifying delays in implementation requiring corrective action.

For future work, it is recommended that this research should be extended to verify the findings using some safety surrogate measures to examine the effectiveness of speed cameras. Safety surrogate measures could be more accurate than road crash statistics. Examples of safety surrogates include the frequency of close calls, exposure levels, and observed speed of vehicles.

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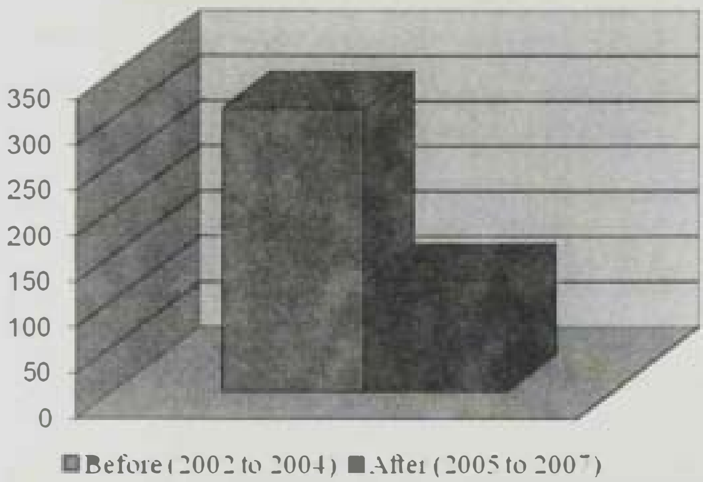
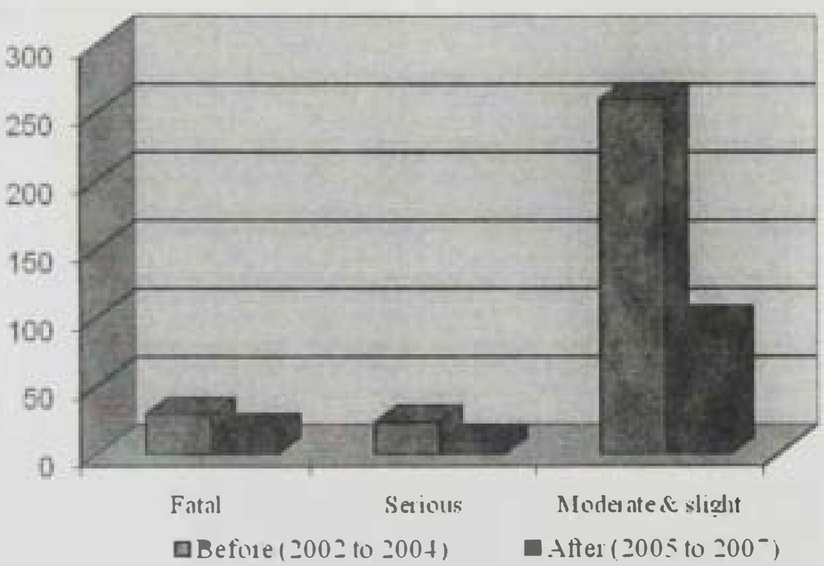
Appendix A

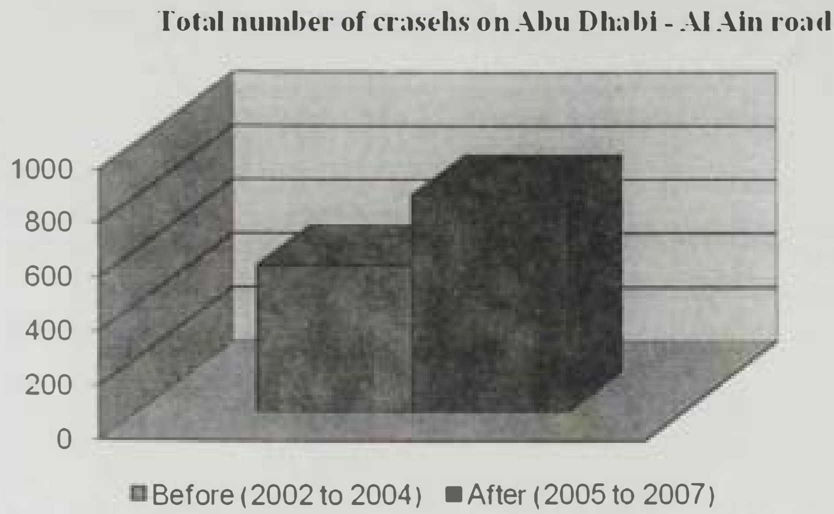
Before and after comparison of crashes on various roads

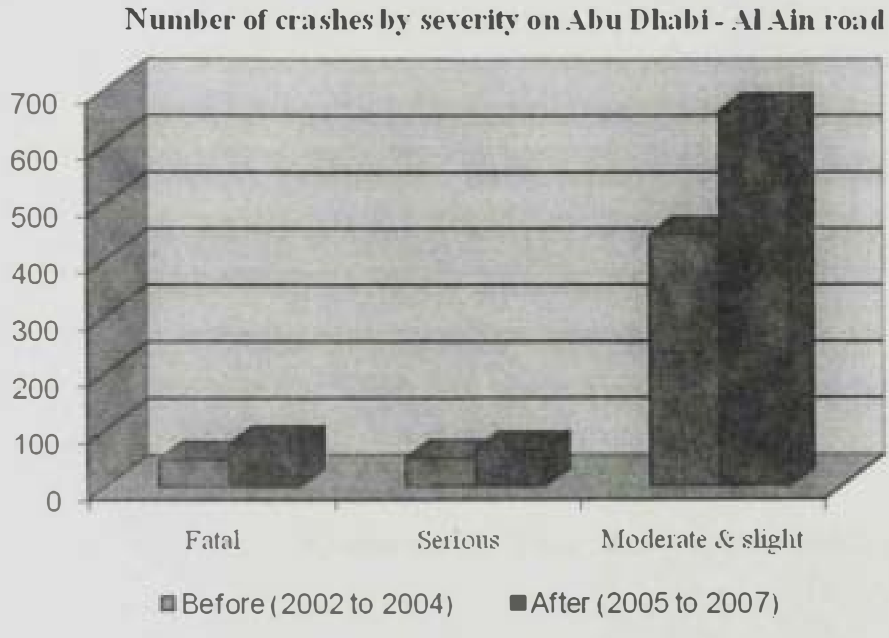
Total number of cr:asehs on Abu Dhabi - Dubai road



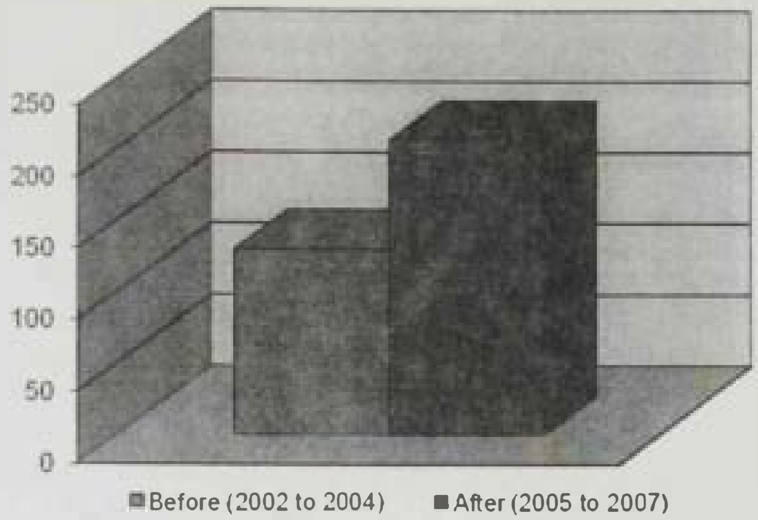
Number of crashes by severity on Abu Dhabi - Dubai road



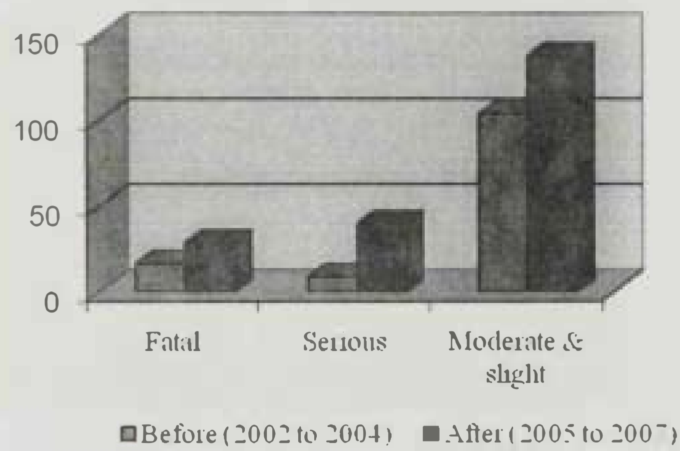

Total number of crasehs on Abu Dhabi - Al Ain road
1000
800
600
400
200
0
Before (2002 to 2004)
After (2005 to 2007)


Number of crashes by severity on Abu Dhabi - Al Ain road
700
600
500
400
300
200
100
0
Fatal
Serious
Moderate & slight
Before (2002 to 2004)
After (2005 to 2007)

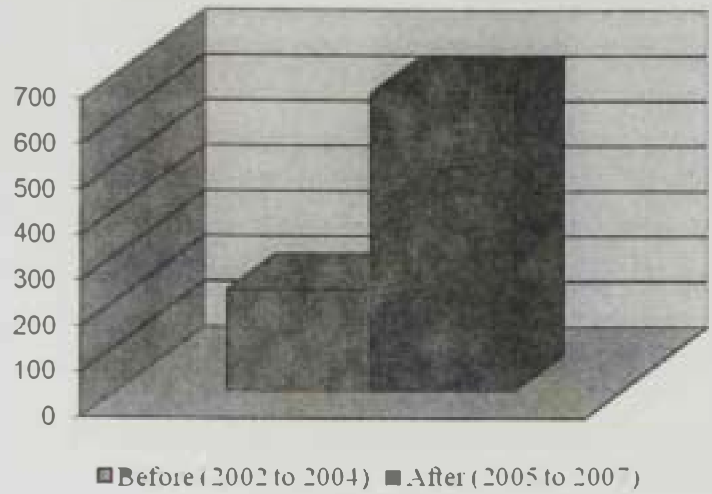
Total number of crashes on Abu Dhabi- Sweehan



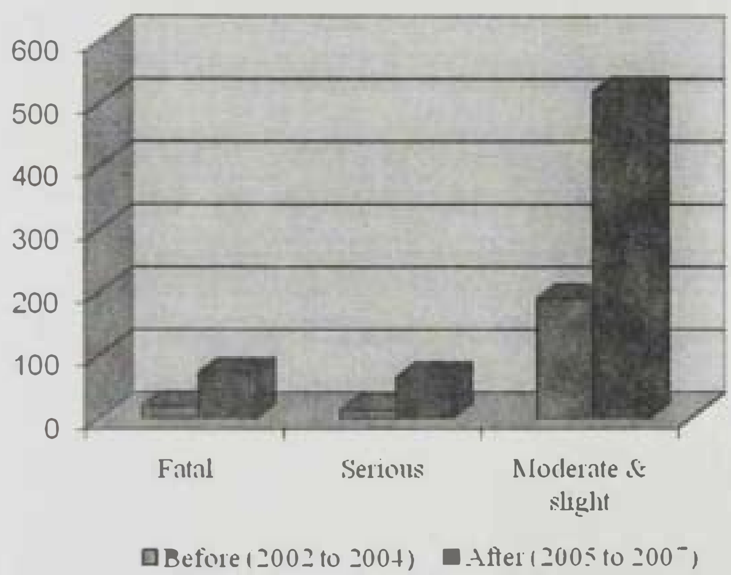
Number of crashes by severity on Abu Dhabi-Sweehan



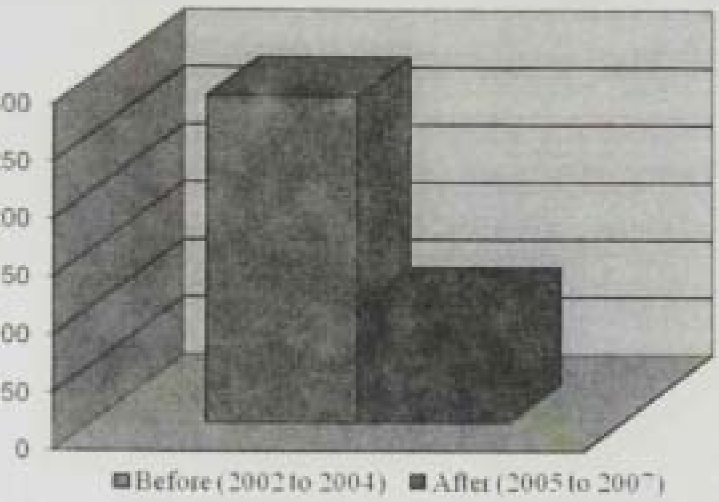
Total number of crashes on Abu Dhabi-Tarief



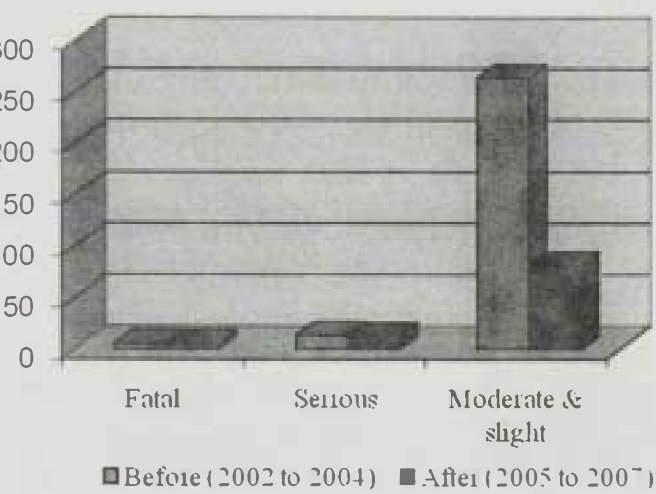
Number of crashes by severity on Abu Dhabi- Tarief

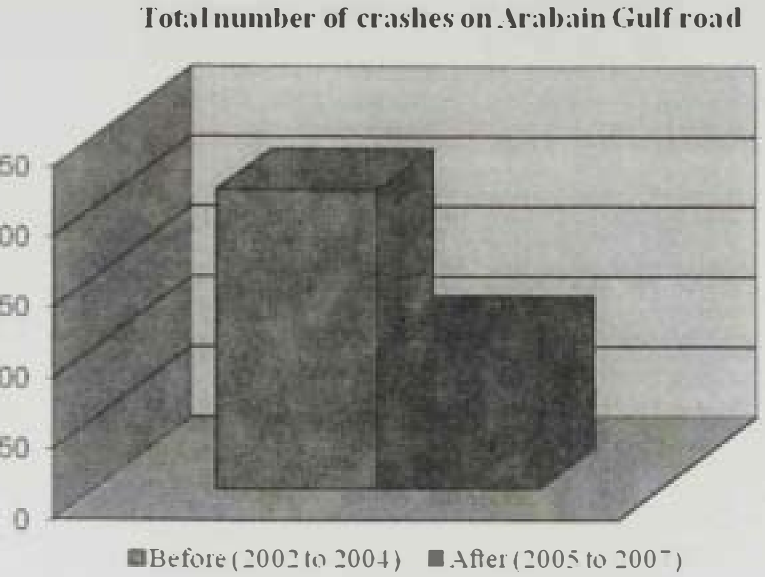


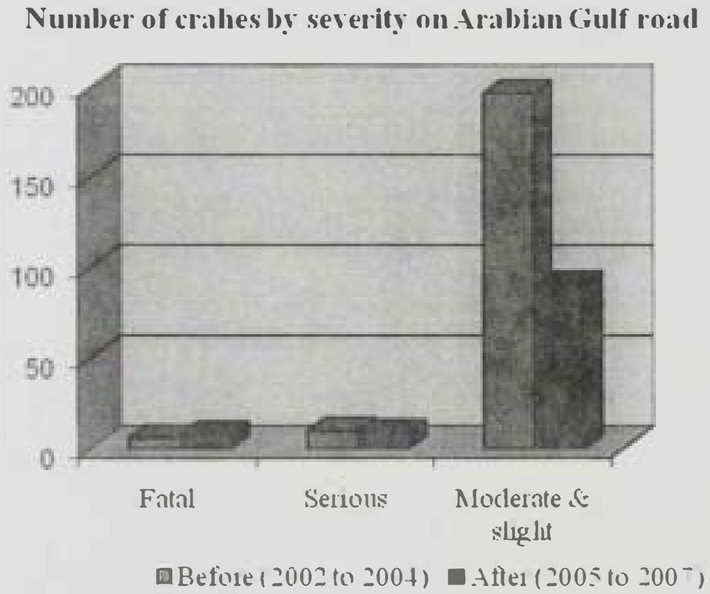
Total number of crashes on Salam road



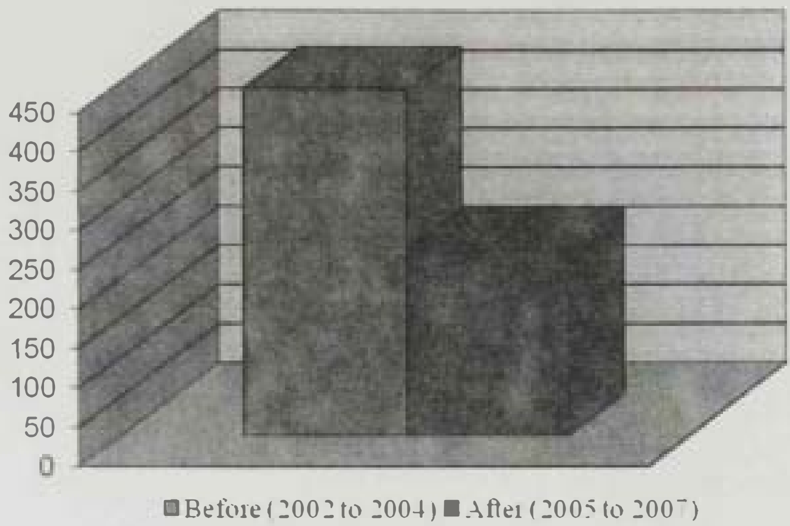
Number of crashes by serverity on Al Salam road




Total number of crashes on Arabain Gulf road
250
200
150
100
50
0
Before (2002 to 2004)
After (2005 to 2007)


Number of crahes by severity on Arabian Gulf road
200
150
100
50
0
Fatal
Serious
Moderate & slight
Before (2002 to 2004)
After (2005 to 2007)

Total number of crashes on Eastern Ring road



جامعة الإمارات العربية المتحدة

عمادة الدراسات العليا

برنامج ماجستير الهندسة المدنية

دراسة تأثير كاميرات مراقبة الطرق (الرادار) على حوادث الطرق في إمارة أبوظبي

علي حميد الدرعي

رسالة مقدمة استكمالاً لمتطلبات
التخرج في برنامج ماجستير
الهندسة المدنية

يونيو 2009