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تأثير كاميرات ضبط سرعة المركبات على الحوادث المرورية المميتة في دولة الكويت

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الخلاصة

تطوير جوانب السلامة المرورية على الطرق السريعة هي من الأولويات بالنسبة للسلطات الإدارية والأمنية الرسمية ذات العلاقة بالموضوع، وذلك للتكلفة الاجتماعية والاقتصادية الباهظة الناتجة عن الحوادث المرورية التي تزهق الأرواح. وتم من خلال هذه الدراسة المقدمة لنيل درجة الماجستير في هندسة الطرق الاستفادة من بيانات صادرة عن كاميرات ضبط سرعة المركبات والموزعة على الطرق السريعة في دولة الكويت، وذلك لقياس مدي تأثير وجودها على الحوادث التي تؤدي إلى الخسائر في الأرواح. وكان الهدف من هذه الدراسة وضع نظام لتحليل أنماط السلامة المرورية وتحديد الأماكن ذات المعدلات العالية لحوادث المرور المميتة وذلك من البيانات التي تم الحصول عليها من الإدارة العامة للمرور بدولة الكويت. وتم تحقيق هذا الهدف بتصميم قاعدة بيانات لحوادث التصادم المميتة مبنية على تقنية تحديد المواقع بالأقمار الصناعية. ومن خلال تطوير نماذج للتنبؤ بالحوادث المرورية المميتة، تبين التحايل الإحصائية بأن هناك علاقة ذات دلالة إحصائية هامة بين حوادث التصادم المميتة وكاميرات ضبط سرعة المركبات في المناطق التي شملتها الدراسة. حيث يبين النموذج ارتفاع في عدد الحوادث المميتة عند مواقع كاميرات ضبط السرعة مما قد يدل على نصب الكاميرات في الأماكن المناسبة على الطرق السريعة في دولة الكويت.

The effect of automated speed cameras on fatal traffic collisions in Kuwait

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ABSTRACT

Improvements to highway safety are a high priority for highway authorities due to the social and economic costs of traffic collisions. The main objective of this research work was to compare the safety performance on road sections near automated speed cameras (ASCs) with other road sections and to examine the safety effect of ASCs measured in terms of fatal traffic collision frequency, using data from Kuwait. This research work established the most comprehensive fatal collision database for Kuwait that can be used to identify locations with history of high fatal collision frequency. The database was incorporated into geographic information system (GIS) platform for easy geographic manipulation and display of the data. Collision prediction models were developed to assess the effect of ASCs, as measured in frequency of fatal traffic collisions. The results of the statistical analysis showed that there is a statistically significant relationship between fatal collisions and ASCs for zones with 2,000-m radius. The models indicated a trend of higher fatal collision frequencies for zones with ASCs compared to similar zones without ASCs. This finding may have been the result of locating the ASCs in areas with a history of high fatal collision or locations with higher potential for fatal collisions.

Keywords: Automated speed cameras; automated traffic enforcement; fatal collisions; traffic safety.

INTRODUCTION

Use of road transportation is associated with a number of negative side effects, among which is a worldwide traffic safety problem in terms of increased traffic collisions leading to significant burden on public health and adverse impacts on the global economic and social development. As estimated by the World Health Organization (WHO, 2011), around 1.3 million people die each year on the world's roads due to traffic collisions, and between 20 and 50 million suffer non-fatal injuries.

Traffic collisions are most severe in the developing countries, where simple prevention measures could reduce the number of deaths. In Kuwait, the most recent

WHO statistics indicate that 482 people have lost their lives to traffic collisions in 2006 (WHO, 2012), which puts the death rate on the Kuwaiti road network to close to 14 fatalities per 100,000 inhabitants. Although this fatality rate is lower than most countries in the region, it is higher than the developed countries, which implies that there are opportunities for considerable improvements in safety practices in Kuwait. According to the 2009-2019 National Traffic & Transport Sector Strategy for Kuwait, congestions and collisions will cost the country around $95 billion in ten years, and the money to be spent by Kuwait to deal with collisions will represent around 6% of its annual GDP (UNDP, 2009).

One of the remedial measures used on roads around the world are automated speed cameras (ASCs), which were introduced in Kuwait as an effort to reduce the high volume of speeding violations and associated severe traffic collisions. However, due to the lack of reliable collision database and standard procedures to identify hazardous road locations in Kuwait, the locations of these ASCs in Kuwait were based mainly on the local experience of police officers. However, there is currently no tool to objectively show that these ASCs have been installed in locations with highest potential for safety improvement or to examine their contribution to improving traffic safety in Kuwait.

The main objective of this paper is to compare the safety characteristics of road segments in the vicinity of ASCs and to examine the effect of ASCs on traffic safety in Kuwait. Associated with achieving this objective, several fatal traffic collision prediction models were developed for Kuwait using regression analysis. It is noted here that the safety performance measure used in this paper is the frequency of mid-block (non-intersection) fatal collisions, where at least one fatality had taken place at the time of the collision. Records of non-fatal collisions were not readily available by the Ministry of Interior at the time of data collection. Due to lack of details on the severity of injuries as well as the amount of effort that would have been required to digitize thousands of non-fatal collision records for the three year period, only reports of collisions where fatality took place at the time of the collision were collected, digitized and considered. Collisions involving property damage only (PDO) and injuries are not investigated in this research.

SPEED AND ROAD SAFETY

Excessive speeding is usually associated with greater potential for loss of vehicle control, longer stopping sight distances, less ability to respond to arising situations, greater impact energy to be passed to the vehicle occupants, and lower effectiveness of passenger safety equipment (Ha *et al.*, 2003). Therefore, traffic speed is believed to influence both the risk of collision occurrence (in terms of collision frequency) and the consequences of these collisions (in terms of collision severity). As a result, a number of before-and-after studies in different countries have concluded that a 1% reduction in speed would yield between 1 and 5.5% reduction in collision frequency (OECD, 2008; Taylor *et al*., 2000). However, the relationship between speed and collision frequency remains a subject of much debate (Hauer, 2009).

Nonetheless, controlling excessive speeding should result in safety improvements at least through the reduction in collision severity. Therefore, traffic officials seek ways to increase compliance with posted speed limits as well as other traffic rules and regulations. Among these ways is increased traffic enforcement by automated tools that can provide more comprehensive enforcement without diverting police officers from other duties (Bochner & Walden, 2010). An automated traffic enforcement system is defined as a recording device that is triggered automatically by a traffic violation, so that information about the violating vehicle is recorded, making possible the subsequent identification of the vehicle for the purpose of sanctioning the owner or driver (Sagberg, 2000).

Automated speed cameras (ASCs) have been used as speed enforcement tools in several countries. Several studies have reported a reduction in the number of collisions and injuries due to the implementation of ASCs. Examples include a reporting of 20% decline in the number of injury collisions and 12% decline in PDO collisions in Saskatchewan, Canada (Liu & Popoff, 1997), 40 to 66% drop in speeding vehicles at camera sites in BC, Canada (IIHS, 1999), around 70% reduction in deaths and 26% reduction in serious injuries in West London, UK (Lyons, 1998), 52% reduction in traffic collisions and injuries in Nottingham, UK (Dalbert, 2001), 26% reduction in vehicle speeds in Canberra, Australia (Anderson, 2000). On the other hand, other before-and-after studies have reported that significant speed reductions are observed only close to ASC locations and that drivers tend to speed back downstream the ASC (Aljassar *et al*., 2004; Ha *et al*., 2003).

SPEED ENFORCEMENT IN KUWAIT

Kuwait is an independent Arab country with an extensive, modern and well–maintained network of highways. The road network in Kuwait is classified into five categories: special road network (SRN) ring, SRN radial, primary road network (PRN), secondary roads (SR), and local roads (LR). They are similar in characteristics to the North American road classification system.

Automated traffic enforcement tools, including ASCs and red light cameras, have been introduced in Kuwait since 1994 as a remedy to control the lack of traffic discipline among violating drivers, reduce collisions, and minimize injuries and fatalities. As of 2010, Kuwait has had 123 automated traffic enforcement cameras installed on major roads and traffic signalized intersections, of which 51 are ASCs. In

Kuwait, drivers are informed of the ASC by road signs posted 1.0 km before each ASC location. It is believed that if these warning signs are not used, vehicle speeds near ASCs would decrease abruptly, thus creating hazardous conditions. However, despite these warning signs, many drivers still exceed the allowable speed limits.

METHODOLOGY AND DATA PREPARATION

Examining the effect of ASC on safety performance is better carried out using a well-designed before-and-after study. However, collision data for the period before ASCs were installed are not available in Kuwait, and therefore, a before-and-after study could not be performed. The alternative approach followed in this study was a regression analysis to develop safety performance models for fatal collision frequency. The dependent variable in these models is the fatal collision frequency on different road sections during a period of time ranging from three to five years, and the independent variables are those representing the highway and traffic characteristics. In this study, an independent dummy variable was also added to indicate locations with or without ASC and thus examine the effect of ASC. Because collisions are rare, random, and non-negative events, the negative binomial regression was used in this study, which is the technique currently followed by safety researchers.

The regression analysis was carried out in this study using the generalized linear model (GENMOD) procedure in the statistical analysis system (SAS) version 9.2. The procedure uses the maximum likelihood method based on the negative binomial error structure and 'log' link function. Both the Chi-Square (χ^2) and scaled deviance measures (D_m) are provided as SAS goodness of fit output. SAS also provides the p–value estimated for each independent variable, which is the probability that the estimated variable's regression coefficient would have a non-zero value, when the true coefficient is zero. A p–value less than 5% is usually considered ample confirmation that the true coefficient is non-zero and that the estimated coefficient is statistically significant.

In attempting to collect information on fatal collision frequency on different road sections, no comprehensive collision database was found for Kuwait due to the lack of data and follow-up after collisions. Therefore, achieving the paper's objective required creating a detailed, digital database of fatal traffic collisions in Kuwait. This database was also integrated in a GIS platform to allow easier spatial identification and analysis of the locations of fatal traffic collisions along the road network in Kuwait.

First, paper copies of the police reports of traffic collisions were collected for a period of three years (2008-2010) from the Kuwaiti Ministry of Interior. A database was then created in Microsoft Excel encompassing all records in the police reports. However, the exact coordinates of the fatal traffic collision locations were not available in the police reports. Therefore, Google Earth was used as a location identification system, as it provides the visual capability through satellite images of roads, buildings, and roadway features that can aid in locating the coordinates of the collisions. A virtual pin was dropped on each collision location that was identified based on the description in the police reports. The pin's coordinates were then exported to the ArcGIS software, which was used as the GIS platform for the spatial analysis in this research, to plot them on the map of Kuwait.

SPATIAL ANALYSIS USING GIS

GIS Database and buffer zones

In addition to the quantitative regression analysis, the creation of the GIS database allowed a spatial analysis of the fatal collision data as seen in the developed pin maps. The distribution of the collision locations seemed to be following a similar pattern across the country each year, with the majority of fatal collisions occurring within the urban area. Most of the fatal traffic collisions outside the urban area occurred on the three main highways. Next, the fatal traffic collisions were plotted according to their type. The distribution across the country showed that the majority of the rollover collisions occurred outside the urban areas, whereas collisions involving other vehicles, road-side objects, and pedestrians were mainly within the urban area.

Since most of the fatal traffic collisions occurred within the urban area and all ASCs in Kuwait are located within the urban area, the main focus of the next set of analysis was limited to this region. As part of the spatial analysis, the 'buffering' tool was employed in ArcGIS. This technique was used to create buffer zones (or influence areas) with radii of 500-m, 1,000-m, and 2,000-m around all road classifications of SRN, PRN, and SR. An example of the buffer zones for the 1,000-m influence area is shown in Figure 1. Zones with ASCs had the center point of the buffer zone being the ASC location. For each buffer zone size, the developed database allowed easy creation of a dataset including fatal collision frequency, annual average daily traffic (AADT), and length of road segments within each zone. For simplicity, the three zone sizes will be referred to using their radii as 500, 1,000, and 2,000-m zones.

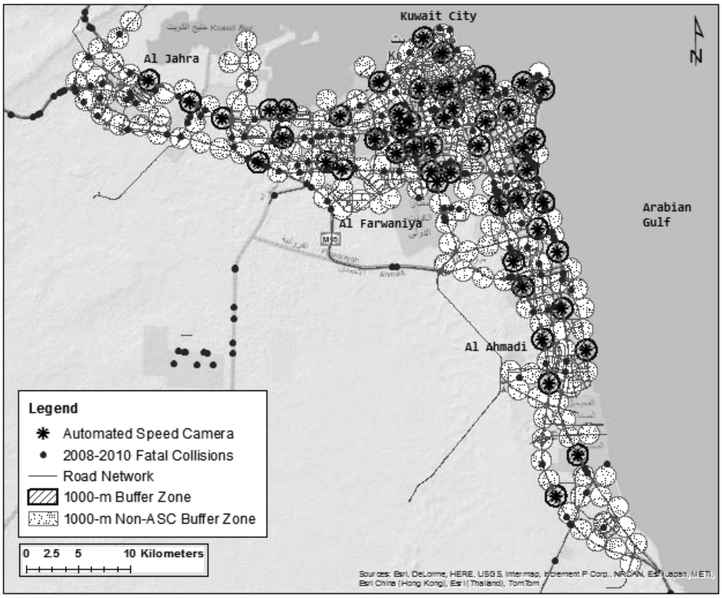

Fig. 1. Road network in Kuwait with 1000-m Zones

ASC vs Non-ASC zones

The number of collisions identifying a location as a high collision location varies depending on many factors including traffic exposure. An approximate method to identify high collision locations is to define a threshold of collision rate or frequency based on the mean value for all locations plus a multiple of the standard deviation (KMCE, 2000). Based on the mean and standard deviation values of fatal collision frequency for the different zone sizes, the thresholds for the 500, 1,000, and 2,000-m zones were 2, 3, and 5 collisions, respectively. However, the threshold value for the 500-m zone was taken as 3 collisions, to reduce the chances of identifying a zone as hazardous because of random fluctuations in collision frequencies. Table 1 presents basic trends within each of the three influence areas.

Table 1. Basic fatal collision trends within the three influence areas

Influence area (m)	Maximum fatal collision frequency per zone	Threshold of fatal collision frequency per zone	Total number of zones		Number of high-collision zones[1]		Average fatal collision frequency in high-collision zones[1]	
			ASC Zones	Non-ASC Zones	ASC Zones	Non-ASC Zones	ASC Zones	Non-ASC Zones
500	4	3	51	577	2	11	4	4
1,000	6	3	51	136	7	11	4	4
2,000	8	5	51	45	7	3	6	5

[1]High collision zones are those where the fatal collision frequency is equal to or greater than the estimated threshold.

Based on these findings, no difference was observed between ASC and non-ASC zones for the cases of 500-m and 1,000-m zones. On the other hand, for the 2,000-m zones, there seems to be evidence that an ASC zone would experience more fatal collisions than a non-ASC zone, or alternatively the ASCs had been located in more collision prone areas.

REGRESSION ANALYSIS

Analysis procedure

With three different zone sizes, three datasets were available for the regression analysis. However, it was noted that the large 2,000-m zone size coupled with forcing a zone for each ASC (with ASC at the center) had produced some overlapping zones. Subsequently, fatal collisions that were located within intersecting regions had overlapped with two zones. Two approaches were taken as to how the collisions were counted: (1) each fatal collision in an intersecting region is assigned one zone only, which is the closest ASC location, and (2) total number of collisions within each zone is assigned to the zone, allowing for double-counting of the overlapping collisions. Subsequently, regression analysis was performed to four datasets corresponding to two datasets for the 2,000-m zones and one dataset for each of the 500-m and 1,000-m zones.

The independent variables used in the regression corresponded to the road sections within each zone. These variables were grouped into three categories: traffic exposure, other road and traffic parameters, and ASC parameter. First, different traffic exposure parameters were considered: (1) AADT, (2) total road section length, and (3) the sum of product of each section length and its AADT, which is termed as *EXPO*. Mathematically, each of these three parameters was considered in the model along with its natural logarithm.

Second, different independent variables were considered to represent other road and traffic parameters. At the end, two parameters were believed to have the most potential to be significant model parameters: (1) *HighFlow*: a dummy variable to indicate road sections with AADT greater than 100,000 veh/d (1 = yes, 0 = no), and (2) *SRN*: a dummy variable to indicate SRN Ring and Radial roads (1 = yes, 0 = no). Finally, the dummy variable *Cam* was used to consider the presence of ASC (1 = yes, 0 = no).

The general model form for different combinations of independent variables can be expressed as follows:

$$\text{Three-year collision frequency} = e^{(\omega+\sum \alpha_i x_i)} \times \prod y_j^{\beta_j} \quad (1)$$

Where ω, α_i, and β_i = regression coefficients; x_i = independent variables taken in their original form; y_i = independent variables entered in the form of the natrural logarithm.

The regression analysis was carried out in two phases as summarized in Table 2. The objective of Phase 1 was to decide the significant exposure variable(s) to be used in the final relationships with the other significant parameters. As shown in the table, six general models were examined for each of the four datasets in this phase. In Phase 2, the significant traffic exposure variable(s) identified in Phase 1 were combined with the dummy variables *HighFlow*, *SRN*, and *Cam* to examine the significance of these parameters' effect on traffic safety (Table 2).

Table 2. Independent variables in regression analysis models

Independent Variables	Phase 1 Models						Phase 2 Models					
	1	2	3	4	5	6	7	8	9	10	11	12
AADT	x		x									
ln(AADT)		x		x								
Length			x									
ln(Length)				x								
EXPO					x							
ln*(EXPO)*						x						
Significant traffic exposure variable(s)							x	x	x	x	x	x
Cam							x			x	x	x
SRN								x		x		x
HighFlow									x		x	x

Phase 1 results

A total of 24 models (6 models for each of the four dataset) were attempted in Phase 1. Out of these models, Table 3 shows the eleven statistically significant models at 5% level of significance. In addition, all models in the table have an acceptable goodness of fit as indicated in the calculated values of χ^2 and D_m. As shown in the table, the length of road segments within the zones was not statistically significant for any of the datasets. The main reason for this is that all zones in each dataset had very close values of this variable, which were exactly equal to or slightly greater than twice the radius of buffer zones. Finally the table shows that the model coefficients for both datasets corresponding to the 2,000-m zones are very close to each other.

Table 3. Phase 1 significant models

Model (Dataset)	Variable	Regression Coefficient	*p*-value	D_m	χ^2	D_m/DF	χ^2/DF
(*a*) 500-m Zones.							
1(1)	Intercept *AADT*	-2.2954 1.4×10^{-05}	<.0001 <.0001	389.8228	659.2443	0.6227	1.0531
2(1)	Intercept ln*(AADT)*	-10.8931 0.8683	<.0001 <.0001	391.8251	688.9104	0.6259	1.005
5(1)	Intercept *EXPO*	-2.2369 6.0×10^{-06}	<.0001 <.0001	389.0495	662.0012	0.6215	1.0575
6(1)	Intercept ln(*EXPO*)	-11.1170 0.8313	<.0001 <.0001	392.1677	696.0432	0.6265	1.1119
(*b*) 1,000-m Zones.							
1(2)	Intercept AADT	-0.4263 5.7×10^{-06}	0.0511 0.0239	202.1401	183.1668	1.0926	0.9901
(*c*) 2,000-m Zones; Collisions Assigned to the Closest ASC.							
1(3)	Intercept *AADT*	0.0956 2.8×10^{-06}	0.7121 0.0069	112.8092	95.2019	1.2001	1.0128
5(3)	Intercept *EXPO*	0.1117 1.2×10^{-06}	0.6425 0.0041	112.8404	95.6964	1.2004	1.0180
6(3)	Intercept ln(*EXPO*)	–3.1734 0.2973	0.0981 0.0406	112.9882	96.9294	1.202	1.0312
(*d*) 2,000-m Zones; Collisions Counted in All Overlapping Zones.							
1(4)	Intercept *AADT*	0.1288 2.8×10^{-06}	0.6156 0.0005	113.3924	93.2995	1.2063	0.9925
5(4)	Intercept *Expo*	0.1861 1.2×10^{-06}	0.4422 0.0005	112.7171	91.8937	1.1991	0.9776
6(4)	Intercept ln(*Expo*)	-4.3198 0.4004	0.0272 0.0068	113.4594	96.3871	1.207	1.0257

Phase 2 results

The modeling attempts in this phase include the significant traffic exposure variables found in Phase 1 combined with the independent variables *HighFlow*, *SRN*, and *Cam*. All modeling attempts including *HighFlow* and *SRN*, were not statistically significant at 5% level of signifcance and will not be discussed further. As for the variable *Cam*, it was found to be insignificant at 5% level of significance for the 500-m and 1,000-m zones. This finding would indicate that the frequency of fatal collisions within such zones is statistically the same, whether an ASC is present or not.

On the other hand, the variable *Cam* was statistically significant at 5% level of significance for the 2,000-m zones, whether overlapping collisions were double-counted or assigned to the nearest ASC. The two resulting significant models are shown in Table 4. As shown in the table, the regression coefficient corresponding to *Cam* has a positive sign, which indicates that with all other parameters being similar an ASC zone would have a greater fatal collision frequency than a non-ASC zone. This result suggests that although the ASCs were indeed installed in locations with high fatal collision frequencies, more than normal fatal collisions still take place within 2.0 km of ASC.

Suggested collision prediction models

While mindful of the fact that the collision database created in this research was limited to collisions with fatalities occurring at the scene based on the available paper police reports, it can be stated that this paper presents the best available fatal collision prediction models for Kuwait. First, Table 3 shows four models to predict the expected three-year frequency of fatal collisions within a buffer zone with 500-m radius. For a buffer zone with a 1,000-m radius, only one model was found to be statistically significant to predict the expected three-year frequency of fatal collisions within the zone, as shown in Table 3. Finally, to predict the frequency of fatal collisions within a buffer zone with a 2,000-m radius, the fourth dataset, where collisions were counted within all overlapping zones should be used. For this case, it is identified as case (*d*) in Table 3 and case (*b*) in Table 4.

Table 4. Phase 2 significant models

Model (Dataset)	Variable	Regression Coefficient	*p*-value	D_m	χ^2	D_m/DF	χ^2/DF
(*a*) 2,000-m Zones; Collisions Assigned to the Closest ASC.							
7(3)	Intercept	–0.0957	0.7013	112.98	99.5317	1.2148	1.0702
	EXPO	0.9×10^{-06}	0.0115				
	Cam	0.4841	0.0056				
(*b*) 2,000-m Zones; Collisions Counted in All Overlapping Zones.							
7(4)	Intercept	-0.1767	0.4637	113.9294	100.7172	1.225	1.083
	EXPO	1×10^{-06}	0.002				
	Cam	0.7893	<.0001				

CONCLUSIONS AND RECOMMENDATIONS

The main objective of this paper was to examine the effect of ASCs on traffic safety in Kuwait measured in terms of the frequency of traffic collisions with at least one fatality taking place on site. To achieve this objective, a digital database was created using three-year data from the police fatal collision reports. The database was incorporated into a GIS platform for easy spatial display and manipulation of the data. The GIS software was used to create buffer zones with three different radii and determine the traffic and road characteristics and the fatal collision frequency within each zone.

The results of both the spatial and regression analysis showed that there was no statistically significant difference in the number of fatal collisions between 500-m and 1000-m zones with or without ASCs. On the other hand, the analysis for 2,000-m zones indicated that an ASC zone would have a greater fatal collision frequency than a similar non-ASC zone. This finding does not necessarily mean that the presence of ASC had contributed to the increase of fatal collisions. An alternative explanation is that the ASC were installed at locations with high collision frequencies or high potential for collisions.

Finally, the regression analysis has also yielded different sets of fatal collision prediction models. It should be cautioned that because the data used in developing these models were missing a number of collision reports, the models would be expected to underestimate the frequency of fatal collisions.

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