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Hana Naghawi¹*, Bushra Al Qatawneh¹, Rabab Al Louzi¹

RESEARCH ARTICLE

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Abstract

This study aims, in a first attempt, to evaluate the effectiveness of using the Automated Enforcement Program (AEP) to improve traffic safety in Amman, Jordan. The evaluation of the program on crashes and violations was examined based on a “before-and-after” study using the paired t-test at 95 percent confidence level. Twenty one locations including signalized intersections monitored by red light cameras and arterial roads monitored by excessive speed cameras were selected. Nine locations were used to study the effectiveness of the program on violations, and twelve locations were used to determine the effectiveness of the program on frequency and severity of crashes. Data on number and severity of crashes were taken from Jordan Traffic Institution. Among the general findings, it was found that the AEP was generally associated with positive impact on crashes. Crash frequency was significantly reduced by up to 63%. Crash severities were reduced by up to 62.5%. Also, traffic violations were significantly reduced by up to 66%. Finally, drivers’ opinion and attitude on the program was also analyzed using a questionnaire survey. The questionnaire survey revealed that 35.5% of drivers are unaware of AEP in Amman, 63.9% of drivers don’t know the camera locations, most drivers knew about excessive speed and red light running penalties, most drivers reduce their speed at camera locations, 44.4% of drivers think that the program satisfies its objective in improving traffic safety and 52% of drivers encourage increasing the number of camera devices in Amman.

Keywords

Automated Enforcement Program, Red Light Camera, Excessive Speed Camera, Public Opinion, Road Safety

1 Introduction

Worldwide, aggressive driving has become a serious problem on roadways. This results in enormous number of crashes every day. The National Highway Traffic Safety Administration (NHTSA, 2015) estimates that 94% of traffic crashes and almost 66% of traffic fatalities are caused by dangerous driving activities or driver’s errors. Excessive speeding and red light running are among the most common illegal dangerous driving activities (Dangerous Roads Organization, 2013).

Excessive speeding (ES) is defined as driving too fast for the prevailing conditions or exceeding the speed limit. Red light running (RLR) can be defined as to pass through an intersection when traffic light has turned red. Traditionally, the enforcement of this type of traffic violations involve policeman monitoring the road or the signalized intersection for violators. This type of manual enforcement can be difficult and hazardous at some locations. Automated Enforcement Program (AEP) addresses this problem. AEP is becoming increasingly popular in many countries to improve traffic safety by controlling drivers’ behaviour. It can briefly be described as the use of image capture technology to monitor traffic twenty four hours a day to enforce traffic laws. It can be done using mobile or fixed cameras. Mobile cameras are accompanied by enforcement officer and maybe moved among various locations, while fixed cameras monitor speeds at specific locations and are unaccompanied by enforcement officers.

The effectiveness of AEP in improving traffic safety was evaluated by many researchers. A study by Al Jassar and Ali (2004) evaluated the AEP in Kuwait. It included 93 camera locations 39 ES cameras and 54 RLR cameras, in addition to 8 mobile cameras. The results indicated that fatalities were reduced by 15% after implementing the AEP. Some researchers evaluated the effectiveness of ES cameras in reducing speeding violations and traffic crashes (Decina et al., 2007; Wilson et al., 2010; Allsop, 2010). In Barcelona, Perez et al. (2007) conducted a study to evaluate the ES cameras for Barcelona’s ring road in reducing traffic crashes. The study revealed that crashes were reduced by 27% after the installation of the ES cameras. Gains et al. (2004), evaluated the effectiveness of ES cameras in the United Kingdom, they

¹ Civil Engineering Department, University of Jordan, Amman 11942, Jordan

* Corresponding author, e-mail: h.naghawi@ju.edu.jo

found that the deployment of speed cameras resulted in 40% reduction in fatalities and serious injuries, 30% reduction in personal injury crashes, and a 35% reduction in the number of pedestrians killed or seriously injured. Another study in the United Kingdom by Mountain (2004) evaluated the ES cameras. He found that there was a reduction of about 25% in injury crashes up to 500 m from camera location. Wilson et al. (2010) conducted a systematic review to evaluate the speed camera effectiveness in Europe and Australia. They reported (14-65) % reduction in the percentage of vehicles exceeding the posted speed limit, (8-49) % reduction in speed associated crashes, (8-50) % reduction in injury crashes and (11-44) % reduction in fatal crashes. In the USA, Hu and McCartt (2015) evaluated the long term effect of the automated speed enforcement program at residential streets with speed limit 35 mph or less and school zones. It was found that the mean speed was reduced by 10% and fatal crashes were reduced by 39%. Researchers at Weill Cornell Medical College in Doha studied the efficiency of using speed camera systems. The study indicated that the mean vehicular injury death rate per 100,000 was decreased from 19.9 ± 4.1 before camera installation to 14.7 ± 1.5 after camera installation (ITS International, 2012).

Other researchers have identified the effect of RLR camera enforcement on crash reduction benefits. Ruby and Hobeika (2003) assessed the RLR camera enforcement program in Fairfax, Virginia. Ten cameras were installed at high commuter traffic intersections. It was found that the violation rates were reduced by 36% during the first three months of installation and up to 69% after six month of camera installation. Retting and Kyrychenko (2002) evaluated the use of RLR cameras at eleven signalized and unsignalized intersections in Oxnard, California. The study revealed a reduction of 7% in all crashes and a reduction of 29% in all injuries. Walden (2011) evaluated the impact of RLR cameras on crash frequency in Texas, USA. He investigated 275 signalized intersections from around the state. He found that the RLR camera reduced the total number of crashes by 28%. Maccubbin et al. (2001) reported reduction in violation rates ranging from 20% to 87% for jurisdictions in the USA. These findings were similar to the findings in Singapore and Canada (Mullen, 2001; Lum and Wong, 2003). On the other hand some studies showed that cameras are not without limitations and possible problems such as increased rear end crashes and spillovers (Chinnock, 2005).

In Jordan, there has been no research conducted to evaluate AEP on crashes and violations. This study aims to evaluate the effectiveness of using the AEP to improve traffic safety at arterial roads and signalized intersections in Amman, Jordan. The effect of the AEP on crash frequencies, severities and violations were examined. Drivers' opinion and attitude on AEP was also examined using a questionnaire survey. Generally, this study proved the success of automated enforcement program in Amman.

2 Program Description and Site Selection

Amman is the capital and most populated city in Jordan, with a geographic area of 1,689 square kilometers and a population of more than nine million in 2015 (DOS, 2016). According to Jordan Traffic Institution (JTI, 2016) approximately every 5 minutes a traffic crash occurs and every 14 hours a person gets killed in a traffic crash.

Table 1 shows crashes, fatalities and injuries between 2006 and 2015. It can be seen that traffic crashes in Jordan has increased from 98,055 in 2006 to 111,057 in 2015; the resulting casualties (fatalities and injuries) have improved leading to a reduction in severity rates (casualty/crash) from 0.19 in 2006 to 0.15 in 2015. Also, the fatality index (fatalities/causalities) has decreased from 0.048 to 0.036 during the same period of time. Jadaan et al. (2013) developed road fatality prediction model under Jordanian conditions and based on aggregated data, they predicted that by 2020, the number of road crash fatalities will reach 1054. This is 73.35% higher than fatalities in 2015. This indicates relatively low level of traffic safety in Jordan.

Table 1 Crash Frequencies Fatalities and Injuries between 2006 and 2015

Year	Crashes	Fatalities	Injuries	Severity Rate	Fatality Index
2006	98055	899	18019	0.193	0.048
2007	110630	992	17969	0.171	0.052
2008	101066	740	13913	0.145	0.051
2009	122793	676	15662	0.133	0.041
2010	140014	670	17403	0.129	0.037
2011	142588	694	18122	0.132	0.037
2012	112817	816	17143	0.159	0.045
2013	107864	768	15954	0.155	0.046
2014	102441	688	14790	0.151	0.044
2015	111057	608	16139	0.151	0.036

Source: JTI, 2016

Excessive speeding and red light running are among the leading causes of crashes in Jordan. Traditional law enforcement alone is not enough to deter violations. Central traffic department at Greater Amman Municipality (GAM) sought to develop AEP that would optimize safety at most dangerous intersections and major arterial roads in Amman. The AEP has gradually expanded since its initiation. Initially there were five cameras installed in December 2004. As of December 2007 there were additional nineteen cameras installed. Finally, twenty one cameras were added in January 2014 to make the total number of cameras forty five cameras. Unfortunately, crash frequency, severity, speed and violation data were not recorded before the year 2011 which will only enable the latest twenty one camera locations to be studied. For the purpose of this study, the effectiveness of RLR cameras on frequency and severity of crashes was examined at five signalized intersections and the effectiveness of ES cameras on frequency and severity

of crashes was examined at seven locations on arterial roads with (60-70) km/hr speed limit, as summarized in Table 2. The effectiveness of RLR cameras on number of violations was examined at different five signalized intersections and the effectiveness of ES cameras on number of violations was also examined at different four locations on arterial roads with (60-70) km/hr speed limit, as summarized in Table 3. This resulted in studying all camera locations installed in the year 2014.

Table 2 Camera locations used for Evaluating AEP on Crash Frequency and Severity

Location ID	Camera Code	Intersection / Street
RLR Camera Location on Intersections		
1	1000	Al-Ersal
2	1001	Abu Baker
3	1002	Queen Zain Al-Sharaf -1
4	1003	Queen Zain Al-Sharaf -2
5	1004	Al-Maslakh
ES Camera Location on Arterial Roads		
6	1100	Al-Hijaz
7	1101	Abu Nusair
8	1102	Al-Urdon
9	1103	Al-Aqsa
10	1104	Al-Shahid
11	1105	Army-1
12	1106	Prince Hashim bin Al-Hussein

Source: GAM, 2017

Table 3 Camera locations used for Evaluating AEP on Violations

Location ID	Camera Code	Intersection / Street
RLR Camera Location on Intersections		
13	103	Crown
14	201	Commodore
15	401	Al-Kindi
16	501	Al-Dokhan
17	801	Al-Thalathin
ES Camera Location on Arterial Roads		
18	901	Army-2
19	904	Al-Hizam Ring Road
20	911	Al-Istiqlal
21	912	Zahran

Source: GAM, 2017

3 Data Collection

Data were obtained from three sources; Greater Amman Municipality, Jordan Traffic Institute, and a questionnaire survey. Data obtained from GAM included location of roads monitored by ES cameras, signalized intersections monitored by RLR cameras and number of violations that were registered by both types of cameras. Number and severity of crashes were taken from JTI. Drivers' attitude and opinion was analyzed using a questionnaire survey.

4 Program Evaluation

Evaluation of AEP in Amman was based on a "before-and-after" study. January 2011 to January 2014 represent the before period and January 2014 to January 2017 represent the after period. The appropriate statistical test for performing this type of comparison is the paired t-test. The paired t-test was performed at 95 percent confidence level to determine if there were any differences in crash frequency, crash severity or violation numbers before and after the implementation of the AEP.

To accomplish this, the following null and alternative hypotheses were used for each comparison:

H_0 : the differences in crash frequency, crash severity or violation numbers before and after the implementation of the AEP are equally.

H_1 : the differences in crash frequency, crash severity or violation numbers before and after the implementation of the AEP are different.

4.1 AEP Effect on Crash Frequency

Locations 1 through 12 were used to study the effect of implementing the AEP on crash frequency. Table 4 summarizes the crash frequency mean value before and after the AEP implementation. The table also shows the percent change in crash frequency before and after the AEP implementation. The statistically significant results are highlighted in the table and shown in italic font.

Table 4 Crash Frequencies Before and After AEP Implementation

Location ID	Crashes Before	Crashes After	% Change	P-value	Hypothesis Test Result
RLR					
1	89	91	2.24	0.557	Fail to Reject
2	31	42	<i>35.48</i>	<i>0.006</i>	<i>Reject</i>
3	29	12	<i>-58.62</i>	<i>0.000</i>	<i>Reject</i>
4	29	12	<i>-58.62</i>	<i>0.000</i>	<i>Reject</i>
5	102	38	<i>-62.75</i>	<i>0.000</i>	<i>Reject</i>
ES					
6	95	50	<i>-47.37</i>	<i>0.002</i>	<i>Reject</i>
7	83	73	-12.05	0.392	Fail to Reject
8	174	79	<i>-54.59</i>	<i>0.023</i>	<i>Reject</i>
9	47	31	<i>-34.04</i>	<i>0.049</i>	<i>Reject</i>
10	78	63	<i>-19.23</i>	<i>0.015</i>	<i>Reject</i>
11	27	22	<i>-18.51</i>	<i>0.041</i>	<i>Reject</i>
12	61	82	34.42	0.086	Fail to Reject

It can be seen that crash frequency was significantly reduced at eight camera locations. It was significantly reduced at three RLR camera locations by almost (59-63) % and by almost (19-55) % at five ES camera locations. It can also be seen that crash frequency was significantly increased by 35% at one RLR camera location. This might be explained by the high speed

of the two intersecting roads at that intersection, Al-Ersal intersection, which might lead to the increased probability of rear-end crashes.

4.2 AEP Effect on Crash Severity

The effect of implementing the AEP on crash severity was also tested on locations 1 through 12. Table 5 summarizes crash severity mean value before and after the AEP implementation. The table also shows the percent change in crash severity before and after the AEP implementation and the statistical significance of the results.

Table 5 Crash Severity Before and After AEP Implementation

Location ID	Injury/Fatally Before	Injury/Fatally After	% Change	P-value	Hypothesis Test Result
RLR					
1	10	10	0	0.885	Fail to Reject
2	4	3	-25	0.049	Reject
3	1	1	0	0.423	Fail to Reject
4	1	1	0	0.423	Fail to Reject
5	15	9	-40	0.035	Reject
ES					
6	9	4	-55.55	0.049	Reject
7	11	6	-45.45	0.034	Reject
8	16	6	-62.5	0.049	Reject
9	4	4	0	0.910	Fail to Reject
10	8	7	-12.5	0.822	Fail to Reject
11	2	2	0	0.885	Fail to Reject
12	6	5	-16.67	0.478	Fail to Reject

Table 5 shows that crash severities were significantly reduced at only five camera locations. Crash severities were significantly reduced by up to 40% at two RLR camera locations and by up to 62.5% at three ES camera locations. The severities on the remaining AEP sites were not changed or were reduced with no statistical significance.

4.3 AEP Effect on Violations

Locations 13 through 21 were used to study the effect of implementing the AEP on violations. Table 6 summarizes violation mean values before and after the AEP implementation. The table shows the percent change in violations before and after the AEP implementation. The statistically significant results are also highlighted in the table and shown in italic font.

It can be concluded that traffic violations were significantly reduced at six locations. Violations were significantly reduced by (40-60) % at two RLR camera locations and by (20-66) % at all ES camera locations. The violations on the remaining AEP sites were reduced but with no statistical significance.

Table 6 Violations Before and After AEP Implementation

Location ID	Violation Before	Violation After	% Change	P-value	Hypothesis Test Result
RLR					
13	5475	3285	-40	0.003	Reject
14	21900	26645	21.7	0.249	Fail to Reject
15	32120	27740	-13.6	0.327	Fail to Reject
16	14600	5840	-60	0.043	Reject
17	8395	7300	-13.1	0.413	Fail to Reject
ES					
18	27375	18980	-30.7	0.013	Reject
19	21270	13870	-34.5	0.007	Reject
20	13870	4745	-65.8	0.001	Reject
21	73730	59130	-19.8	0.019	Reject

5 Drivers Opinion and Attitude

To assess drivers' opinion and attitude towards the AEP, a questionnaire survey was conducted in November 2016. A sample size of 385 was calculated using an online calculator assuming a confidence level of 95% with a marginal error of 5%, 301 drivers responded. The questionnaire was distributed to drivers having different driving license types. The survey was divided into two parts. Part one of the survey contained three demographic questions about gender, age and educational level and one question was about the driver's driving license type. 67.6% of the respondents were male drivers, 83.4% were younger than 35 years old, 30.4% had higher educational level and the remaining had high school or diploma educational level, 88.4% had a private driving license while 7.5% had a public driving license and 4.1% had other types of driving license.

Part two of the survey contained a total of fifteen AEP related questions. Four of them were about driver's awareness of the AEP, two questions were about the AEP penalties, four questions were about the effectiveness of the AEP on driving behaviour, one question was about the perceived effects of AEP on roadway safety, two question were about the level of support and acceptance of AEP, and two question were if drivers favour AEP than policeman. Table 7 shows a list of the AEP related survey questions showing the percentages of the probable answer.

When drivers were asked about the AEP awareness, it was found that 35.5% of drivers are unaware of AEP in Amman and 63.9% of them don't know the camera locations in Amman, almost half of them think that drivers should not be informed about camera locations. Finally, 41.8% of drivers understand the concept behind the AEP.

Also, when drivers were asked about the AEP penalties, it was found that most drivers knew about ES and RLR penalties.

With regard to the effectiveness of the program on driving behaviour, 85.4% of drivers reduce their speed at camera

Table 7 AEP Related Survey Questions

	Question	Response (%)		
		Yes	No	Maybe
AEP Awareness	1. Do you know about the AEP in Amman?	35.5	49.3	15.2
	2. Do you know camera locations in Amman?	11.8	63.9	24.3
	3. Do you think that drivers should not be informed about camera location?	42.4	42.7	14.9
	4. Do you know how AEP works?	41.8	38.5	19.7
AEP Penalty	5. Do you know the penalty of exceeding speed limits?	59.3	20.5	20.2
	6. Do you know the penalty of red right running?	70.7	19.1	10.2
	7. Do you reduce your speed at camera location?	85.4	5.4	9.2
AEP Effect on Driving Behaviour	8. Do the presences of cameras affect your behavior at similar locations with no cameras?	56.1	21.3	22.6
	9. Do the presences of camera deter the drivers from breaking traffic laws?	72.1	9.4	18.5
	10. Do you note that the behavior of other drivers is affected by the presence of camera?	76.9	12.6	10.5
AEP Effect on Safety	11. Where you involved in a crash at the camera location?	12.8	85.2	2.0
AEP Acceptance	12. Do you approve the use of AEP to enhance safety?	44.4	25.4	30.2
	13. Do you encourage the idea of increasing the number of camera devices in Amman?	52	34.4	13.6
AEP than Policeman	14. Comparing the policeman with camera device, cameras deter the drivers with traffic laws more than policemen?	54.1	26	19.9
	15. Do you think that policemen can be replaced by camera devices?	32.4	51.7	15.9

locations, 56.1% indicated that the AEP affect their behaviour at similar locations with no cameras. 72.1% of them stated that the AEP discourage them from braking traffic laws. Also, 76.9% think that the behaviour of other drivers is affected by the AEP.

Drivers were also asked about AEP effect on safety; it was found that only 12.8% were involved in a crash at the camera location.

When the AEP acceptance was evaluated, 44.4% of drivers think that the AEP satisfy its objective in enhancing traffic safety and 52% of drivers encourage increasing number of camera devices in Amman.

Finally, when comparing the policeman with camera device, 54.1% of participant stated that cameras deter the drivers from breaking traffic laws more than policemen and 32.4% of them favour cameras than policemen.

6 Conclusion

This study adds to the evidence that excessive speed cameras and red light running cameras can enhance road safety at arterial roads and signalized intersections.

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