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EFFECT OF REDUCING SPEED BUFFER POLICY ON SAFETY AT SIGNALIZED INTERSECTIONS - ABU DHABI CASE STUDY

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ABSTRACT

In 2018, Abu Dhabi Police announced that there would be no speed buffer in all roads and the Municipalities added the amount of the buffer (20 kph) to all posted speeds. The move seems to respond to the need to standardize road traffic policies with global practices. The research narrows on this speed buffer policy in an attempt to establish its possible effect on the safety at signalized intersections in Abu Dhabi. There were no changes in road characteristics, signal plan and signal timing during the study period except the posted speed limit before and after the removal of the speed buffers. This was done to find the impact of removing speed buffer on safety performance of signalized intersections. Overall, the policy change was attributed to increase an average speed which was suspected to have resulted in the increased average number of incidences and accidents at the intersections. Increased speeds affected the practical breaking distance and reaction time, and thus resulted into increased potential cases of conflicts at intersections. Empirical Bayes (EB) analysis was used to find the impact of removing speed buffer on safety performance of signalized intersections. In summary, the study noted increased traffic incidences with the removal of the speed buffers. The policy makers should therefore reconsider their decision.

Keywords: Split Signal Phasing, Lead-Lag Signal, Speed Buffer, Signalized Intersection, Abu Dhabi City

INTRODUCTION

Apart from driver specific factors, accidents and traffic incidents often result from unsafe operational conditions of road traffic systems, design, and policies. Consequently, understanding the potential areas of probable unsafe operational conditions within the road traffic system becomes the beginning point for researchers intending to address safety issues on the road. Accordingly, most UAE states rely on international standards in road design to meet the operational and safety requirements of road users. However, excess speed has been identified as one of the main causes of road accidents in the UAE (Maceda, 2018). Reasons for speeding have been attributed to, among other factors, improvement in the level of luxury and technology in most vehicles which have affected the driver's sense of the road. Different demographics have also been associated with speeding. For instance, male drivers were found to be more likely to be involved in accidents while speeding and female drivers were overwhelmed by traffic volumes (Abdel-Aty & Radwan, 2000).

Abu Dhabi seemed to have recognized the effect of speed and led in the Gulf States region to remove the 20 kph speed buffer between the speed sign and the speed of the enforcement in order to reduce the variation in the speed of vehicles going on the same direction. According to the police chief, the policy change was conceived from extensive studies on the effect of the speed buffer and

how it could contribute to conflicts (Zaatari, 2018). Indeed, extensive studies have associated speeding with road accidents including at intersections.

According to a study by Schultz, et al., (2007), it is contended that motorists often face splitting second decisions at signalized intersections as the signals are dynamic. The decision to stop or proceed can be significantly informed by the approaching speed and influenced by location and weather conditions among other factors. As such, stopping distance as a factor of vehicles approaching speed is a significant factor in investigating conflicts at intersections.

However, Abu Dhabi Police announced that there would be no speed buffer in all roads and the Municipalities added the amount of the buffer (20 kph) to all posted speeds (Zaatari, 2018). The main objective of this study was to investigate the impact of removing the speed buffer (20 kph) and speed amount to the speed signs on traffic safety performance at the signalized intersections in Abu Dhabi, UAE. The study relied on severe traffic accident records for 48 months and traffic signal phases sequence before and after the removal of speed buffers. The analysis was conducted for signalized intersections which experienced changes in posted speed. Moreover, the safety performance of signalized intersection was evaluated after removing the speed buffer in terms of the number of violations that occurred at the signalized intersections compared to the same period before the implementation.

RESEARCH BACKGROUND AND LITERATURE REVIEW

Signalized intersections are some of the most critical aspects of transportation design. As such, safety at these intersections is a major concern. This is because of the higher chance of fatal accidents occurring at such sections due to increased number of conflicts associated with them. Extensive studies have been conducted to continually assure safety at intersections including signaling, timing, lane design and approach speed among other factors (Amundson & Hyden, 1977; Buckholz, 1933; Lu et al., 2008; Tian, 2013).

According to traffic-safety data in the United States, more than 20% of fatalities arising from traffic happen at intersections. The crashes at the intersections may be caused by several factors, but signalized intersections with high approach speeds generate the highest number of fatal crashes (Pirdavani et al., 2010). Several studies have shown that counter-measures involving the reduction of speed limits on the intersection approaches can greatly reduce the frequency and the severity of the injuries resulting from the crashes (Wu et al., 2013).

According to a study by Alghafli & Shawky, (2013) regarding the operational conditions of accidents occurrence and severity at the signalized intersections, the lead/lag signal phasing sequence increases the probability of serious injuries. Also, five significant variables affect the severity of accidents occurrence at signalized intersections, they are: speed of the main road, traffic signal sequences, number of through lanes of minor road, number of left lanes of main and minor road.

There have been several studies conducted to determine the effectiveness of reducing speed limits enacted due to changes in laws/regulations, special transition zones, variable speed limits, and dynamic message signs. The results from these studies have confirmed that the driver's speed affects the severity of crashes due to the relationship between vehicle velocity, absorbed energy upon impact and kinetic energy (Wang & Sharma, 2017). Because of this, a study by Devalla, et al., (2015) showed that enforcement of speed limit programs at signalized intersections would lead to a significant reduction in the speed of the vehicle and the frequency of crashes.

The current research investigated if the speeding violation and running red light camera could cause conflicts. As such, perhaps reducing speed buffer could significantly reduce conflicts at intersections. The notion could be associated with discourse about the decision zone for vehicles approaching an intersection. Among other factors, such a zone is characterized by the minimum

stopping distance which is a factor of speed, driver-specific factors, and the type of vehicle. Milazzo et al., (2002) observed that the minimum stopping distance is based on deceleration rate and reaction time. However, it is further noted that the case varies from one driver to another. This assertion could be further associated with the findings by Abdel-Aty & Radwan, (2000) which indicated demographic specific factors. Effectively, others such as Huang & Pant, (1994) and Klugman et al., (1992) suggested that the decision zone and consequent stopping distance for specific intersections can be analyzed by observing braking characteristics of approaching vehicles. Shorter decision zones mean shorter braking distance and the need for shorter reaction times which could result in conflicts at intersections (Schultz, et al., 2007). However, since there were limited resources to capture the conflict in the network, this research investigated if the driver's violations could lead to unsafe movement, which may cause a conflict and result in an accident.

For evaluation studies, the effect of mean speeds and the number of crashes leading to injuries and casualties were compared between signalized intersections, where speed limits were enforced, as well as intersections where there were no speed limits. A study by Stephens et al., (2017) is an example of these evaluation studies. Stephens et al., (2017) study showed that the frequency and fatality of crashes at signalized intersections where speed limits were enforced were significantly lower than signalized intersections where speed limits were not enforced. This study, among other studies, confirmed the advantages of enforcing speed limits at signalized junctions which is a reduction in the frequency of crashes at the intersections.

Other studies have been conducted to evaluate the effect of enforcing the speed limits at signalized intersections by comparing observed speeds and the frequencies of crashes in the periods before and after enforcement of the speed limits. Several methods of analysis ranging from generalized least square estimation (Shin, et al., 2009) to Full Bayesian (FB) before-after evaluation (Islam & El-Basyouny, 2015) have been conducted. The studies confirmed that reducing speed limits were effective in improving safety at the intersections. However, in the case of Abu Dhabi, even if the speed buffer is been removed in Abu Dhabi, the enforcement speed remained unchanged because the Municipalities added the amount of the buffer to the posted speed sign. In this case, before and after analysis has been conducted for the number of speed violations red light running violations in order to evaluate the effect of the policy on the traffic safety.

Actions on Signalized intersection

Several actions have been implemented to the signalized intersections which affected the traffic operation at the intersections (Figure 1). In July 2009, the Department of Transport (DoT) of Abu Dhabi changed the signal design to include flashing green at the end of the green intervals to all Abu Dhabi Island traffic signals. In January 2010, the DoT started the Lead-Lag phasing left turn plan instead of splits at several signalized intersections. The aim was to maintain a green wave at certain corridors to increase the capacity because through movements are considered to be majority compared to the left turning movements. In March 2011, a speed limit review study recommended changes to the speed limits of three corridors in Abu Dhabi Island from 60 kph to 80 kph. In August 2018, Abu Dhabi Police announced that there would be no speed tolerance in all roads, and the Municipalities added the amount of the tolerance (20 kph) to all posted speeds.

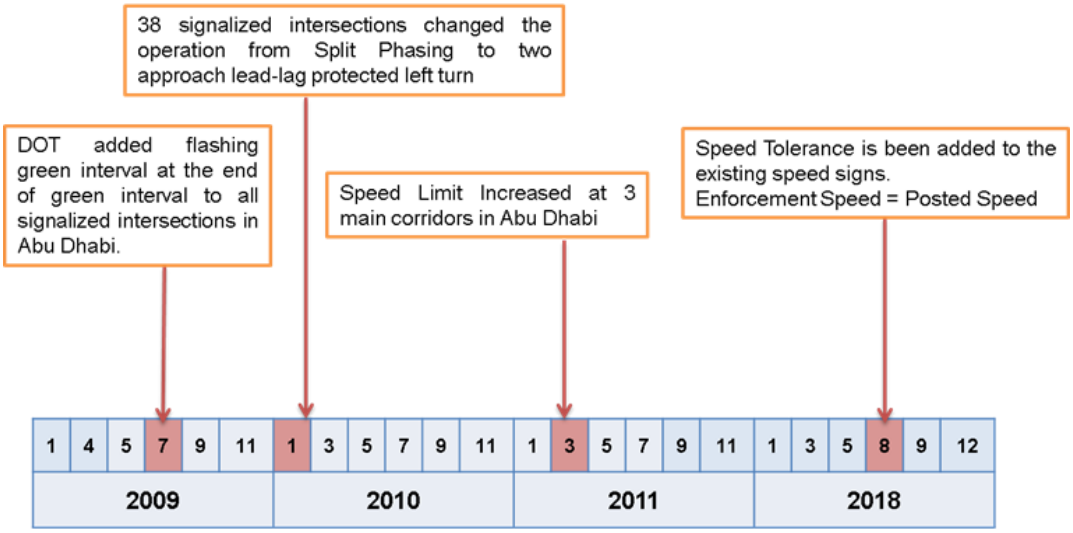

FIGURE 1
CHANGES AND IMPROVEMENTS IN THE TRAFFIC SYSTEM BETWEEN THE YEARS 2008 AND 2018

MATERIALS AND METHODS

Modeling Technique

In order to perform the signalized intersections safety performance before and after analysis, Empirical Bayes (EB) technique was employed. The technique was employed because it controls for the effects of potential confounding factors such as the long-term trends, exogenous changes in traffic volume and regression-to-the mean. Empirical Bayes technique is mainly used to determine to expected number of accidents before implementation of a treatment and comparing the results with the actual recorded number of accidents after implementation of the treatment.

EB involves five steps: determination of the Safety Performance Function (SPF), determination of overdispersion parameter (ϕ), determination of the relative weights (α), the expected number of crashes if the treatment were not implemented (π) and the effectiveness index (θ). For this study (determination of the effect of removing speed buffers on crashes in Abu Dhabi's signalized intersections), these factors were determined as follows.

$$SPF = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + E$$

Where:

SPF = Safety Performance function
β_0 = Constant
β_i = Coefficients
X_1 = Enforcement speed
X_2 = Average Hourly traffic volume
X_3 = Number of lanes

These coefficients were determined using Negative Binomial regression on the before removal of speed buffer data.

Weights

$$\alpha = 1 \div (1 + (SPF/\phi)$$

Expected accidents after implementation of Buffer was calculated as follows

$$\pi = (\alpha \times SPF) + (1-\alpha)(\lambda)$$

Where

λ = Actual recorded number of accidents after buffer

π = Expected number of accidents had the buffer not implemented

ϕ = Dispersion

The Expected number of accidents had the buffer not implemented (π) were then compared with Actual recorded number of accidents after buffer (λ) to determine the effectiveness of the implementation of removal of buffer from the speed limits.

Sources of data

These data sources include: Abu Dhabi Police, Department of Transport (DoT) and Department of Urban Planning and Municipalities. Abu Dhabi Police stores all accidents data in a Federal Traffic Database was the source of traffic accident data; DoT has data regarding signal phasing plans and was the source of data regarding signal phasing at the intersections; and Department of Urban Planning and Municipalities was the source of data associated with road works and redesign of the intersections. The severe accident data collected from Federal Traffic Database were identified and collected. This included severe accidents (at least one injury resulted in the accident) that occurred at signalized intersections in Abu Dhabi Island for the period from August 2016 to end of 2020.

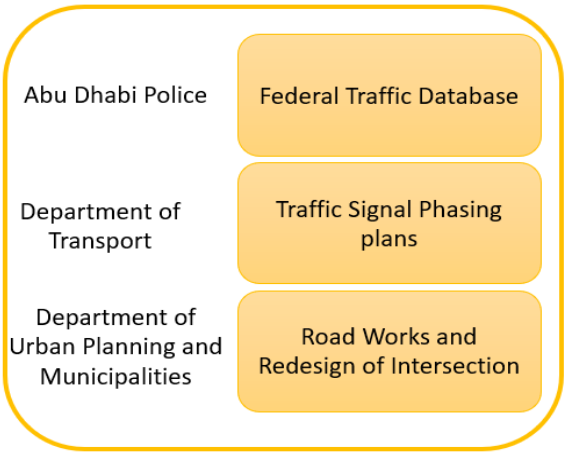

FIGURE 2
SOURCES OF DATA

The obtained data were classified into four. The four classifications are:

1. Type 1: Accidents where pedestrians were involved.
2. Type 2: Rear-End Accidents.
3. Type 3: Right- Angle accidents.
4. Type 4: Roll-Over Accidents.

The above classification conformed with a classification adopted by a prior research that was carried out by Alghafli et al., (2013).

Since most of the signal phasing sequences of all approaches in Abu Dhabi is either split phasing or Lead-Lag phasing, traffic signal phasing plans that had been provided by the Traffic Control Center of Abu Dhabi Department of Transport and signalized intersections with a lead lag phasing sequence have been defined. Additionally, some investigations were made to define intersections that experienced geometry change through the years 2018 to 2019 to illuminate intersections that had major geometric change. Such data were obtained from the Department of Urban Planning and Municipalities.

Moreover, because of the removal the speed buffer which was mentioned earlier in August 2018, the analysis done before and after the incident was based on the following time periods:

- Period 1: Starts in August 2016 and ends in July 2018 (24 months). This is period before speed buffer was removed.
- Period 2: Starts in January 2019 and ends on December 2020 (24 months). This is the period after speed buffer was removed.

It is, however, important to note the period from August 2018 to December 2018 (4.5 months) have been excluded from the study as it was a transition period. During this transition period, drivers were getting used to the new posted speed signs.

Abu Dhabi Police in 2013 started to adopt a red signal running violation camera system. In 2016, 196 running red light camera systems had been installed in Abu Dhabi and since then, no changes have been done. This system is able to capture running red signal and speed limit violations. However, according to Traffic Engineering and Road safety Department, during 2020 some of the red signal running violations cameras stopped working for maintenance. Therefore, the analysis for the red-light running violation will be as the following:

- Period 1: Starts in August 2017 and ends in July 2018 (12 months). Period before removal of speed limit buffers.
- Period 2: Starts in January 2019 and ends on December 2019 (12 months). The period after removal of speed limit violation.

Since there were no changes in road characteristics and signal plan, as well as in signal timing during the study period, except for the posted speed, before and after methodology were performed in order to find the impact of removing speed buffer on safety performance of signalized intersections Alghafli et al., (2013).

Research Limitation

This research employed an archival research strategy where data used in the study were obtained from secondary sources (databases). This type of research strategy may be associated with two limitations: (1) The archived data could be outdated as instruments used in collection of the such may be outdated and hence their accuracy may be questioned. Also, people's behavior and perceptions change over time. Therefore, the accuracy of results of this study are subject to the accuracy secondary data collected. (2) The researcher never participated in the collection of data, and as such, issues that may have been faced during data collection may not be understood by the researcher.

Validity and reliability

In order to ensure validity and reliability of the research method and results, the research employed a methodology that was successfully employed by previous study. The research method involves comparing the before and after performances. The methodology was used was employed by carried out by Alghafli et al., (2013).

RESULTS AND DISCUSSION

Summary statistics of the number of different types of accidents before and after removal of speed buffers

The summary statistics of the four types of severe accidents recorded at all the signalized intersections in Abu Dhabi Island before and after removal of the speed buffers is shown in Table 1 were.

Table 1 ACCIDENT DATA BY TYPE				
	Accident Type			
	Pedestrian	**Rear End**	**Right Angle**	**Rollover**
Before	18	27	94	9
After	9	12	57	6
Total	27	39	113	15

Determination of the EB factors

Negative binomial regression model

$SPF = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + E$

Where:

SPF = Safety Performance function

β_0 = Constant

β_i = Coefficients

X_1 = Enforcement speed

X_2 = Average Hourly traffic volume

X_3 = Number of lanes

These coefficients were determined using Negative Binomial regression on the before removal of speed buffer data.

The regression results showed that

SPF model at 4-legged intersection

$\beta_0 = -2.08$ ($p = 0.018$)

$\beta_1 = 0.0207$ ($p = 0.009$)

$\beta_2 = 5.16 \times 10^{=6}$ ($p = 0.895$)

$\beta_3 = 0.295$ ($p = 0.039$)

Therefore,

$SPF = -2.08 + 0.0207X_1 + 0.295X_3$

Dispersion (ϕ) = 0.126

Weights

$\alpha = 1 \div (1 + (SPF/0.126)$

Expected accidents after implementation of Buffer was calculated as follows

$\pi = (\alpha \times SPF) + (1-\alpha)(\lambda)$

Where

λ = Actual recorded number of accidents after buffer

π = Expected number of accidents had the buffer not implemented

The results are shown in the subsequent sections.

Effect of Removing Speed Buffers at 4 Leg Intersection

The results of EB determining the expected number of crashes were the speed buffers not implemented are shown in table 2 below. Table 2 also shows values of SPFs, and actual accidents number of accidents recorded after implementation of the speed buffers. The results in table 2 show that implementation of speed buffers never improved the safety performance at 4-leg intersections. In fact, the results show that removal of speed buffers and adding the speed buffer amount to the speed limit made matters worse. Adding speed buffers increased the number of accidents by between 4% and 76% with most of days recording increase in the number crashes. Only a few days recorded improvement of safety performance in which the number of crashes reduced by between

2% and 4%. The increase in speed limit by the buffer amount may be major cause of the increase accidents at the 4-leg intersections. Increasing speed limit increases drivers' reaction time, affects their judgment and visibility, and increases practical breaking distance, and thus resulting into increased potential cases of conflicts at intersections. All these factors result into increase in traffic accident occurrences.

Since the removal of speed buffers resulted into increase of traffic accidents at signaled 4-leg intersection, the transport authorities in Abu Dhabi need to reconsider their decision. Probably maintaining the speed buffers was better than removing them as this study show.

Table 2
EFFECT OF REMOVING SPEED BUFFERS AT 4 LEG INTERSECTION

SPF	α	1-a	Expected number of accidents (p)	Actual Number of accidents recorded (λ)	Percentage change
0.76	0.14	0.86	2.68	3	12%
0.58	0.18	0.82	1.75	2	15%
0.76	0.14	0.86	0.97	1	4%
0.46	0.21	0.79	1.67	2	20%
1.17	0.1	0.9	1.02	1	-2%
1.17	0.1	0.9	1.02	1	-2%
0.46	0.21	0.79	0.88	1	13%
0.76	0.14	0.86	0.97	1	4%
0.76	0.14	0.86	0.97	1	4%
0.13	0.49	0.51	0.57	1	76%
0.76	0.14	0.86	0.97	1	4%
0.76	0.14	0.86	2.68	3	12%
1.17	0.1	0.9	1.02	1	-2%
0.17	0.43	0.57	0.64	1	56%
0.46	0.21	0.79	0.88	1	13%
1.17	0.1	0.9	1.02	1	-2%
0.88	0.13	0.87	1.86	2	8%
1.17	0.1	0.9	4.63	5	8%
1.17	0.1	0.9	1.02	1	-2%
1.17	0.1	0.9	1.92	2	4%
1.17	0.1	0.9	1.92	2	4%
0.76	0.14	0.86	0.97	1	4%
0.76	0.14	0.86	0.97	1	4%
0.76	0.14	0.86	0.97	1	4%
0.46	0.21	0.79	0.88	1	13%
0.46	0.21	0.79	0.88	1	13%
1.17	0.1	0.9	3.72	4	7%
1.47	0.08	0.92	1.04	1	-4%
1.17	0.1	0.9	1.92	2	4%
0.76	0.14	0.86	0.97	1	4%
0.76	0.14	0.86	0.97	1	4%
1.17	0.1	0.9	1.02	1	-2%
0.46	0.21	0.79	0.88	1	13%
0.76	0.14	0.86	0.97	1	4%
0.46	0.21	0.79	0.88	1	13%
0.46	0.21	0.79	0.88	1	13%
0.76	0.14	0.86	0.97	1	4%
0.88	0.13	0.87	4.48	5	12%
0.76	0.14	0.86	0.97	1	4%
1.17	0.1	0.9	1.92	2	4%
0.76	0.14	0.86	0.97	1	4%
0.46	0.21	0.79	0.88	1	13%

0.76	0.14	0.86	0.97	1	4%
1.17	0.1	0.9	1.02	1	-2%
1.17	0.1	0.9	1.02	1	-2%
1.17	0.1	0.9	4.63	5	8%
1.17	0.1	0.9	1.02	1	-2%
0.88	0.13	0.87	0.98	1	2%
1.17	0.1	0.9	1.02	1	-2%
0.76	0.14	0.86	1.82	2	10%
0.46	0.21	0.79	0.88	1	13%
1.17	0.1	0.9	5.53	6	8%
0.76	0.14	0.86	0.97	1	4%
0.13	0.49	0.51	0.57	1	76%
0.76	0.14	0.86	1.82	2	10%
1.17	0.1	0.9	4.63	5	8%
0.46	0.21	0.79	0.88	1	13%
0.76	0.14	0.86	0.97	1	4%
0.76	0.14	0.86	0.97	1	4%
1.17	0.1	0.9	1.02	1	-2%
0.76	0.14	0.86	0.97	1	4%

Effect of Removing Speed Buffers at 3-Leg Intersection

Table 3 shows the results of the effects removing speed buffers and adding the buffer amount to the speed limit at 3-leg signalized junction. The table also shows values of SPFs, and actual accidents number of accidents recorded after implementation of the speed buffers. The results indicate that removal of the speed buffers and adding the buffer amount to the speed limit does not enhance safety at 3-leg signalized intersection. It makes matters worse just as seen in the 4-leg intersections. From table 3 it is observed that improvement of safety performance was recorded in only 3 of the 17 days examined. During the period of examination, traffic crashes increases by 4 to 418% which were recorded in 14 of the 17 days in which traffic accidents were recorded in the 3 leg intersections. This increase in traffic crashes may be associated with increasing drivers' reaction time and breaking distance, poor judgments and visibility all of which are initiated by high speeds.

Since removal of speed buffers and adding the buffer amount to the speed limit worsens the safety performance of 3-leg signalized junctions, Abu Dhabi traffic and transport authorities should reconsider their decision of removing the speed buffers and replacing them with increased speed limits.

Table 3
EFFECT OF REMOVING SPEED BUFFERS AT 3 LEG INTERSECTION

SPF	a	1-a	Expected number of accidents (p)	Actual Number of accidents recorded (λ)	Percentage change
0.46	0.21	0.79	0.88	1	13%
0.46	0.21	0.79	1.67	1	-40%
0.46	0.21	0.79	0.88	1	13%
0.76	0.14	0.86	0.97	2	107%
0.76	0.14	0.86	0.97	1	4%
0.76	0.14	0.86	3.54	1	-72%
0.76	0.14	0.86	0.97	5	418%
0.76	0.14	0.86	0.97	1	4%
0.46	0.21	0.79	0.88	1	13%
0.46	0.21	0.79	3.24	1	-69%

0.76	0.14	0.86	0.97	1	4%
0.76	0.14	0.86	0.97	1	4%
0.76	0.14	0.86	0.97	1	4%
0.17	0.43	0.57	0.64	1	56%
0.46	0.21	0.79	0.88	1	13%
0.46	0.21	0.79	0.88	1	13%
0.76	0.14	0.86	0.97	1	4%

Effect of Removing Speed Buffers at Different Intersection

Table 4 indicates the effects removing speed buffers and adding the buffer amount to the speed limit at different intersection types (such as roundabouts) in Abu Dhabi. The table also show values of SPFs,α, and actual accidents number of accidents recorded after implementation of the speed buffers. The results in the table show that the proposed removal of the speed buffers and increasing the speed limit by the buffer amount will actually increase traffic crashes at these intersections thereby worsening the safety performance of these intersections. From table 4 it is observed that improvement of safety performance was recorded in only 2 out of the 6 instances. The rest of the instances recorded decrease in safety performance. For instance, safety performance at these intersections decreased by 97 to 314% and were recorded in 4 times in these intersections (Table 4). Safety performance increase which was recorded in only 2 instances ranged between 45% and 77% (Table 4). This increase in traffic crashes may be attributed to increase drivers' reaction time and breaking distance, poor judgement and visibility all of which are initiated by high speeds. Since removal of speed buffers and adding the buffer amount to the speed limit worsens the safety performance of different types of intersection, it is recommended that Abu Dhabi traffic and transport authorities should reconsider their decision of removing the speed buffers.

Table 4
EFFECT OF REMOVING SPEED BUFFERS AT DIFFERENT INTERSECTION

SPF	α	1-a	Expected number of accidents (p)	Actual Number of accidents recorded (λ)	Percentage change
0.76	0.14	0.86	0.97	4	314%
0.76	0.14	0.86	1.82	1	-45%
0.76	0.14	0.86	4.39	1	-77%
0.46	0.21	0.79	0.88	2	126%
1.17	0.1	0.9	1.02	2	97%
1.17	0.1	0.9	1.02	2	97%

CONCLUSION

In summary, Abu Dhabi Police announced in 2018 that there would be no speed buffer in all roads, and the Municipalities added the amount of the buffer (20 kph) to all posted speeds. Consequently, since this legislation or policy affects the speed of vehicles, and most of the road accidents in the UAE are associated with speeding, it is important to understand the unsafe operational conditions within the road traffic system. Since there were no changes in road characteristics, signal plan and signal timing during the study period, except for the posted speed limit, which was applied before and after study was performed, Empirical Bayes (EB) analysis was used to find the impact of removing speed buffer on safety performance of signalized intersections.

The study found that in all types of the signalized intersections, the proposed removal of speed buffers and adding the buffer amount to the posted speed limits would actually decrease safety performance of the intersections. This is because results of the study showed that this planned removal of speed buffers would actually result into increase in traffic accidents instead of reducing them, thereby making the situation worse. The increase in crashes may attributed to increase drivers' reaction time and breaking distance, poor judgement and visibility all of which are initiated by high speeds. The policy makers should therefore reconsider their decision and reduce the speed limit to the previous speed posted speed limit (20 kph less than the current posted speed limits) in the roads that have signalized intersections.

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