UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SAFETY PERFORMANCE ANALYSIS OF SIGNALIZED INTERSECTIONS IN ABU DHABI USING A MIXED RESEARCH APPROACH

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DOCTOR OF PHILOSOPHY

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Institute of Technology Management and Entrepreneurship

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A thesis submitted
in fulfilment of the requirements for the degree of Doctor of Philosophy

Institute of Technology Management and Entrepreneurship

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2023

DECLARATION

I declare that this thesis entitled “Safety Performance Analysis of Signalized Intersections in Abu Dhabi Using a Mixed Research Approach” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : 15 May 2023

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APPROVAL

I hereby declare that I have read this thesis, and, in my opinion, this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : *fendi*

.....

Supervisor Name : PROFESSOR TS. DR EFFENDI MOHAMAD

.....

Date :

.....

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DEDICATION

To my beloved father and mother, for your uninterrupted prayers.

To my wife, my beloved companion who spared no time or effort to help me complete my studies.

To my sisters, for all the support and encouragement.

To my leaders and role models in work, research and persevereance, Sheikh Mohammed bin Rashid Al Maktoum and Sheikh Mohammed bin Zayed Al Nahyan for your unlimited support in empowering Emiratis in all fields.

To the Commander-in-Chief of Abu Dhabi Police and the Head of the Department of Municipalities and Transport, for your support and approval to use the data to complete this work.

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I dedicate to you my scientific thesis that will improve traffic safety at traffic light intersections in the United Arab Emirates.

ABSTRACT

Even though Abu Dhabi government has taken a number of steps to reduce the number of road accidents, and fatalities as well as injuries associated with them, the city has continued to experience high number of traffic accidents especially at the intersections. According to Abu Dhabi's Police Traffic Engineering Department, in 2013 for instance, of all the 1400 severe traffic accidents, signalized intersections were responsible for 240 traffic accidents which was the highest contribution by a single factor. On the other hand, red light violation (RLV) is considered one of the major contributors of traffic accidents in many cities including Abu Dhabi. Several studies done elsewhere have attributed this to reaction times after activation of red light but not in Abu Dhabi which may help the authorities implement appropriate signal phasing timings at the intersections. Moreover, in an effort to homogenize Abu Dhabi City's Road traffic rules with those of international rules, Abu Dhabi government removed the 20 kph speed buffers on all roads in 2018. This was implemented in such a way that the enforcement speed and the posted speed have the same value. However, few studies have examined the effect of implementing policies to the safety performance at the signalized intersections. The study aims at improving the safety performance of these intersections by determining operational and geometric factors affecting safety performance of the Abu Dhabi's Signalized intersection; determining the effect of drivers' reaction time; determining the effect of removal of speed buffers on the safety performance of Abu Dhabi's Signalized intersections; ascertain the recommendations used by road safety audit staff while evaluating signalized intersections; and proposing practical and feasible safety performance indicators that could act as a standard to the administrative authorities for developing the signalized intersections. The objectives were achieved via quantitative research methodology (objectives 1 to 3) and qualitative research (Objective 4 and 5). The data were analysed via descriptive and inferential statistics (negative binomial regression) and thematic analysis. The result shows that when compared to other intersections, 3-leg intersections tend to be more sensitive to variations of the geometric and operational factors. This is such that the size of the mid-island (major direction), the size of separation between through and left and number of lanes in minor left are negatively related with number of accidents. The size of mid-island (minor direction), number lanes in the main through, number of pedestrian crossings, intersection speed, and average hourly traffic are positively related at this intersection. In terms of objective 2, the research found that most of the red violations and hence traffic accidents occur between less than 1s to 2 to 3 seconds after activation of red light at the intersections which indicates drivers' reaction is a major contributor safety performance of these intersections. In terms of objective 3, the study found that introduction of speed buffers indeed reduced traffic accidents, and thus improved the safety performance of the intersections. In terms of objectives 4 and 5, the research found that: there is the poor implementation of guidelines by the auditors. Based on the above results, it is recommended that other emirates in UAE should consider implementing the policy; safety manual should be improved to conform to the internationally renowned manuals.

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ANALISIS PRESTASI KESELAMATAN PERSIMPANGAN BERISYARAT DI ABU DHABI MENGGUNAKAN PENDEKATAN PENYELIDIKAN GABUNGAN

ABSTRAK

Biarpun kerajaan Abu Dhabi telah mengambil langkah untuk mengurangkan jumlah kemalangan jalan raya dan kaitannya dengan kematian dan kecederaan, bandar itu masih menunjukkan jumlah kemalangan jalan raya yang tinggi, terutamanya di persimpangan. Menurut Jabatan Kejuruteraan Trafik Polis Abu Dhabi, pada 2013, persimpangan berisyarat adalah punca 240 daripada 1400 kemalangan serius jalan raya yang merupakan faktor penyumbang tertinggi. Pelanggaran lampu merah (Red light violations) adalah punca utama kemalangan jalan raya di banyak bandar, termasuk Abu Dhabi dan beberapa kajian telah mengaitkan keadaan ini dengan masa tindak balas pemandu selepas lampu merah diaktifkan. Walau bagaimanapun, tidak ada kajian seperti itu dijalankan di Abu Dhabi. Pada 2018, kerajaan Abu Dhabi mengalih penampan berkelajuan 20 kph di semua jalan sebagai sebahagian daripada usaha untuk menyesuaikan peraturan jalan raya bandar dengan peraturan antarabangsa. Kini kelajuan penguatkuasaan dan kelajuan yang ditetapkan mempunyai nilai yang sama. Di sebalik perubahan ini, beberapa kajian telah melihat kesan dasar tersebut terhadap prestasi keselamatan persimpangan berisyarat. Kajian ini bertujuan menambah baik prestasi keselamatan persimpangan ini dengan mengenal pasti faktor-faktor operasi dan geometri yang mempengaruhi keselamatan persimpangan berisyarat di Abu Dhabi, menentukan kesan masa tindak balas pemandu, menganalisis kesan pengalihan penampan kelajuan dan mencadangkan indikator prestasi keselamatan yang praktikal dan boleh dilaksanakan untuk digunakan oleh pihak berkuasa pentadbiran apabila membangunkan persimpangan berisyarat. Objektif kajian dicapai melalui gabungan kaedah penyelidikan kuantitatif (objektif 1 hingga 3) dan kualitatif (objektif 4). Data telah dianalisis menggunakan statistik deskriptif dan inferensi (regresi binomial negatif) dan teknik analisis tematik. Keputusan telah menunjukkan bahawa apabila dibandingkan dengan jenis persimpangan lain, persimpangan tiga cabang lebih terdedah kepada perubahan dalam faktor geometri dan operasi. Ini bermakna saiz separuh pulau di laluan utama, jarak antara lorong yang dilalui dan lorong kiri serta bilangan lorong di laluan sisi membelok ke kiri semuanya didapati ada kaitan negatif dengan bilangan kemalangan. Sebaliknya, saiz separuh pulau dalam laluan sisi, bilangan lorong yang melewati laluan utama, bilangan lintasan pejalan kaki, kelajuan persimpangan dan purata lalu lintas setiap jam terdapat kaitan positif dengan bilangan kemalangan. Berhubung dengan objektif kedua, kajian mendapati bahawa kebanyakan pelanggaran lampu merah yang menyebabkan kemalangan berlaku antara 0 hingga 2 hingga 3 saat selepas pengaktifan lampu merah, menunjukkan bahawa masa tindak balas pemandu adalah faktor penting yang mempengaruhi prestasi keselamatan persimpangan berisyarat. Berkenaan objektif ketiga, keputusan menunjukkan bahawa pengenalan penampan kelajuan sememangnya membawa kepada penurunan kemalangan jalan raya dan penambahbaikan prestasi keselamatan persimpangan. Bagi objektif keempat dan kelima, kajian mendedahkan bahawa pelaksanaan garis panduan oleh juruaudit adalah lemah. Berdasarkan penemuan ini, adalah disyorkan agar bahagian lain di UAE menerima pakai dasar ini dan manual keselamatan perlu dikemas kini agar sejajar dengan piawaian antarabangsa.

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LIST OF SYMBOLS AND ABBREVIATIONS

AADT	-	Annual Average Daily Traffic
DoT	-	Department of Transport
NB	-	Negative Binomial
EB	-	Empirical Bayes
NN	-	Neural Networks
OECD	-	Organization for Economic Co-operation and Development
Pi	-	A dependent variable, where the probability of yi = 1
PSL	-	Posted Speed Limit
RLR	-	Red Light Running
RLV	-	Red Light Violation
RSA	-	Road Safety Auditing
SPF	-	Safety Performance function
SPI	-	Safety performance indicators
UAE	-	United Arabs Emirates
β_0	-	Constant
λ	-	Actual recorded number of accidents after buffer
π	-	Expected number of accidents had the buffer not implemented
ϕ	-	Dispersion

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LIST OF PUBLICATIONS

Journal with Impact Factor

Indexed Journal

i. Alghafli, A., Mohamad, E., and Ahmed, A.Z., 2021. The Effect of Geometric Road Conditions on Safety Performance of Abu Dhabi Road Intersections. *Safety*, 7(4), p.73.

ii. Alghafli, A., Mohamad, E., and Zaidy, A.A., 2021. The relationship between the elapsed time from the onset of red signal until its violation and traffic accident occurrence in Abu Dhabi, UAE. *Safety*, 7(3), p.53.

Conference Proceedings

i. Alghafli, A., Mohamad, E., and Rahman, A.A., Analysis of Safety Performance of Signalized Intersections in Abu Dhabi. *Proceedings of the 11th Annual International Conference on Industrial Engineering and Operations Management Singapore*, March 7-11, 2021, pp. 6009-6019.

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CHAPTER 1

INTRODUCTION

1.1 Background

Every country tries to ensure that motorists and civilians can safely use the roads and intersections. As such, nations globally endeavour to adapt and implement plans, initiatives, rules, and traffic regulations to reduce road accidents (Atchley et al., 2014). Traffic safety authorities and the traffic police are responsible for these tasks (Batool et al., 2012).

To ensure the responsibility of ensuring pedestrian and motorist safety, these authorities assess all significant traffic safety-specific aspects, suggested standards and recommendations (Wiegmann et al., 2007).

Several aspects of traffic safety characteristics include human-specific factors, road geometry and vehicle factors (Hassan et al., 2012; Reveron and Cretu, 2019; Alshamsi, 2021). Considering these aspects, the human factor (or aspect) is considered the foremost cause of most traffic accidents (Das, 2022). Research suggests that road mishaps are primarily caused due to human factors, accounting for 90 to 95% of traffic accidents in several nations (Sayed et al., 2022).

It is critical to understand that safety is assessed using safety performance metrics. This research uses the mean of traffic accidents at intersections as the performance metric. Hence, traffic safety characteristics are compromised if the count of accidents is higher and vice-versa (Cunto and Saccomanno, 2008). Several aspects impact traffic mishaps at

intersections, impacting safety characteristics: geometric aspects of the intersection, operating conditions, and driver demographics (Fortuijn, 2009).

Further, regulations and guidelines are specified; driver compliance is critical. Geometric aspects comprise intersection geometry such as leg count (3-leg, 4-leg, and several intersections), pedestrian crossing count, mid-island area, and other factors (Morency et al., 2012). Operational factors comprise traffic flow regulation at an intersection, like maximum permissible speed, signal control, and average hourly traffic (Yang et al., 2019).

The primary issue concerning traffic incidents is the potential to cause injury and death. Global research estimates that over 3,600 individuals lose their lives to road accidents daily (Ankit et al., 2018; Global Burden of Disease (GBD) Eastern Mediterranean Region Transportation Injuries Collaborators, 2018). Furthermore, accidents cause millions of injuries annually (World Health Organization, 2018). Despite the human factor being significantly correlated with traffic accidents, several engineering aspects like signal control and road geometry share noteworthy correlations with road mishaps, specifically close to intersections.

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Several traffic safety guidelines have been proposed considering the substantial rise in fatal road accidents and overall injuries (Chung et al., 2010). Such measures facilitate specifying countermeasures that enhance traffic movement on the road. Countermeasures comprise engineering aspects like road design changes or enforcement-specific measures like amending the laws to change how individuals drive on the roads (Haworth et al., 2012). Further to the change implemented by nations, the World Health Organization (WHO) has advocated for enhancing road safety. The WHO drafted a post-accident response plan for 2011 to 2020, which suggested that government and other authorities, including civil society bodies, consider and devise safer road safety guidelines (Ouni and Belloumi, 2018) like rapid

response for accidents, enhancing vehicular safety and road safety handling (World Health Organisation, 2018).

The United Arab Emirates has nationally considered road safety enhancement. The authorities have devised several traffic-mishap mitigation approaches that improve the nation's competitiveness globally (Al-Shayeb and Hatemi-J, 2016). To this effect, the UAE government endeavoured to reduce traffic fatalities to three in 100000 individuals by 2021 from six in 100,000 in 2015 (Ankit et al., 2018). Local bodies corresponding to every Emirate devised operational and tactical measures to meet this milestone, including building expert working groups from numerous government bodies (Ankit et al., 2018). Such strategy initiatives comprise safety and awareness, education, vehicular safety, engineering, and emergency action. Several aspects targeted enhancing intersection-specific safety in the country.

Considering that several traffic incidents are witnessed at intersections, the safety authorities of every Emirate (specifically in Abu Dhabi) have enhanced non-controlled (specifically 3- and 4-leg intersections) to include signal-based control. Notwithstanding this initiative, research by Essa and Sayed (2018) suggests that signal-enabled intersections witness additional traffic incidents in Abu Dhabi if the implementation is improper. It has been suggested that additional conflict points at such intersections than usual signal-less counterparts are responsible for additional incidents (Al-Ghafli et al., 2013). High-speed movement might deem such conflict points critical.

Studies also suggest that road accidents in Abu Dhabi have been witnessing increasing severity despite the initiatives implemented by Abu Dhabi authorities (Traffic Engineering Department and Road Safety-Abu Dhabi Police, 2019). It suggests the inadequacy of the present Road Safety Manual (standard) enforced by the authorities.

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Numerous aspects like outdated recommendations, improper execution of recommendations and substandard road safety manuals might be responsible for severe accidents.

The present work reduces the gap by assessing road safety standards used by auditors to evaluate signal-enabled intersections. Additionally, this study recommends feasible real-world safety characteristics and metrics that the traffic administration may use as a reference for devising signal-enabled intersections.

1.2 Problem statement and justification

The Abu Dhabi government has devised several plans for reducing road accidents, deaths, and injuries at intersections. Nevertheless, additional efforts are required since numerous accidents still happen at intersections (Alkheder, 2023). The Traffic Engineering Department of the Abu Dhabi Police (2019) suggested that signal-enabled intersections (specifically the 3- and 4-leg variants) witness a majority of the overall road accidents in Abu Dhabi. The department indicated that in 2013, 17% (240/ 1400) of the overall road accidents were witnessed at signal-enabled intersections (Table 1.1) (Traffic Engineering Department and Road Safety-Abu Dhabi Police, 2019). By 2018, the number had reduced to 7%, as listed in Table 1.1 (Traffic Engineering Department and Road Safety-Abu Dhabi Police, 2019). Therefore, a comprehensive assessment is critical to assess the aspects contributing to traffic incidents at signalized intersections.

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Table 1.1: The number of severe road accidents in Abu Dhabi City between 2013 to 2021

Year	Total Number of Accidents	Number of RLR Accidents	Red Light Running (RLR) Accidents				
			Minor Injury	Moderate Injury	Serious Injury	Fatality	Probability of causing at least one serious injury
2013	1,409	240	354	106	19	6	10%
2014	1,246	160	236	102	23	6	18%
2015	1,112	114	184	99	14	2	14%
2016	1,014	112	126	64	12	2	12%
2017	918	93	129	76	12	3	16%
2018	940	66	109	70	5	4	13%
2019	901	52	32	35	9	3	23%
2020	873	48	32	32	8	3	22%
2021	758	59	47	50	3	3	10%

(Source: Traffic Engineering Department and Road Safety, Abu Dhabi Police, 2022)

It is critical to assess the effect of road geometry and operational factors on traffic and pedestrian accidents (safety performance metrics) to help Abu Dhabi traffic safety authorities to pinpoint the critical reasons that compromise safety at signal-enabled junctions.

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In addition to geometry and operating conditions, human aspects like non-compliance to red signals are among the primary contributors to intersection-specific traffic accidents. Data from Dubai strengthens the argument because it suggests that red-light non-compliance has massively increased road accidents in the nation (Table 1.1).

Data from 2011 indicate that red-light violations caused 6% of the overall traffic incidents, which increased to over 17% in 2013 (240 out of 1406, Table 1.1) (Goldenbeld, 2016). The metric is more worrying if cities (specifically larger cities) are evaluated individually.