Jurnal
Teknologi

Full Paper

PREDICTION OF PEDESTRIAN RISK AT SIGNALIZED INTERSECTIONS

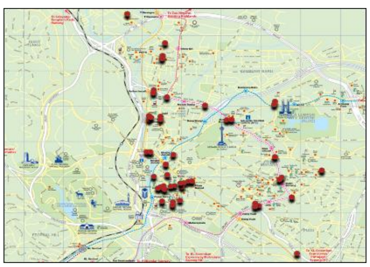
Rizati Hamidun[a*], Siti Zaharah Ishak[a], Nurul Elma Kordi[b], Intan Rohani Endut[b,c]

[a]Malaysian Institute of Road Safety Research (MIROS), Kajang, Selangor, Malaysia
[b]Malaysia Institute of Transport (MITRANS), Universiti Teknologi Mara (UiTM), Shah Alam, Selangor, Malaysia
[c]Faculty of Engineering, Universiti Teknologi Mara (UiTM), Shah Alam, Selangor, Malaysia

Article history
Received
24 June2015
Received in revised form
20 September 2015
Accepted
2 December 2015

*Corresponding author
rizati@miros.gov.my

Graphical abstract



Abstract

Signalized intersections in an urban area are expecting the high volume of mixed traffic with various conflicting movements. This situation would greatly risk the safety of pedestrian as vulnerable road users, especially in a busy capital city like Kuala Lumpur. However, predicting risk based on accident data would neglect many risk factors associated. Thus, this paper presented an application of the pedestrian crossing risk assessment (PedCRA) model using Petri Nets approach to be compared with the risk calculated using accident data for thirty signalized intersections in Kuala Lumpur. The prediction of risk using this model is able to consider various risk factors, including illegal behavior, signal setting, traffic volume, road geometric layout and environment. Prediction of risk for selected sites were compared with the pedestrian accident data for 5 year period as the actual risk value. The Chi-Square goodness of fit was performed and the result showed that the predicted risk value and actual risk values follow the same distribution pattern.

Keywords: Pedestrian crossing, accident risk, signalized intersections, Petri Nets, model

1.0 INTRODUCTION

Signalized intersections located in an urbanized area are expecting a large number of conflicting movement from various road users. Among these road users, pedestrian are more vulnerable to death and severity when involved in an accident. Their risk is even higher while they are crossing the road [1]. There is an evidence stating that the risk of pedestrian accident will increase eight times when they adopt an illegal crossing behavior at signalized intersections [2]. Comparing the risk of illegal pedestrians, risk of those violating signal is higher than those who jaywalk [3].

The complexity of a signalized intersection requires a high driving task load which might create various errors for drivers. Speeding violation is the most common driving error made at signalized intersections [4]. Failure to yield, excessive speed, distraction, improper braking and alcohol impairment are among the most common factors of pedestrian accident involving drivers [5].

The movement of pedestrians and other road users are controlled by means of signal setting at the intersections. Thus, an appropriate signal setting is crucial in promoting the safety of pedestrians at this location. The modification of signal setting at concentrated pedestrian accident sites could be used as a treatment in reducing the vehicle approaching speed which related to the risks of accidents [6].

The minimum time required for a pedestrian to completely cross a road should be the basis of time setting for each phase of the signal cycle [7]. Crossing two directions of a signalized intersection practically needs a very long clearance time by any pedestrians [8].

The number of lanes and the types of medians on a road are found to be correlated with pedestrian accidents involving school children [9]. An increase in the lane number tends to create long distance and time spent on road for pedestrians. This creates an additional pedestrian exposure to vehicles. An evaluation of pedestrian safety by Agarwal (2011) reveals that the number of lanes is significantly correlated with potential pedestrian conflicts at signalized intersections. This may be due to the influence of the road configuration toward the spatial pedestrian crossing compliance [11].

An increase in the number of approaches at signalized intersections would generally increase the number of pedestrian accidents [12]. The number of approaches, together with the number of lanes for each approach may vary among intersections. The variety of geometric features at intersections create different forms of traffic movement, such as going straight, turning, merging, diverging and crossing. Thus, an intersection in an urban area, having multi directions of traffic passing the same joint of a road becomes a traffic conflict or an accident prone area [13].

The speed of vehicular traffic on a particular road section is a major parameter in measuring the risks of pedestrian accidents. It is because speeding is one of the significant variables that will increase the probability of an accident[14]. A study explored the relation of speed and pedestrian accidents conducted by Garder in [15] found that high speed locations having an average speed of above 40km/h had a strong relation to higher pedestrian accidents. In another study, Siddiqui *et al*. [16] studied the occurrence of pedestrian accidents using macro level prediction model, that retained nine significant variables including the roadway length with 35mph posted speed limit. Speeding does not only increase the occurrence of the accident, but also the likelihood of being fatal or severely injured in an accident [17]–[19].

Apart from that, the volume of pedestrians that would increase the activity of pedestrians at signalized intersections may also resulted in an exponential increase in pedestrian accidents [12]. This result is supported by Miranda-Moreno *et al*. [20], where 30 percent of traffic volume reduction could reduce the total number of injured pedestrians by 35 percent. The average risk of pedestrian collision at the intersections will also reduce with the reduction in the number of motor vehicles entering a particular intersection.

Various factors including pedestrian volume, speed of vehicular traffic, number of lanes and approaches were associated with the pedestrian accidents at signalized intersections. The variety of factors that influencing pedestrian accidents become a challenge to the researchers in estimating the risk of pedestrian to be involved in an accident when the risk prediction is only relied on accident history data. Risk prediction based on accident history data would result in the inconsistent value of risk since the occurrence of the accident is random in nature. Thus, this paper highlighted the application of a development model using Petri Nets named the PedCRA model as in [21] which has successful in predicting the risk of pedestrian accident at signalized intersections. The risk prediction using the PedCRA is then compared with risk calculated using accident historical data.

2.0 METHOD

2.1 Site Selection

A total of 30 signalized intersections in Kuala Lumpur had been selected for the risk comparison value. These intersections were selected based on the real pedestrian accident data provided by the Malaysia Institute of Road Safety (MIROS).

Data for five years (2007-2011) were screened out to get the accident cases occurred within 20 meters of an intersection. The exact locations of these pedestrian accidents at the intersection were identified based on the latitude and longitude coordinates given in the data. The locations of pedestrian accidents were mapped out to ease the identification of the pedestrian accident distribution in Kuala Lumpur. The mapping process utilized Google map application to pinpoint the locations of the pedestrian accidents based on the given coordinates in the data.

Through pedestrian accident mapping, the accident prone signalized intersections according to SCATS coding were easily determined. The identified pedestrian accident prone intersections distribution in Kuala Lumpur is illustrated in Figure 1.

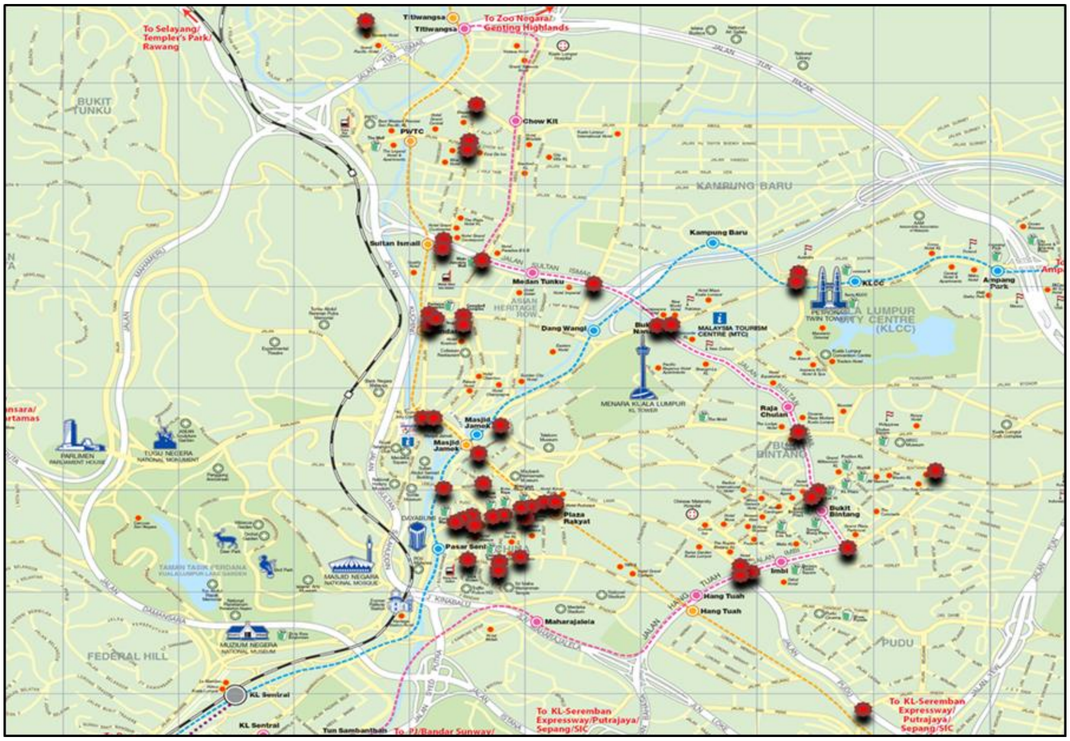


Figure 1 Pedestrian accident prone intersections

2.1 Matching Accident Data with SCATS Code and Calculate the Actual Risk

Once the pedestrian accidents were mapped out, the prone accident intersections were matched with the SCATS junction codes that use by the Kuala Lumpur City Hall (DBKL) to recognize their signalized intersections within their territory. Matching the accident locations with SCATS junction codes was essential to characterize the traffic volume patterns at particular intersections. Traffic volume data with the signal timing setting can be easily obtained from the SCATS data.

The pedestrian accident locations according to the SCATS junction code were listed out as in Table 1. The actual risk values for these locations were calculated based on the pedestrian accident rates. These accident rates can be computed according to the frequency of pedestrian accidents over the observed period in the hour.

Since the observed period for this study had been taken for five years, the observed period in hours can be computed by multiplying 5 years x 365 days x 24 hours, equivalent to 43,800 hours.

.

2.2 Risk Prediction using PedCRA Model

Predicting the risk value for selected sites using the PedCRA model required several input parameters before the simulation was performed. The input parameters of signalized intersections according to the SCATS junction codes needed for model simulation include information about the green time in seconds, pedestrian volume in pedestrian per hour, vehicular volume in vehicle per hour, the number of lanes, the behavior of the pedestrians, speed of vehicles and the existence of medians. These input parameters were extracted from SCATS data and site observations. SCATS data provide information related to real time data such as traffic volume, and the signal setting. The advantage of SCATS data in providing the detail layout of the particular signalized intersection becomes a great support for data collection. Data such as the number of intersection approaches, number of lanes of each approach, existence of median are important since the intersection variables could be the factors in accident risk analysis [22].

Data related to pedestrian volume and pedestrian behavior could be obtained directly from the site observations. The highest pedestrian volume was observed at site no.159, Jalan Sultan Ismail vs Jalan Bukit Bintang with a pedestrian volume of 3800 ped/hour and the lowest is 300 ped/hour.

Table 1 Actual pedestrian risk value for 30 selected sites

No	SCATS Code	Intersection	No. of approaches	Accident frequency	Actual risk value
1	131	Jalan Cheng Lock/Jalan Silang/Jalan Sultan	4	3	6.84932E-05
2	162	Jalan Pudu/Jalan Imbi	4	3	6.84932E-05
3	129	Jalan Cheng Lock/Jalan Tun H.S.Lee	4	3	6.84932E-05
4	150	Jalan Raja Laut/Jalan Dang Wangi	3	3	6.84932E-05
5	104	Jalan Tun Perak/Jalan TAR/Jalan Raja Laut	4	2	4.56621E-05
6	130	Jalan Petaling/Jalan Cheng Lock	4	2	4.56621E-05
7	206	Jalan Putra/Jalan Raja Laut	4	2	4.56621E-05
8	132	Jalan Tun Perak/Jalan Pudu/Jalan Cheng Lock	3	2	4.56621E-05
9	149	Jalan TAR/Jalan Dang Wangi	4	2	4.56621E-05
10	153	Jalan Sultan Ismail/Jalan Raja Laut	4	2	4.56621E-05
11	155	Jalan Sultan Ismail/Jalan Ampang	4	2	4.56621E-05
12	159	Jalan Sultan Ismail/Jalan Bukit Bintang	4	2	4.56621E-05
13	137	Jalan Petaling/Jalan Sultan	4	2	4.56621E-05
14	214	Jalan Ampang/Jalan Yap Kuan Seng	4	2	4.56621E-05
15	501	Jalan Ipoh/Jalan Sentul	3	1	2.28311E-05
16	116	Jalan Gereja/Jalan Melaka	3	1	2.28311E-05
17	121	Jalan Hang Kasturi/Leboh Pasar Besar	4	1	2.28311E-05
18	128	Jalan Cheng Lock/Jalan Hang Kasturi	4	1	2.28311E-05
19	152	Jalan Sultan Ismail/Jalan TAR	4	1	2.28311E-05
20	158	Jalan Sultan Ismail/Jalan Raja Chulan	4	1	2.28311E-05
21	170	Jalan Sultan Ismail/Jalan Raja Abdullah	4	1	2.28311E-05
22	204	Jalan Ipoh/Jalan Raja Laut	3	1	2.28311E-05
23	212	Jalan Bukit Bintang/Jalan Imbi	3	1	2.28311E-05
24	219	Jalan Pudu/Jalan Sg. Besi	4	1	2.28311E-05
25	412	Jalan Maarof/Jalan Ara	3	1	2.28311E-05
26	136	Jalan Sultan/Jalan H.S Lee	4	1	2.28311E-05
27	107	Jalan Tun Perak/Leboh Ampang	4	1	2.28311E-05
28	167	Jalan Sultan/Jalan Hang Jebat	3	1	2.28311E-05
29	160	Jalan Sultan Ismail/Jalan Imbi	4	1	2.28311E-05
30	119	Jalan Silang/Jalan Yap Ah Loy	3	1	2.28311E-05

3.0 RESULTS

3.1 Predicted and Actual Risk

The prediction of risk value of selected sites using the PedCRA model and the actual risk calculated using accident history was plotted and compared as Figure 2. Predicted risk values from the PedCRA model provide a numeric value of the safety level at particular location considering various risk factors defined as parameters in this model. The risk values are simulated to indicate the probability of pedestrian accident occurrence at particular signalized intersection. As an example, the probability of 4.878881E05 or 0.000004878881 accidents/hour for the site number 153 means that the 0.001788 accident happens within a day, or 0.042739 accidents per year. This calculation is based on the conjecture that 1 year is equal to 365 days or 8760 hours.

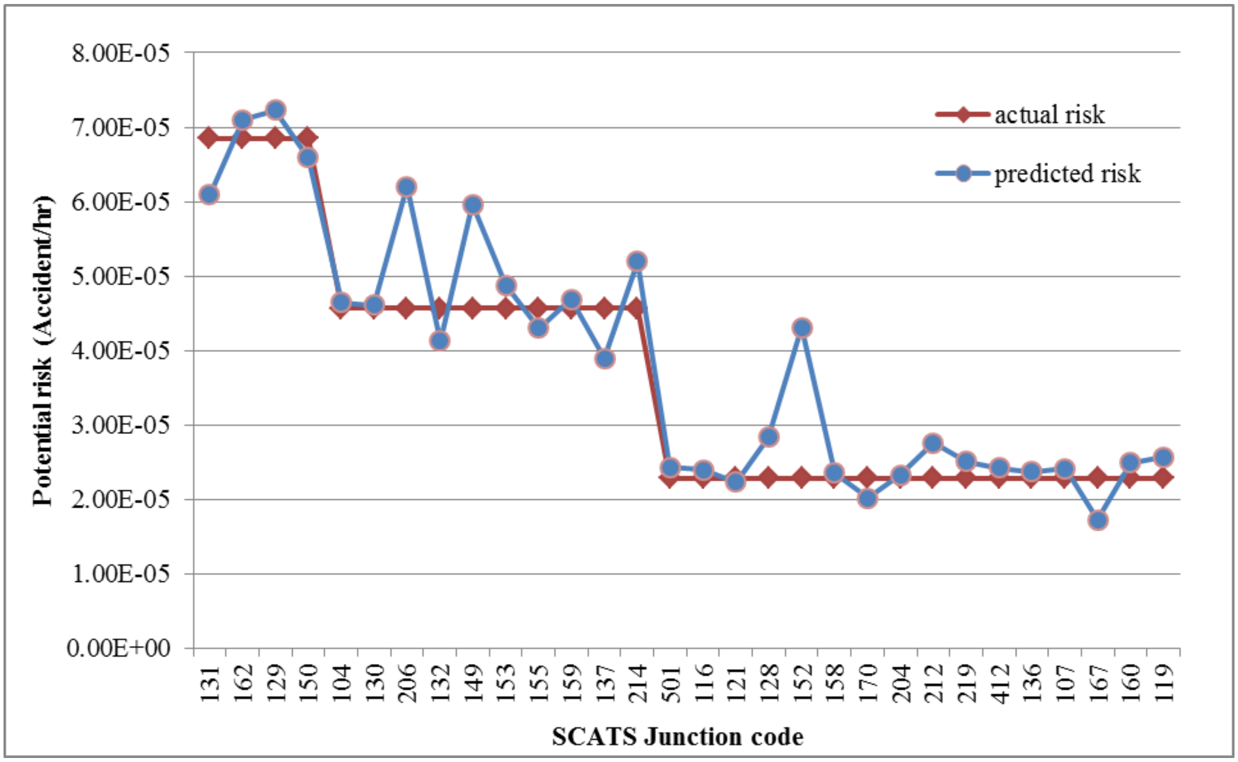


Figure 2 Comparison of actual and predicted risk for selected sites

3.2 Chi-Square

A Chi-Square goodness of fit test was conducted to measure if the distribution of model output is best fitted with the distribution of actual value. This test is actually part of model validation that concern with building the right model and to make sure the model actually used in the correct manner.

Using this test, the decision can be made whether to accept or to reject the null hypothesis after comparing the calculated Chi-Square value for the data set with the critical Chi-Square value. Since the calculated Chi-Square value is too small, even smaller than the critical Chi-Square value, thus there was no reason to reject the null hypothesis. It shows that the discrepancies between the observed and expected risk value were merely due to chance as stated in the initial assumption. From this test, it can be concluded that there is a good fit between the actual risk value distribution and the expected risk value distribution at a 5 percent significance level ($p = 0.05$).

4.0 CONCLUSION

The risk of pedestrian at signalized intersections can be also estimated using the pedestrian accident estimation model [12], is normally developed based on pedestrian accident data [23], [24]. The estimated number of pedestrian accident occurrence related to its factors became the output of the developed model. Simplified calculation of the number of accident occurrence to estimate the actual risk of pedestrian, which also based on the accident data was highlighted in this paper. The actual risk of pedestrian representing the occurrence of pedestrian accident over the observed period for the selected signalized intersections. These risk values, however did not consider any factor associated with pedestrian accident.

Comparison made with the predicted risk value simulated using the PedCRA model, which based on the input parameters used to represent the characteristics of each approach of the selected signalized intersections. All input parameters in the model consider various risk factors including engineering, environmental and human behavioral aspects that may be missing in the conventional pedestrian accident estimation models that being developed based on the accident data.

A good fit between the actual risk and the expected risk value distribution at a 5 percent significance level indicated that the prediction of pedestrian risk at signalized intersections using the PedCRA model is seem to be reliable.

Acknowledgement

We are grateful for the Malaysia Institute of Road Safety Research (MIROS) and the Fundamental Research Grant Scheme (FRGS) provided by the Ministry of Education in supporting this research work.

References

[1] Hatfield, J., Fernandes, R., Job, R. S., And Smith, K. 2007. Misunderstanding Of Right-Of-Way Rules At Various Pedestrian Crossing Types: Observational Study And Survey. *Accident Analysis And Prevention*. 39(4): 833-842.

[2] King, M. J., Soole, D., And Ghafourian, A. 2009. Illegal Pedestrian Crossing At Signalised Intersections: Incidence And Relative Risk. *Accident Analysis And Prevention*. 41(3): 485-4.

[3] Hamidun, R., Kordi, N. E., Endut, I. R., Ishak, S. Z., And Yusoff, M. F. M. 2015. Estimation Of Illegal Crossing Accident Risk Using Stochastic Petri Nets. *Journal Of Engineering Science And Technology.* Special Issue On ACEE 2015: 81-93.

[4] Young, K. L., Salmon, P. M., And Lenné, M. G. 2013. At The Cross-Roads: An On-Road Examination Of Driving Errors At Intersections. *Accident Analysis And Prevention*. 58: 226-34.

[5] Stutts, J. C., Hunter, W. W., And Pein, W. E. 1996. Pedestrian Crash Types: 1990s Update. *Transportation Research Record: Journal Of The Transportation Research Board*. 1538: 68-74.

[6] Lenné, M. G., Corben, B. F., And Stephan, K. 2007. Traffic Signal Phasing At Intersections To Improve Safety For Alcohol-Affected Pedestrians. *Accident Analysis And Prevention*. 39(4): 751-756.

[7] Tiwari, G., Bangdiwala, S., Saraswat, A., And Gaurav, S. 2007. Survival Analysis: Pedestrian Risk Exposure At Signalized Intersections. *Transportation Research Part F: Traffic Psychology And Behaviour*. 10(2): 77-89.

[8] Li, Y., And Fernie, G. 2010. Pedestrian Behavior And Safety On A Two-Stage Crossing With A Center Refuge Island And The Effect Of Winter Weather On Pedestrian Compliance Rate. *Accident Analysis And Prevention*. 42(4): 1156-63.

[9] Abdel-Aty, M., Chundi, S. S., And Lee, C. 2007. Geo-Spatial And Log-Linear Analysis Of Pedestrian And Bicyclist Crashes Involving School-Aged Children. *Journal Of Safety Research*. 38(5): 571-579.

[10] Agarwal, N. K. 2011. Estimation Of Pedestrian Safety At Intersections Using Simulation. Unpublished Doctoral Dissertation. University Of Kentucky.

[11] Tom, A., And Granié, M. A. 2011. Gender Differences In Pedestrian Rule Compliance And Visual Search At Signalized And Unsignalized Crossroads. *Accident Analysis And Prevention*. 43(5): 1794-1801.

[12] Pulugurtha, S. S., And Sambhara, V. R. 2011. Pedestrian Crash Estimation Models For Signalized Intersections. *Accident Analysis And Prevention*. 43(1): 439-446.

[13] Li, X., Yan, X., Li, X., And Wang, J. 2012. Using Cellular Automata To Investigate Pedestrian Conflicts With Vehicles In Crosswalk At Signalized Intersection. *Discrete Dynamics In Nature And Society*. 2012: 1-16.

[14] Abdel-Aty, M. A., And Radwan, A. E. 2000. Modeling Traffic Accident Occurrence And Involvement. *Accident Analysis And Prevention*. 32(5): 633-642.

[15] Gårder, P. E. 2004. The Impact Of Speed And Other Variables On Pedestrian Safety In Maine. *Accident Analysis And Prevention*. 36(4): 533-42.

[16] Siddiqui, C., Abdel-Aty, M., And Choi, K. 2012. Macroscopic Spatial Analysis Of Pedestrian And Bicycle Crashes. *Accident Analysis And Prevention*. 45: 382-391.

[17] Anderson, R. W. G., Mclean, A. J., Farmer, M. J. B., Lee, B. H., And Brooks, C. G. 1997. Vehicle Travel Speeds And The Incidence Of Fatal Pedestrian Crashes. *Accident Analysis And Prevention*. 29(5): 667-674.

[18] Rosén, E., And Sander, U. 2009. Pedestrian Fatality Risk As A Function Of Car Impact Speed. *Accident Analysis And Prevention*. 41(3): 536-42.

[19] Kong, C., And Yang, J. 2010. Logistic Regression Analysis Of Pedestrian Casualty Risk In Passenger Vehicle Collisions In China. *Accident Analysis And Prevention*. 42(4): 987-93.

[20] Miranda-Moreno, L. F., Morency, P., And El-Geneidy, A. M. 2011. The Link Between Built Environment, Pedestrian Activity And Pedestrian–Vehicle Collision Occurrence At Signalized Intersections. *Accident Analysis And Prevention*. 43(5): 1624-1634.

[21] Hamidun, R. 2015. Pedestrian Crossing Risk Assessment (Pedcra) Model. *International Journal Of Science And Advanced Technology.* 5(1): 17-22.

[22] Retting, R. A., Chapline, J. F., And Williams, A. F. 2002. Changes In Crash Risk Following Re-Timing Of Traffic Signal Change Intervals. *Accident Analysis And Prevention*. 34(2): 215-220.

[23] Lee, C., And Abdel-Aty, M. 2005. Comprehensive Analysis Of Vehicle–Pedestrian Crashes At Intersections In Florida. *Accident Analysis And Prevention*. 37(4): 775-786.

[24] Wong, S. C., Sze, N. N., And Li, Y. C. 2007. Contributory Factors To Traffic Crashes At Signalized Intersections In Hong Kong. *Accident Analysis And Prevention*. 39(6): 1107-1113.