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A Sustainable Strategy to Upgrade Safety at Traffic System

استراتيجية مستدامة لرفع مستوى الامان في منظومة المرور

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Abstract

Traffic safety studies based on crashes data are used to enhance safety by specifying appropriate countermeasures. Rather to wait for crash events, that involve losses in human and properties, this paper demonstrates a sustainable strategy to evaluate and upgrade safety at traffic system as well.

The paper demonstrates analysis of traffic conflict "near-crash" data at specified sites in the traffic system. A case study of traffic conflict is performed at selected sites of three legs signalized intersections in Baghdad City. Regression analysis is used to develop model relating observed hourly traffic conflict and average stopped delay. Based on HCM output, a countermeasure is evaluated due to before and after study of average stopped delay and accordingly the involved conflicts based on the developed statistical model.

A developed statistical model indicates that 92.5 % of variation in hourly traffic conflict can be described significantly by average stopped delay. In consequence, more than 35 % of potential conflicts can be reduced due to countermeasures and the highest reduction (62.6 %) is due to increase of lane width. This strategy maximizes the usefulness of conflict study as a sustainable aid to predict the effectiveness of any proposed countermeasure, thereby upgrades safety at any traffic system.

Keywords: sustainable, traffic conflict, traffic safety, countermeasure.

الخلاصة

تستخدم دراسات السلامة المرورية المعتمدة على بيانات الاصطدامات في تحسين السلامة بمعالجات مرورية مناسبة. بدلا من انتظار حوادث الاصطدامات التي تكتنف خسائر في الارواح والممتلكات يقدم البحث استراتيجية مستدامة لتقييم ورفع مستوى السلامة لمنظومة المرور.

يستعرض البحث تحليل لبيانات التعارضات المرورية في مواقع معينة من منظومة المرور. تم انجاز دراسة حالة للتعارضات المرورية لمواقع مختارة من تقاطعات ثلاثية مسيطر عليها باشارات ضوئية في مدينة بغداد. استخدم تحليل الانحدار لاستحداث نموذج رياضي يربط التعارضات المرورية ومعدل وقت التأخير. اعتمادا على مخرجات دليل السعة للطرق تم تقييم معالجات وحسب معدل وقت التأخير لما قبل وبعد الدراسة يمكن احتساب التعارضات المرورية المتوقعة وحسب النموذج المستحدث.

النموذج الاحصائي المستحدث يبين ان ما نسبته 92.5 % من التعارضات المرورية الساعية يمكن توصيفها بدلالة معدل وقت التأخير. بالنتيجة فان ما يزيد على 35% من التعارضات المرورية المحتملة يمكن تقليلها باستخدام معالجات وان أعلى تقليل في التعارضات بما يقرب من 62.6 % ينتج عن زيادة عرض المسرب. تعظم الاستراتيجية المقترحة من فائدة التعارضات المرورية كأداة مستدامة للتنبأ بكفاءة أي معالجة وبالتالي تزيد مستوى السلامة في أي منظومة مرورية.

1.Introduction

Crashes (traffic accidents) frequency is considered as a principal measure of safety. A drawback of observing crashes is waiting for crashes to occur and hence, this involves long time of costly losses in human and properties. This paper introduces conflict (near-to-crashes) as an alternative aid to maintain sustainability at transport system.

Highway Safety Manual (HSM 2010) introduced Crash Modification Factors (CMFs) to " represent the relative change in crash frequency due to a change in one specific condition (when all other conditions and site characteristics remain constant" [1]. Crash frequency is reduced through achieving any proposed countermeasure. A drawback of studying safety condition at any site and estimating reduction efficiency of any countermeasure is that, crashes involve; rare occurrence, under-reporting, unreliability, and difficult observation.

The paper aims at proposing a new strategy of safety study using conflict technique as an indirect measure aid to evaluate safety condition and the appropriate countermeasure before its implementation. The paper shows the usefulness of conflict as a sustainable aid rather than to wait for observing crashes that involve unreasonable; costs, social losses, negative environmental impact.

2. Conflicts and Sustainability

According to 2002 data compiled by the National Highway Traffic Safety Administration in the USA, 21 percent of crashes and 24 percent of all fatalities and injuries occurred at signalized intersections [2]. This is because, signalized intersections involve traffic movements most frequently conflict with one another. Hence, improving road traffic safety at such sites is highly appreciated to save human and properties.

Parker and Zegeer (1988) [3] define traffic conflict technique as" an event involving two or more road user which the action of one user causes the other user to make an evasive maneuver to avoid collision. Further, conflict can be considered as an indirect measure of traffic safety [1]. The technique itself is grounded in the ability to register the occurrence of near–crashes directly in real time [4]. Glauz *et al* (1985) [5] reported that conflict data is not used to predict crash rates, but rather as a surrogate measure of safety when crash data is insufficient.

Gledec 1996 [6] recommended applying the traffic conflict technique because it has a good correlation with the crashes and that these techniques are (mainly) evaluated in a satisfying way as a procedure used for establishing the risk in road traffic. Also, Ewadh, H. and Neham 2011 [7] concluded that evaluation of traffic safety at four leg-signalized intersections can be achieved efficiently using traffic conflict technique.

The conception of sustainability has a strong relation with economic, environmental, social, and energy goals, all of which have interchange effect on transportation system [8]. Beella *et. al* considered the traffic safety for people driving the object and the people surrounding it, as the first sustainable transport indicator on the list as follows [9]:

1. Traffic safety of road users.
2. Energy use.
3. CO2 emissions.
4. Environmental effects (materials, production, waste).
5. Comfort / Affordability.
6. Emissions of toxic and harmful substances, air pollution.
7. Land use (for example by parking it)
8. Disruption and fragmentation of natural areas.
9. Noise pollution.

Cars are found not to be sustainable because they involve that result in significant losses in human, properties, and other negative environmental and social consequences. However, there are no comfortable, reliable, affordable, sustainable replacements for cars. Traffic safety studies based on crashes data are used to enhance safety by specifying appropriate countermeasures. But, it is not reasonable to use costly aid that involves losses in human and properties as an aid to enhance safety. Rather to wait for crash events , "direct observing of a site to examine conflicts "near-crashes" is used as an indirect measure of potential crash problems at a site" [1]. Hence, conflict study can be considered as a sustainable aid that may result in enhancement for the degree of sustainability at the transport system.

3. Strategy and Data collection

The Proposed Strategy involves the following aspects:

- Study Area Selected.
- Site Selection.
- Traffic analysis operation by HCS software.
- Modeling of relation between observed hourly traffic conflict and average stopped delay (output of HCS)
- Based on HCS output, a countermeasure is evaluated due to before and after study of average stopped delay and accordingly the involved conflicts based on the developed statistical model.

Three legs signalized intersections in Baghdad city in 2003 are selected for analysis according to the guidelines recommended by FHWA [3][], where the specific intersections has no pedestrian facilities, no appreciable grades and had entering traffic volume more than 1000 vehicle per day. Three signalized 3-legs intersections are selected to conduct the study; Abu-Talib, Ras Al-Hawash, and Al-Emam Al-Adham intersections.

According to the definition of FHWA the data are collect by using a Sony video digital camera, 700x/ zoom, high quality USB streaming. A four weekday (4 hour minimum at each day), traffic conflict study was conducted at each of the selected intersections. Data was collected between the hours of 7:00 A.M. and 6:00 P.M. The data collection procedure included a 10 minute set – up period before the start of the conflict study followed by data collection for 20 minutes, and then changes the place of set–up of the video camera. Video tapes are played back in the laboratory to process and extract conflict data and for supplementary observations of traffic volume, geometric design, and cycle time. Traffic conflicts are generally categorized by type of maneuver. Four types of conflicts are observed at 3– legs signalized intersections:

- Slow vehicle.
- Lane change
- Right turn same direction
- Left turn same direction

4. Traffic Operation and Conflict Analysis

Average stopped delay at each approach is a measure used to represent the traffic operation at the study intersections. Before analysis is performed on all study intersections using; existing traffic control, lane configuration, and traffic volumes as input. Software of HCM 2000 is used to determine the average stopped delay for all approaches in the study intersections. On the other hand, traffic conflicts at each approach are obtained due to different types of conflict. It is intended to conduct the study for the total traffic conflict rather than for each type of conflict. However, the extension of the concept and methodology presented in this study may be easily extendable to each type of conflicts and other types of intersections and traffic control as well. The relation between the average stopped delay at each approach due to the output of HCS and the involved hourly traffic conflicts is detected through a linear regression analysis. Figure (1) shows that a linear relation explains increasing variation (92.5 %) of hourly traffic conflict in relation with average stopped delay according to the following statistical model:

$$C = 1.605 * D - 67.57 \quad \ldots\ldots\ldots\ldots (1)$$

Where:
C = hourly traffic conflict at approach
D = Average stopped delay at approach $61 \leq D \leq 96$
Parameters of the statistical model are summarized as follows:

F sig.	Stand. Error	P-value Intercept	P-value Delay (D)	R^2
3.46E-05	6.24026	0.001734	3.46E-05	0.925

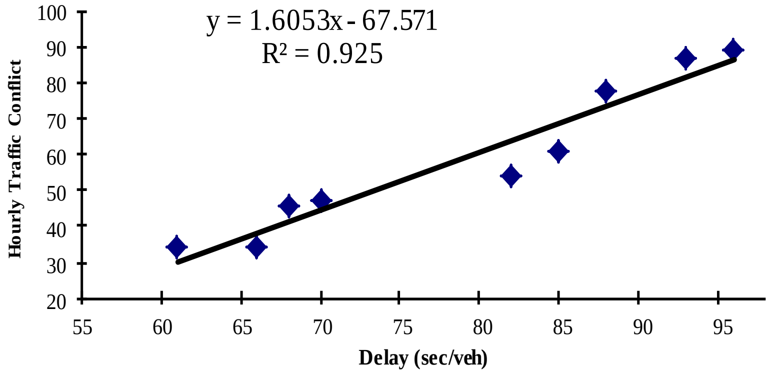


Figure (1) Linear Relationship between Hourly Traffic Conflict & Average Stopped Delay

5. Selection of Proposed Countermeasures

Five countermeasures are selected to demonstrate the procedure of predicting any proposed one:

- Optimization of cycle length from 80 sec to 110.
- Use of a Permitted Left Turn Treatment.
- Use of a Protected Left Turn Treatment.
- Increase lane width (existing lane width is ranged between 2.8m to 3.6m and increased to 3.65m)
- Increase number of lane (existing number of lane is three and proposed increase to four)

However, this selection should not preclude the possibility of addressing the traffic safety issues at the studied intersections by mean of other countermeasures of traffic operations and geometric design.

6. Prediction of Countermeasure Effectiveness

Traffic operation analysis is conducted for the condition of the proposed countermeasures. HCS outputs are reduced and summarized for the average stopped delay each approach. Table (1) shows that average stopped delay is decreased due to the entire proposed countermeasure. Furthermore, LOS is enhanced from F to E in many approaches and the most effective countermeasures are cycle time optimization, and increase in number of lanes.

Based on the developed statistical model in equation (1), the potential conflict (after a proposed countermeasure) is predicted at each approach as shown in Table (2). Percentages of reduction in conflicts (C.R.) can be determined by the following equation:

$C.R. = (C_{before}-C_{after}) / C_{before}$ …………..(2)

Figure (2) shows that more than 35 % of potential conflicts can be reduced due to countermeasures and the highest reduction (62.6 %) is due to increase of lane width. Furthermore, the proposed countermeasures strategy shows that:

- Optimization of cycle length from 80 sec to 110 sec reduces average stopped delay 73.21 % while it reduces hourly traffic conflict 42.27 %.
- Use of a Permitted Left Turn countermeasure reduces average stopped delay 71.23 % while it reduces hourly traffic conflict 39.62 %.
- Use of a Protected Left Turn countermeasure reduces average stopped delay 79.26 % while it reduces hourly traffic conflict 53.39 %.
- Increase lane width countermeasure reduces average stopped delay 82.37 % while it reduces hourly traffic conflict 62.64 %.
- Increase number of lane countermeasure reduces average stopped delay 69.40 % while it reduces hourly traffic conflict 35.85 %.

Table (1) Summary of HCS Output for Average Stopped Delay Due to the Proposed Countermeasures

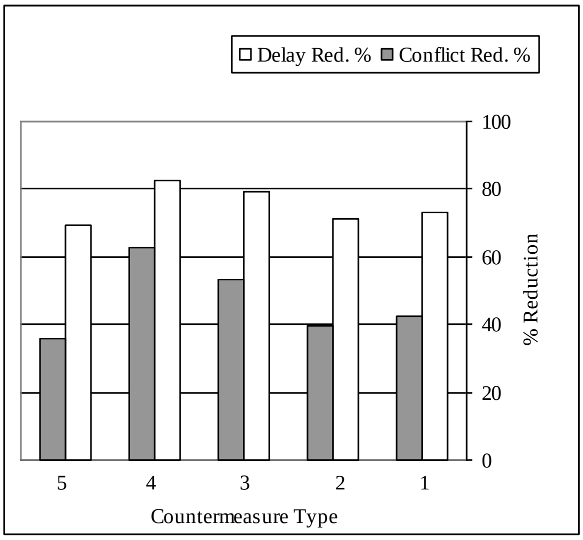
Int. Name	App. No.	Delay (sec / stopped veh.) / (L.O.S)					
		Type of Countermeasure*					
		before	(1)	(2)	(3)	(4)	(5)
Abu-Talib	1	61(F)	55 (E)	48 (E)	58 (E)	47 (E)	50 (E)
	2	82(F)	57 (E)	50 (E)	64 (F)	75 (F)	54 (E)
	3	96(F)	58 (E)	72 (F)	66 (F)	80 (F)	57 (E)
Ras Al-Hawash	4	66(F)	46 (E)	47 (E)	62 (F)	54 (E)	48 (E)
	5	85(F)	60 (E)	60 (E)	65 (F)	72 (F)	58 (E)
	6	88(F)	53 (E)	52 (E)	56 (E)	76 (F)	50 (E)
Al-Emam Al-Adhm	7	93(F)	84 (F)	77 (F)	82 (F)	67 (F)	76 (F)
	8	70(F)	56 (E)	53 (E)	57 (E)	58 (E)	52 (E)
	9	68(F)	50 (E)	46 (E)	52 (E)	55 (E)	47 (E)

1- optimization of cycle length from 80 sec to 110 sec
2- use of a permitted left turn treatment.
3- use of a protected left turn treatment.
4- increase lane width.
5- increase number of lanes.

Table (2) Predicted Traffic Conflicts Based on the Developed Statistical Model Due to the Proposed Countermeasures.

Int. Name	App. No.	Traffic Conflicts /hr					
		Type of Countermeasure*					
		before	(1)	(2)	(3)	(4)	(5)
Abu-Talib	1	34	19	12	26	11	13
	2	54	25	13	33	57	17
	3	89	26	47	37	60	25
Ras Al-Hawash	4	34	8	11	30	17	12
	5	61	28	28	35	47	26
	6	78	17	16	20	57	13
Al-Emam Al-Adhm	7	87	68	58	61	38	57
	8	47	20	17	25	26	16
	9	46	13	8	16	19	11

1- optimization of cycle length from 80 sec to 110 sec
2- use of a permitted left turn treatment.
3- use of a protected left turn treatment.
4- increase lane width.
5- increase number of lanes.



1- optimization of cycle length from 80 sec to 110 sec
2- use of a permitted left turn treatment.
3- use of a protected left turn treatment.
4- increase lane width.
5- increase number of lanes.

Figure (2) Reduction in Hourly Traffic Conflicts & Average Stopped Delay Due to Proposed Countermeasures

7. Conclusions

- This paper maximizes the usefulness of conflicts as a sustainable aid to predict the effectiveness of any proposed countermeasure before its implementation, rather than to wait for observing crashes that involve unreasonable costs.
- A developed statistical model indicates that 92.5 % of variation in hourly traffic conflict can be predicted significantly by average stopped delay.
- A countermeasure can be evaluated due to before and after average stopped delay based on HCS output and accordingly the involved conflicts based on the developed statistical model.
- A percentage of reduction; more than 69 % in average stopped delay is achieved due to each proposed countermeasure. Furthermore, LOS is enhanced from F to E in many approaches and the most effective countermeasures are; cycle time optimization and increase in number of lanes.
- The results show that, more than 35 % of potential conflicts can be reduced due to each countermeasure of; signal optimization, use of permitted or protected left-turn, increase of number or width of lanes. The highest reduction (62.6 %) is introduced due to increase of lane width because the existing lane width is out of the standard and result in unsafe movements of road users.

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