Journal of Materials and Engineering Structures

Research Paper

Determining factors affecting road users' acceptability level of waiting time at signalized intersections

Tien Dung Chu

Faculty of Civil Engineering, University of Transport and Communications, No.3 Cau Giay Street, Lang Thuong Ward, Dong Da District, Hanoi, Vietnam

A R T I C L E I N F O

Article history:

Received : 15 November 2022

Revised : 15 December 2022

Accepted : 19 December 2022

Keywords:

Waiting time

Signalized intersection

Level of service

Delay

A B S T R A C T

Traffic lights are installed to reduce crucial conflicts at high-traffic volume intersections. However, waiting time, a critical factor related to the delay and level of service, cannot be avoided at these intersections. In addition, the long waiting time may lead to road users' impatience. Consequentially, it can motivate them to violate red lights. Therefore, designers should provide an appropriate cycle length and waiting time that meets the road users' acceptability level. This paper tends to determine factors affecting road users' acceptability level of waiting time in Hanoi by applying an ordered probit model using questionnaire data. The results demonstrate that the most significant factors include gender, occupation, transportation mode, commuting time/frequency, and traffic law understanding. Specifically, males, people whose occupation is business, who have commuting time in peak hours, who have commuting frequency more than three times per week, and motorcycle riders are sensitive and have less patience with the delay. By contrast, people who understand the traffic law may be more patient to wait at long cycle-length signalized intersection.

F. ASMA & H. HAMMOUM (Eds.) special issue, 4th International Conference on Sustainability in Civil Engineering ICSCE 2022, Hanoi, Vietnam, J. Mater. Eng. Struct. 9(4) (2022)

1 Introduction

Traffic lights are installed at high-traffic volume intersections to give the right of way to a specific movement and reduce crucial conflicts. Consequently, they can minimize traffic accidents at these intersections. However, the waiting time and delay cannot be avoided at these intersections. The studies of travel times in urban areas demonstrated that delays induced by intersections account for 12-55% of daily commute travel [1, 2]. The waiting time affects not only the overall satisfaction but also the acceptance of road users. In addition, it influences the Level-of-Service (LOS) of the signalized intersection. According to Dai and Fishbach [3], waiting is constantly

* *Corresponding author. Tel.: +84.2437663311*
E-mail address: dungchu@utc.edu.vn

e-ISSN: 2170-127X,

RESEARCH REVIEW of Sciences and Technologies

regarded as a negative experience. The waiting time is annoying, frustrating, and psychologically painful to road users [4]. In the field of transportation, time is usually considered as a measure of performance [5, 6] The delay is used to evaluate the performance of the signalized intersections [7]. On the other hand, the long waiting time may lead to road users' impatience. Consequentially, it can motivate them to violate red lights [8]. Therefore, understanding the waiting time that the road users can accept is very important for the design of signalized intersections. To fill in this gap, this paper aims at analyzingthe waiting time and the factors that affect the acceptability level of the road users at the signalized intersections by using questionnaire data collected from a survey in Hanoi, Vietnam.

2 Literature review

In the US, as indicated by the Highway Capacity Manual (HCM) [7] , the average waiting time (in seconds - s) is used to evaluate the LOS for a signalized intersection. The LOS is divided into 6 levels A (≤ 10 seconds), B (10 – 20s), C (20 – 35s), D (35 – 55s), E (55 – 80s) and F (> 80s). The road users may feel uncomfortable when the waiting time is too long. It is found to be intolerable when the waiting time exceeds 60–65s [5]. However, this may differ from country to country, especially between developed and developing countries. In developed countries, some studies [9, 10] concluded that it is common to wait more than 2 minutes for traffic signals due to extensive urbanization, which increases vehicle ownership. By contrast, in developing countries, the overall traffic scenario is different. The traffic is distinguished by mixed traffic conditions and a lack of lane discipline. Additionally, different income groups have different living standards. These all reflect how the people from each group perceive the delay at signalized intersections. A study [11] in India with mixed traffic conditions showed that the waiting time for LOS thresholds is nearly double compared to the HCM [7]. They supposed that Indian road users maintain a higher patience to waiting time than those noted in HCM, which may be due to the prevalent operating conditions at intersections. In fact, studies related to waiting time in developing countries are still limited.

3 Methodology

The ordered choice model is usually used to examine the opinions of respondents using attitude scales, for example, rating systems (poor, fair, good excellent) or opinion surveys (strongly disagree - strongly agree) [12]. In this sense, the ordered choice model provides an appropriate method for capturing the influencing factors to the choice made among a set of ordered alternatives.

In this paper, the respondents were asked about the feeling of experiencing a delay at the signalized intersection. How long is the delay that you start to feel uncomfortable? The respondents' opinion on delay is in order (1: < 30s, 2: 30 – 45s, 3: 45 – 60s, 4: 60 – 90s, 5. > 90s). This is used as an independent variable; therefore, the ordered choice model is applied for this study. It is noteworthy that the ordered choice model can be probit or logit. However, logit and probit models are similar; the difference is in the distribution. The ordered logit model uses cumulative standard logistic distribution (F) while the ordered probit model applies cumulative standard normal distribution (Φ).Both models deliver identical results [13]. The ordered probit model is explained as follows [12]. Let's denote y^*_i as the utility functions of the respondents' opinion on delay as shown in Eq. (1).

$$y^* = \gamma + \beta x_i + \varepsilon_i \tag{1}$$

Where y^*_i is the unobserved dependent variable, x_i is a vector of explanatory variables, γ is a constant term and β is a vector of the unknown parameter to be estimated. ε_i is a random error term that is assumed to follow a normal distribution with zero mean. Further suppose that while we cannot observe y^*_i, we instead can only observe the categories of response:

$$y_i = j \quad \text{if} \quad \mu_{j-1} < y_i^* \le \mu_j \quad \text{j=1,2,....,J} \tag{2}$$

μ_j is estimated threshold parameters and y_i is the observed values of the respondents' opinion on delay. The respondents' opinion on delay was observed as categories y_i a choice set j = (1, 2, 3, 4, 5) for intervals of "< 30s", "30 – 45s", "45 – 60s", "60 – 90s", and "> 90s". Then, the probability that individual i will select alternative j is:

$$P(y_i = j \mid x_i)=\phi\left\{\mu_j - (\gamma + \beta x_i)\right\} - \phi\left\{\mu_{j-1} - (\gamma + \beta x_i)\right\} \tag{3}$$

Normally, if μ_0 = -∞ and μ_J = ∞ then Φ(-∞) = 0 and $\Phi(\infty)$ = 1. However, these probabilities consist of too many parameters, and we cannot identify all threshold parameters if the constant is included in the model. Therefore, it is needed to normalize one parameter, either to fix the first threshold parameter (μ_1) to zero or eliminate the constant term (γ)[12]. This paper set the first threshold parameter to zero. Finally, the likelihood function for the entire observations can be written as:

$$L(\beta, \mu_j, \mu_{j-1}, x_i) = \prod_{i=1}^{I} \prod_{j=1}^{J} [P_r(y_i = j \mid x_i)^{hij}] \tag{4}$$

Where, h_{ij} equals 1 if the respondent i chooses outcome j, otherwise h_{ij} equals 0. In this paper, the maximum log-likelihood implemented in R programming language was used to estimate the unknown parameters.

4 Data

This study used the same data set in the previous studies [14, 15]. This data set was collected through a questionnaire survey in January 2020. The respondents were asked to answer the questionnaire at their homes, coffee shops, school gates, and other places. On the other hand, the questionnaire was posted on social media to enhance the samples. Finally, a total of 796 valid samples (379 offline and 417 online surveys), were obtained. Noticeably, 45 respondents reported using the bus as their daily travel mode. Those samples were excluded since the bus users do not drive on the road by themselves. And they may have different feelings when waiting for the traffic signal. Finally, this study considers only 751 private-transportation-modes respondents. It is noted also that the age of respondents in our data set varies between 18 and 75 years old.

Table 1 – Independent variables used in the model.

Independent variables	Mean	Standard deviation	Note
Gender (dummy): Male = 1, Female = 0	0.61	0.49	(1)
Age (dummy): 35 or under = 1, Over 35 = 0	0.68	0.42	(2)
Occupation (dummy): Business = 1, Otherwise = 0	0.27	0.44	(3)
Transportation mode (dummy): Car = 1, Otherwise = 0	0.10	0.30	(4)
Commuting time (dummy): In peak hours = 1, Otherwise = 0	0.21	0.41	(5)
Trip purpose (dummy): To school = 1, Otherwise = 0	0.23	0.42	(6)
Traffic law understanding (dummy): Know amercement for red light running = 1, Otherwise = 0	0.51	0.50	(7)
Commuting frequency (dummy): > 3 – 4 times/week, Otherwise = 0	0.91	0.14	(8)
Distance from home to work/school (km)	7.57	6.98	(9)

Table 1shows some independent variables used in the current paper. It can be seen that males account for a larger proportion (61%) than females (39%). The respondents younger than 35 years old in the data set are dominant (68%). The high proportion of young respondents may come from the fact that this age group belongs to Internet penetration. In addition, the younger respondents may have more willingness to participate in the survey than the older ages. The respondents, who do a small business in the shop or the market (e.g. selling clothes, fruits, food, etc.), occupy 27%. About 10% of respondents use the car as their transportation mode and 21% of them travel during peak hours. Most respondents have a commuting frequency of at least 3 – 4 times per week. The average distance from home to work/school among the respondent is 7.57km. It implies that the people in Hanoi tend to live near their workplaces. In the data set, more than half of the respondents know the exact amercement for red light running. More detail on the data characteristics can be seen in [14, 15]. It is worth noting that the correlations among independent variables were computed to exclude the highly correlated variables (see Table 2). Regarding the dependent variable, as mentioned above, this paper used respondents' opinions on delay at the signalized intersections. It is found that most of the respondents (41.28%) started to feel uncomfortable when the delay is longer than 90s. 29.56% of them reported to feel uncomfortable when the delay ranges between 60 to 90s.

Table 2 – Correlation matrix of independent variables.

Var(s)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)	1								
(2)	0.02	1							
(3)	-0.17	-0.35	1						
(4)	-0.1	0.17	-0.18	1					
(5)	-0.02	-0.02	0.08	-0.06	1				
(6)	0.13	0.29	-0.28	0.16	-0.03	1			
(7)	0.02	-0.07	-0.05	-0.08	0.03	0.02	1		
(8)	-0.02	0.02	-0.01	0.05	0.03	0.01	-0.02	1	
(9)	-0.11	0.02	-0.16	0.17	0.04	0.19	0.02	-0.09	1

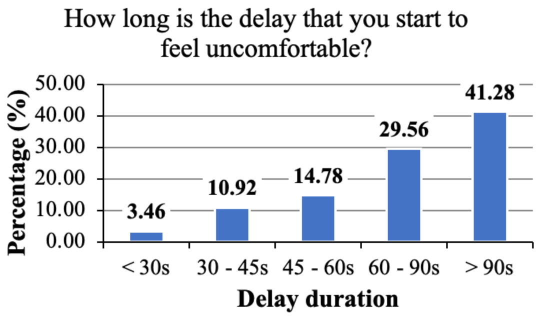

Fig. 1– The respondents' opinion on delay at the signalized intersections.

5 Results and discussion

Table 3 represents the estimation results and the goodness of fit of the ordered probit model. Overall, the results presented in Table 3 show that most of the variables are statistically significant (a p-value of 0.05 or less). Only two variables (age and trip purpose) are kept at a 90 confidence level (p-value of 0.1 or less). The results demonstrate that males are less patient than females. It indicates that males are easy to feel uncomfortable when waiting at the signalized intersections. Previous studies [14, 15] have found that males are more likely to violate traffic signals than females. It means that males may run the red light if the waiting time at the signalized intersection is long. The findings are similar for the young age groups (35 or less), people whose occupation is business, and people who have commuting time in peak hours and have commuting frequency more than three times per week. The findings suggest that these groups are also sensitive to the long delay at the signalized intersections. They may be impatient and be the red light runner at the signalized intersection with a very long cycle length. These findings are consistent with previous results [14, 15]. By contrast, the car users and the ones who know the exact amercement for red light running seem to be more patient to wait for the traffic signals. In addition, a similar tendency can be found for the respondents with the trip purpose of going to school. Notice that, the age and trip purpose may need further investigation since the significant level is only 10%. For the last variable, it is found that the respondents living far from work/school will be more sensitive to the long delay. A reason may come from the fact that longer travel distance is correlated to a higher chance of being late to work or school.

Table 3 – Ordered Probit Model estimation results.

Independent variables	**Coeff.**	**t-value**	**Sig.**
Constant	2.05	6.94	***
Gender (dummy): Male = 1, Female = 0	-0.20	-2.41	**
Age (dummy): 35 or under = 1, Over 35 = 0	- 0.11	- 1.73	*
Occupation (dummy): Business*) = 1, Otherwise = 0	-0.33	-2.34	**
Transportation mode (dummy): Car = 1, Otherwise = 0	0.02	1.97	**
Commuting time (dummy): In peak hours = 1, Otherwise = 0	-0.26	-2.66	***
Trip purpose (dummy): To school = 1, Otherwise = 0	0.25	1.74	*
Traffic law understanding (dummy): Know exact amercement for red light running = 1, Otherwise = 0	0.22	2.82	***
Commuting frequency (dummy): 3 – 4 times per week or more = 1, Otherwise = 0	-0.38	-2.12	***
Distance from home to work/school (km)	-0.01	-2.01	***
μ_1 (Normalized to 0)	0		
μ_2	0.73		
μ_3	0.86		
μ_4	0.90		

Goodness of fit measure	**Notation**	**Equation**	**Value**
Number of parameters	p		13
Sample size	N		751
Log-likelihood at 0 (empty model)	$LL(0)$		-2155.13
Log-likelihood at convergence	$LL(\beta)$		-1012.83
Rho-square	ρ_0^2	$1-LL(\beta)/LL(0)$	0.53
Adjusted rho-square	$\bar{\rho}_0^2$	$1-(LL(\beta)-p)/LL(0)$	0.52

Note: *) the people who do a small business in the shop or the market (e.g. selling clothes, fruits, food, etc.)
***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$

6 Conclusion

This paper determines factors affecting road users' acceptability level of waiting time at the signalized intersections using the questionnaire data of 751 private-transportation-modes respondents. The ordered probit model was applied and the parameters of the model were estimated based on the maximum log-likelihood implemented in the R programming language. The most important factors that affect the acceptability level of waiting time include gender, occupation, transportation mode, commuting time/frequency, and traffic law understanding. The evidence from this study points toward the idea that males, people whose occupation is business, who have commuting time in peak hours, who have commuting frequency more than three times per week, and motorcycle riders are less patient to experience a delay. It may motivate them to violate the traffic signals. Interestingly, it was found that the people who understand the traffic law, may be patient to wait at the signalized intersection where the cycle length is long. Those people are less possible to run the red light. Therefore, training courses and propaganda campaigns to raise awareness about traffic laws for road users are very necessary.

It is plausible that several limitations could have influenced the results obtained. Firstly, the data set used in this paper has features site-specific characteristics. Future works should therefore collect more samples in other cities to generalize the results. Secondly, motorcycles are the dominant modes used for traveling and motorcycle riders may have different behaviors compared to car users. The future direction also focuses on motorcycle riders' behaviors at the signalized intersection.

REFERENCES

[1]- D.M. Levinson, Speed and delay on signalized arterials. J. Transp. Eng., 124(3) (1998) 258-263. doi:10.1061/(ASCE)0733-947X(1998)124:3(258).

[2]- A. Tirachini, Estimation of travel time and the benefits of upgrading the fare payment technology in urban bus services. Transp. Res. C, 30 (2013) 239-256. doi:10.1016/j.trc.2011.11.007.

[3]- X. Dai, A. Fishbach, When waiting to choose increases patience. Organ. Behav. Hum. Decis. Process., 121(2) (2013) 256-266. doi:10.1016/j.obhdp.2013.01.007.

[4]- L. Dube-Rioux, B.H. Schmitt, F. Leclerc, Consumers' reactions to waiting: when delays affect the perception of service quality. ACR North American Advances, (1989).

[5]- B. van der Bijl, J. Vreeswijk, J. Bie, E. van Berkum. Car drivers' perception and acceptance of waiting time at signalized intersections. in 2011 14th International IEEE Conference on Intelligent Transportation Systems (ITSC). IEEE. (2011), 451-456. doi:10.1109/ITSC.2011.6082880.

[6]- J. Vreeswijk, E. Van Berkum, B. Van Arem, Evaluating awareness and perception of waiting time at signalized intersections: field study. Transportation research record, 2518(1) (2015) 86-94. doi:10.3141/2518-12.

[7]- N.R.C. Transportation Research Board, Manual Highway Capacity, Washington, DC. (2010).

[8]- P. Chen, G. Yu, X. Wu, Y. Ren, Y. Li, Estimation of red-light running frequency using high-resolution traffic and signal data. Accid. Anal. Prev., 102 (2017) 235-247. doi:10.1016/j.aap.2017.03.010.

[9]- W.E. Baumgaertner, Levels of service--Getting ready for the 21st century. ITE J., 66(1) (1996).

[10]- R. Cameron, G3 F7--An expanded LOS gradation system. ITE J., 66(1) (1996) 36-39.

[11]- D. Othayoth, K.K. Rao, Assessing the relationship between perceived waiting time and level of service at signalized intersection under heterogeneous traffic conditions. Asian Trans.t Stud., 6 (2020) 100024. doi:10.1016/j.eastsj.2020.100024.

[12]- W.H. Greene, D.A. Hensher, Modeling ordered choices: A primer. Cambridge University Press, 2010.

[13]- O. Torres-Reyna, Getting started in Logit and ordered logit regression. Princeton University, (2012).

[14]- T.D. Chu, T. Miwa, T.A. Bui, Q.P. Nguyen, Q.H. Vu, Examining unobserved factors associated with red light running in Vietnam: A latent class model analysis. Transp. Safety Env., 4(1) (2022). doi:10.1093/tse/tdac006.

[15]- T.D. Chu, Exploring factors associated with red-light running: a case study of Hanoi city. Transp. Commun. Sci. J., 72(7) (2021) 800-810. doi:10.47869/tcsj.72.7.3.