engineering proceedings

MDPI

Proceeding Paper

Driving Speed Analysis Using Real-Time Traffic Light Status Information at Signalized Intersections †

Eunjin Choi *, Hyangmi Han, Ockhee Jeon, Seungcheol Lee and Kwangyoung Ko

Korea Road Traffic Authority, Department of Advanced Traffic, Hyeocksin-ro, Wonju-si 26466, Gangwon-do, Republic of Korea; hyan9m1@naver.com (H.H.); okki@koroad.or.kr (O.J.); leesc@koroad.or.kr (S.L.); gwangyoung@gmail.com (K.K.)

* Correspondence: toryjin1532@naver.com; Tel.: +82-33-74-5454

† Presented at the Second International Conference on Maintenance and Rehabilitation of Constructed Infrastructure Facilities, Honolulu, HI, USA, 16–19 August 2023.

Abstract: This study aims to analyze driver behavior when traffic light status information is provided to the in-vehicle systems of individual vehicles. In the case where signal information was provided when the vehicle was approaching an intersection in a red-light state, a statistically significant difference in both the driving speed and standard deviation of the speed was observed. The driving speed was 2.770 km/h, and the standard deviation of the speed increased by 0.153 km/h. In addition, an average speed increase of 2.751 km/h was observed when the remaining time information was provided, then when it was not. When only light was provided, the speed increased by 1.549 km/h; this was statistically insignificant.

Keywords: traffic light information; remaining time of the current traffic light; traffic signal with countdown indicator; driving behavior; SPaT message

check for updates

Citation: Choi, E.; Han, H.; Jeon, O.; Lee, S.; Ko, K. Driving Speed Analysis Using Real-Time Traffic Light Status Information at Signalized Intersections. *Eng. Proc.* **2023**, *36*, 28. https://doi.org/10.3390/engproc2023036028

Academic Editor: Hosin (David) Lee

Published: 10 July 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Recently, South Korea has enhanced its transport information services by implementing signal phase and timing (SPaT) messages through the C-ITS project. SPaT messages convey the state of the signal information, including the remaining time for the direction in which each vehicle intends to follow. Based on this message, individual drivers can receive warnings about the danger of traffic violations or suggestions for safer intersection-approaching speeds [1]. This study aims to analyze driver behavior when traffic light status information is provided to the in-vehicle systems of individual vehicles.

2. Experimental Design

To set up a testing environment, a vehicle was equipped with an automotive black box and a device that could provide signal information to the driver. Subsequently, a driving test was conducted at an intersection of a public road where vehicles were controlled. The speed, gear state, and brake state of the vehicle were recorded in 100 ms increments, and the signal information device was used to simultaneously record the lighting state (red, yellow, or green) and the remaining time of the traffic lights (Figure 1).

In total, 12 scenarios were designed for the driving test, considering three external factors: the presence or absence of a preceding vehicle, initial lighting conditions (red/green), and provision of information on the status (Table 1). The test set comprised 60 participants, of which 20 were in their 20 s and 30 s, 20 were in their 40 s and 50 s, and 20 were aged 60 years and older.

The main objective of the test is to determine the driver's behavior based on the provision of information on traffic light status. For this purpose, the case in which information was provided was further divided into one case in which only the state of lighting was

provided and another case in which information on both the state of lighting and the remaining time was provided.

(**a**) (**b**)

Figure 1. Experimental vehicle (**a**); in-vehicle system (**b**).

Table 1. External factor of the driving test scenario.

Preceding Vehicle (2)	Initial Lightning Condition (2)	Type of Information (3) [1]
Presence Absence	Red Green	Not provided Only lightning conditions Lighting conditions with the remaining time

[1] Traffic light status information.

Additionally, the test was further divided into two cases to investigate a scenario in which the vehicle approaches an intersection: when the state of the signal light was red and when it was green. This is because different actions are required depending on the color of the signal when a vehicle approaches an intersection.

3. Data Analysis

3.1. Red Light State

For the case in which signal information was provided when the vehicle was approaching an intersection **in a red-light state**, a statistically significant difference in both the driving speed and standard deviation of the speed was observed, where the driving speed was 2.770 km/h, and the standard deviation of the speed was increased by 0.153 km/h (Table 2). Hence, providing information on the status of the traffic light and the remaining time was believed to affect the reaction time required by drivers to freely select the speed of approaching and passing the intersection.

Table 2. Results of statistical analysis for the average difference in the vehicle speed according to whether traffic light status information is provided (t-test; $p < 0.01$).

	Information	Mean	Std.D	Std.E	t	df	Sig.	Mean Diff.	95%CI		N
									Lower	Upper	
V (kph)	Not provided	24.707	11.765	0.346	−6.658	2244	0.000	−2.770	−3.585	−1.954	1156
	Provision *	27.477	12.764	0.231							3057
Std.V	Not provided	1.287	0.843	0.025	−5.116	2270	0.000	−0.153	−0.212	−0.094	1155
	Provision *	1.441	0.926	0.017							3054

* In experiments where drivers received real-time traffic light state information through an in-vehicle system.

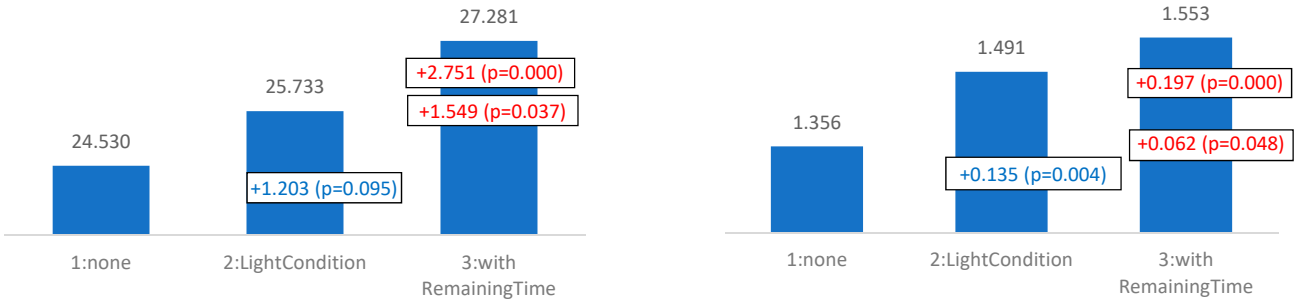
To analyze this effect based on the form in which information was provided, the effect was divided into three categories: non-providing, providing only the light condition, and simultaneously providing the light condition and remaining time. Consequently, an average speed increase of 2.751 km/h was observed when the remaining time information was provided, then when it was not (Table 3).

Table 3. ANOVA table for vehicle driving characteristics for the type of information at red light state.

	Information	N	Mean	Std.D	Std.E	Sum of Square	df	Mean Square	F	Sig.
V (kph)	None	686	24.530	12.978	0.495					
	Light condition	672	25.733	13.633	0.526					
	With remaining time	606	27.281	13.202	0.536					
	Between-group					2439.066	2	1219.533	6.921	0.001
	Within group					345,522.821	1961	176.197		
	Total					347,961.887	1963			
Std.V	None	685	1.356	0.806	0.031					
	Light condition	672	1.491	0.876	0.034					
	With remaining time	605	1.553	0.889	0.036					
	Between-group					13.263	2	6.632	9.041	0.000
	Within group					1436.916	1959	0.733		
	Total					1450.179	1961			

Notably, providing and utilizing the red remaining time information of vehicles approaching an intersection during a red light increased the frequency of vehicles passing the intersection without stopping.

When only the light condition was provided, the speed increased by 1.549 km/h; therefore, the statistical significance was minimal (Figure 2).



(**a**) Average vehicle speed

(**b**) Standard deviation of vehicle speed

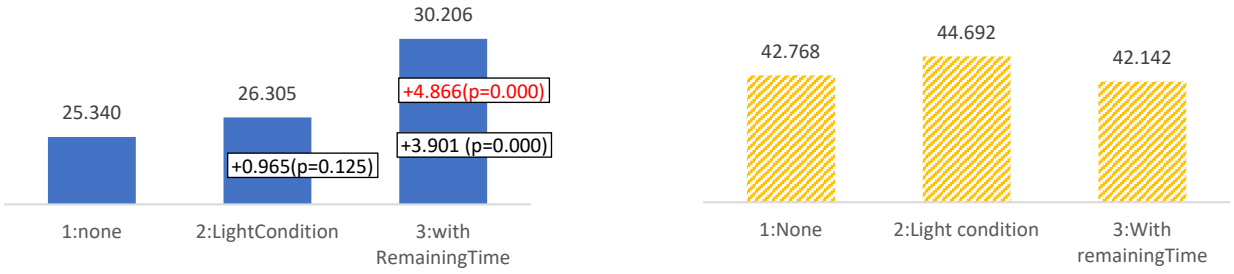
Figure 2. Vehicle driving characteristics by type of information provided at red light state.

However, during driving without any visibility restrictions, displaying the traffic lights inside the vehicle in a manner similar to that at the intersection did not significantly affect the driver's behavior. Thus, the case where only the light condition information was provided in the car was useful when visually recognizing the actual traffic light was difficult owing to distance limitations such as the preceding vehicle, fog, or heavy rain.

3.2. Green Light State

When approaching an intersection in a green light state, the simultaneous provision of signal information and remaining time can be used to prevent dangerous behavior wherein drivers recklessly cross the intersection. The vehicles that approached the intersection in a green light state had significantly different average speeds when the information with remaining time was provided than when it was not.

Notably, when the green remaining time information was provided, the speed of passing the intersection was 4.866 km/h higher than that when no information was provided. The average intersection approaching speed during the green signal time was 30.206 km/h, which was 4.866 km/h higher than when no information was provided (Figure 3a). In the case of providing remaining time, vehicle speed statistically increases on average by 5 km/h at a confidence level of 95%.



(**a**) Average vehicle speed (**b**) Speed of passing the intersection during yellow time

Figure 3. Vehicle speed by type of information provided at green and yellow light state.

Additionally, the speed of passing the intersection was 44.692 km/h when only the light condition information was provided and 42.142 km/h during the yellow signal time (Table 4); this was lower than that when information was not provided (42.768 km/h). This implied that when the remaining time information was provided, reckless entry into the intersection was reduced; conversely, the driver's driving speed could be maintained if information containing sufficient remaining time was provided (Figure 3b).

Table 4. ANOVA table for vehicle driving characteristics for the type of information at green light state.

	Information	N	Mean	Std.D	Std.E	Sum of Square	df	Mean Square	F	Sig.
V (kph)	None	463	25.340	9.316	0.433					
	Light condition	431	26.305	8.779	0.423					
	With remaining time	743	30.206	9.770	0.358					
	Between-group					8066.882	2	4033.441	45.748	0.000
	Within group					144,064.435	1634	88.167		
	Total					152,131.317	1636			
Std.V	None	463	1.202	0.882	0.041					
	Light condition	431	1.272	0.850	0.041					
	With remaining time	743	1.269	0.885	0.032					
	Between-group					1.512	2	0.756	0.987	0.373
	Within group					1249.898	1632	0.756		
	Total					1251.410	1634			

The biggest cause of the increase in speed is passing through the intersection without stopping or decelerating, and misusing the remaining time information. Furthermore, a case existed in which the participant accelerated through the intersection at high speed, based on the provided information.

4. Conclusions

Providing the driver with real-time information on the status of traffic lights and remaining time at an intersection was determined to help individual drivers to select vehicle speeds irrespective of the initial lighting condition. Moreover, when information on the traffic light status was provided, the selection of the speed resulted in a higher speed of passing through the intersection than when it was not. Therefore, future signal remaining time information studies should consider these characteristics and enhance the message format and communication method based on the requirements.

Author Contributions: Conceptualization, methodology, analysis, writing, E.C.; investigation and data curation, H.H.; validation, S.L.; supervision, O.J.; project administration, K.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Korea Road Authority.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets used/or analysed during the current study available from the corresponding author on reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

Reference

1. Bo, Y.; Shan, B.; Fred, F.; James, S. Examination and prediction of drivers' reaction when provided with V2I communication—Based intersection maneuver strategies. *Transp. Res. Part C* **2019**, *106*, 17–28.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.