SPATIAL AND TEMPORAL ANALYSIS OF VEHICLE MOVEMENTS APPROACHING SIGNALAIZED INTERSECTION FOR PROVISION OF SIGNAL CHANGE INFORMATION

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ABSTRACT

Unnecessary vehicle movements such as rapid acceleration/deceleration and long idling are occurred around a signalized intersection, especially in urban area. It is thought that such unnecessary vehicle movements are able to be decreased by provision of appropriate information. Actual vehicle movements should be grasped before providing such information or developing a provision method of the information. Thus, we analyze an impact of a pedestrian signal on each vehicle movement approaching a signalized intersection. Pedestrian flashing green can be regarded as prior information of signal change from green to amber and red for drivers. As a result, during pedestrian flashing green, acceleration of a vehicle was observed near the signalized intersection and deceleration was also observed far from the intersection. It is found that providing information that the signal changes from green to amber and red may lead to unsafe vehicle movements near an intersection. Conversely, the providing information is expected to reduce the unnecessary vehicle movements running far from the intersection and contribute to decrease amount of CO_2 emissions from vehicles.

Keywords: Vehicle movement, Intersection, Signal information, Traffic control, CO_2

INTRODUCTION

Short distance between intersections and long signal cycle are characteristics of road traffic situation in Japan. These characteristics may occur traffic congestion and also unnecessary vehicle movements such as rapid acceleration/deceleration and long idling around a signalized intersection. As measures to ease these traffic conditions, it seems to be effective to provide information on traffic conditions or the signal state for drivers. In particular, it is expected to provide the prior information on signal change all over the world. When a traffic signal is green, drivers approaching a signalized intersection naturally keep their driving speed. However, when the signal changes to amber and red, drivers running near the intersection stop before a stop line with rapid deceleration. Consequently, the idling time becomes longer and CO_2 emissions are also increased. If drivers would know the signal change prior to the signal change from green to amber and red, drivers could decelerate in advance and reduce idling time at the intersection. Conversely, when a signal is red, drivers keep their driving speed and decelerate to stop near the intersection. However, if drivers would know when the signal ahead would change from red to green, they could decelerate enough to pass through the intersection with lower speed and prevent stopping and idling at the intersection. Improvement of vehicle movements therefore leads to reduction of CO_2 emissions from vehicles at a signalized intersection.

The provision of the signal change information to drivers approaching a signalized intersection is effective for improving vehicle movements. As existing signal information provision, there is a countdown signal and pre-information of signal change to green sin some countries. However, such information is provided for other purposes such as easing drivers' stress and increasing a capacity of the intersection rather than the reduction of CO_2 emissions.

The information on signal change is provided to drivers approaching a signalized intersection in this study. Drivers change their driving behavior when they receive the information. Changes in the vehicle movements start far from the signalized intersection. Therefore, in order to evaluate the effect of the providing signal change information, vehicle movements approaching a signalized intersection must be grasped and analyzed.

Vehicle movements under the provision of the signal information have been observed by several studies. A green signal countdown device (GSCD) is installed to a signalized intersection in Singapore (K. M. Lum and Harun 2006). The GSCD which is set aside a signal is to show drivers countdown time of remaining green. The installation of GSCD significantly reduces red-running violation. However, it is found that its effects do not last long. Furthermore, this study observes only vehicle movements in front and back of a stop line.

The impact of Co-operative Systems for Intelligent Road Safety (COOPERS), which is one of an infrastructure-to-vehicle co-operative system on a driver, has been investigated in five countries, Germany, Austria, Italy, France, and the Netherlands (Haneen et al. 2012). COOPERS' services are expected to improve traffic safety by providing early warning of risky traffic conditions such as accidents, traffic congestion, adverse weather conditions and so on. The results in terms of speeds, following gaps and physiological measurements indicate a positive impact. Furthermore, drivers' opinions show that the system is in general acceptable and useful.

Traffic signals in Bangkok typically utilize a long cycle length and the lengthy signal cycle causes stress among drivers and serious traffic congestion (Thirayoot et al. 2010). As a countermeasure, over 400 signal countdown system is installed in a signalized intersection. An opinion survey was conducted on more than 300 local regular drivers who are familiar with the system. As a result, more than half of the local drivers reported that the countdown timers help to relieve the frustration caused by stopping for uncertain amounts of time during the red phase in Bangkok.

Deceleration Support System (DSS) which is designed to reduce wasteful fuel consumption by encouraging a driver to release an accelerator pedal earlier at red signal and to stop safely without hesitation at amber signal (Iwata et al. 2012). The DSS could reduce CO_2 emissions by more than 7%, and had almost zero effect on the travel times.

We analyze vehicle movements approaching a signalized intersection spatially and temporarily. Especially, we also clarify the differences in vehicle movements focusing on an existence of a pedestrian signal. The reason of focusing on a pedestrian signal is that a pedestrian signal changes prior to a vehicle signal from green to amber. This means that drivers are able to anticipate vehicle signal change from green to amber and red by watching pedestrian flashing green. To clarify the changes of vehicle movements by a pedestrian signal shows usefulness and effectiveness of providing signal change information.

METHOD OF OBSERVING VEHICLE MOVEMENTS

Actual vehicle movements were observed around signalized intersections with/without a pedestrian signal. The pedestrian signal can be regarded as prior information on signal change for vehicles. Observation locations were selected considering the layout of a signalized intersection, the alignment of the approach to the intersection, the perspective of the intersection and the visibility of the signal. The approaches must cross at right angle and the alignment of the observed section must be straight because the influences of the layout and the alignment of the intersection on vehicle movements are eliminated. If there is something obstructing the view to the intersection, drivers approaching the signalized intersection cannot watch the signal ahead. In this case, changes of vehicle movements are not regarded by only the signal change.

It is necessary to observe continuous vehicle movements spatially and temporally in this study. If obstacles such as some structures and trees exist around observation location, it is impossible to observe continuous vehicle movements for a section more than 300 meters from the intersection. Therefore, there must be no obstacle to observe vehicle movements from the far side of the approaches to the intersection. At a signalized intersection with a pedestrian signal, the pedestrian signal can be also visible by drivers approaching the intersection, otherwise the impact of the pedestrian signal cannot be observed.

Selecting observed intersection

Two signalized intersections to be observed were selected based on the conditions mentioned above. A signalized intersection without a pedestrian signal is Nishiura-Intersection located at Nisshin-city, Aichi prefecture, Japan. Another intersection with a pedestrian signal is Shiyakusyo-Higashi-Intersection located near Nishiura-Intersection. The common characteristics of two intersections are a crossing intersection at right angle, one lane each direction, 40km/h of speed limit and having right-turn lane (left-hand side driving). The approaches to each intersections cross at right angel. Therefore, influences of the layout and alignment of the intersection on vehicle movements can be eliminated from the observation. The most significant difference between both intersections is whether there is a pedestrian signal or not. Shiyakusyo-Higashi-Intersection has a pedestrian signal and Nishiura-Intersection has no pedestrian signal. The impact of pedestrian signal information on vehicle movements can be analyzed by the observation of such two intersections. This

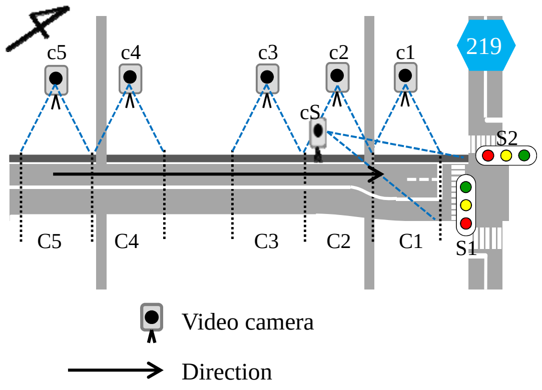

Figure 1 – Layout of Nishiura-Intersection

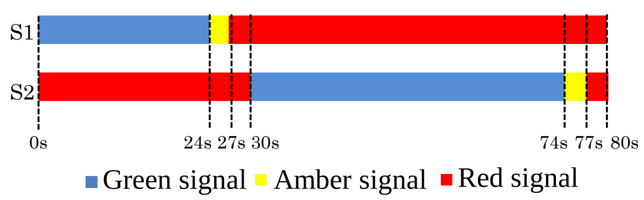

Figure 2 – Signal timing at Nishiura-Intersection

Table 1 – Outline of each observation

Observation location	Date	Point	Observation segment(m)					
			C1	C2	C3	C4	C5	CS
Nishiura No.1	December 5, 2011 15:30-16:30	Start	0	50	100	200	250	Signal
		End	50	100	150	250	300	
Nishiura No.2	December 21, 2011 14:00-15:30	Start	0	50	100	200	280	Signal
		End	50	100	150	250	330	
Shiyakusho-Higashi	June 5, 2012 10:00-12:00	Start	0	20	100	200	300	Signal
		End	20	100	200	300	400	

result can estimate an impact on vehicle movements when prior information on signal change for vehicles is provided to drivers approaching a signalized intersection.

Outline of observed intersection

The layout of Nishiura-Intersection is illustrated in Figure 1. Each vehicle movement approaching the intersection was recorded by six digital video cameras at two days on December 5 2011 and December 21 2011. The observed section and time of each observation are shown in Table 1. The length of the observed section for Nishiura-Intersection is more than 300 meters. This length was set longer than the distance mentioned by MIYATA et al. (2001) for grasping changes of vehicle movements.

Signal timings of Nishiura-Intersection are illustrated in figure 2. One cycle of the signal is 80 seconds, in which green is 24 seconds, amber is 3 seconds and red is 53 seconds for the observed direction. All red is 3 seconds to clear vehicles within the intersection.

The layout of Shiyakusho-Higashi-Intersection is illustrated in Figure 3, where H1 and H2 denote pedestrian signals. The observed section and time is also shown in Table 1. The length of the section is 40 meters. Vehicle movements were observed by six digital video cameras on June 5 2012. Since several obstacles such as a house and warehouse were existed at sides of the observed section, it was necessary to observe the section both side to avoid the obstacles.

The signal timing at Shiyakusho-Higashi-Intersection is illustrated in Figure 4. One cycle is 120 seconds, in which green, amber and red are 33, 4 and 83 seconds respectively. All red is 3 seconds. Drivers approaching the intersection are able to see the pedestrian signal of H1.

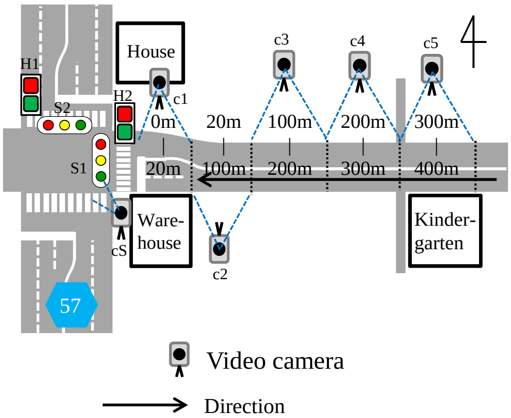

Figure 3 – Layout of Shiyakusyo-Higashi-Intersection

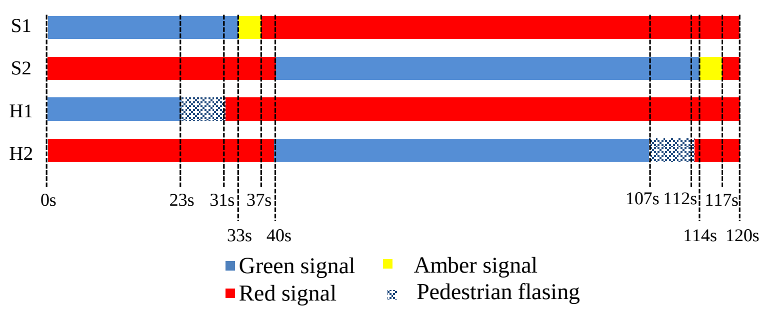

Figure 4 – Signal timing at Shiyakusyo-Higashi-Intersection

One cycle of H1 consists of 23 seconds of green, 8 seconds of flashing green and 89 seconds of red. Time duration between the time a green signal for pedestrian starts to flash and the time a signal for a vehicle changes to red is 14 seconds. Therefore, drivers can anticipate the change of the signal for a vehicle from green to red before 14 seconds by perception of the change of a pedestrian signal.

Condition to choose object vehicles for analysis

All vehicles running the observed section are not freely running. Some vehicles must follow the vehicle running ahead. For instance, a vehicle with a short headway must follow the leading vehicle regardless of the signal state. These vehicle movements should be removed from analysis objects. Therefore, passenger cars, which has a headway more than 3 seconds all the time, does not turn left or right and does not stop on the approach sections, are only chosen for the analysis objects.

Method to obtain continuous average speeds

Continuous average speeds of each vehicle for the observed section are calculated by the following steps:

Step 1: Marking a line on the video screen where a pole was set to show an interval of 10 meters during the observation,

Step 2: Separating the observed section by 10 meters intervals based on the mark of the pole. In other words, more than 300 meter observed section is divided into more than 30 segments for obtaineing an average speed for a segment of 10 meters,

Step 3: Synchronizing the time records of all videos,

Step 4: Reading the time during a vehicle takes to pass through each segment from the time record of the video,

Step 5: Calculating an average speed of each vehicle for all segments,

Step 6: Obtaining continuous changes of average speeds in accordance with spatial and temporal axes.

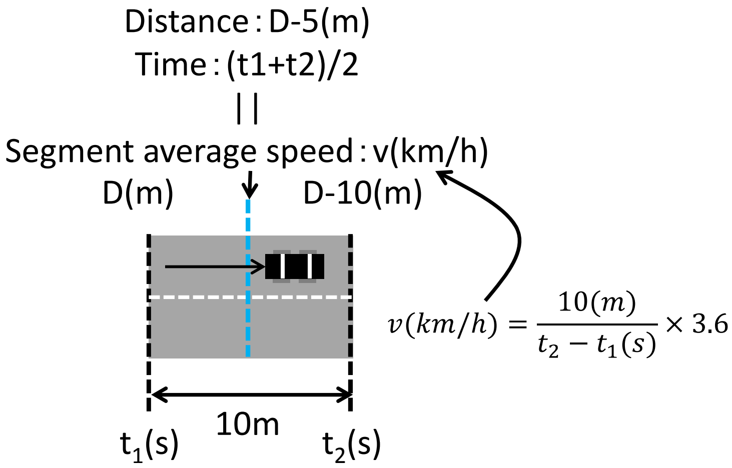

Figure 5 – Calculation of segment average speed of each vehicle

Figure 5 shows the process to calculate an average speed for a segment of 10 meters, which is defined as a segment average speed. The calculated segment average speed is regarded as the speed at the center of the segment. The segment average speed is not always correct because the speed of an actual vehicle does not vary linearly.

RESULTS OF ANALYZING VEHICLE MOVEMENTS

Vehicle movements of Nishiura-Intersection

The samples of 137 are selected form the observed vehicle approaching Nishiura-Intersection as object vehicles for the analysis based on the condition mentioned above. The continuous segment average speeds of the vehicles are obtained as shown in Figure 6. Vehicle movements can be seen easily from lines drawn in Figure 6. The horizontal axis and vertical axis are time and segment average speed respectively. The background color of the figure means a signal state which changes in accordance with the time. The origin point of time axis is the start of green signal. In this figure, the time axis returns to origin point when the signal changes to green by every 80 seconds at Nishiura-Intersection. This time axis makes it possible to easily understand vehicle movements at signal change from green to amber and from amber to red. On the other hand, as vehicle movements at signal change from red to green are divided into both ends of the figure, it is difficult to grasp the vehicle movements. Therefore, vehicles entered the observed section before 40 seconds are drawn in the left area and the other vehicles are drawn in the right area. Consequently, this figure also makes it possible to easily understand the vehicle movements at signal change from red to green.

From Figure 6, it is found that the segment average speeds tend to become lower in proportion as the red time elapses. On the other hand, it is also found that the segment average speeds tend to become higher in proportion as the green time elapses. Accordingly, the overall tendency of the segment average speeds becomes a wavy form.

Figure 7 is a box plot in which some statistics are calculated from the vehicle movements in Figure 6. This figure is illustrated by the following. First, the time axis of Figure 6 is divided into some intervals. Second, the segment average speeds of each vehicle within this interval

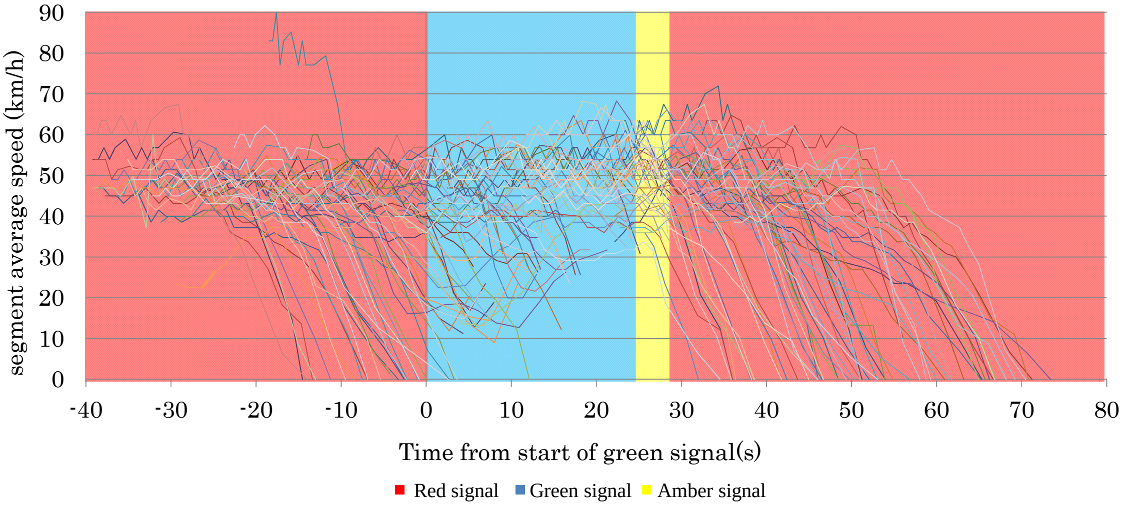

Figure 6 – Changes of segment average speed by each vehicle at Nishiura-Intersection

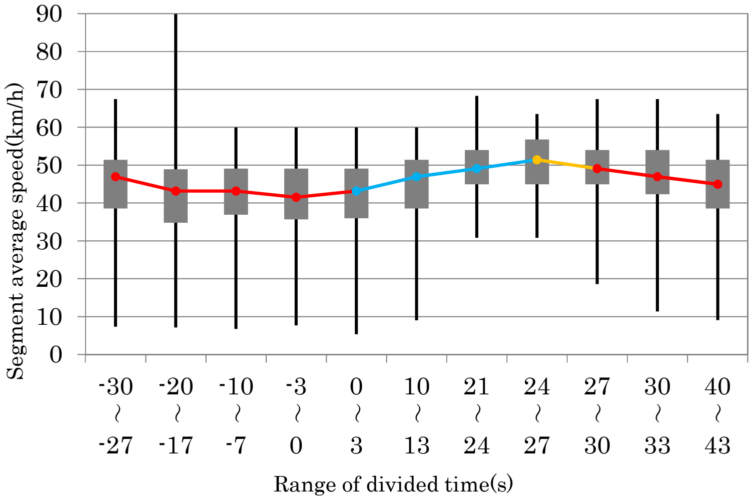

Figure 7 – Box plot of segment average speed by divided time at Nishiura-Intersection

are selected. Third, the maximum, the minimum, the average and the standard deviation are calculated for each interval. The horizontal axis indicates the intervals, for instance, the most left of the horizontal axis in Figure 7 denotes a range from -30 seconds to -27 seconds. This range from -30 seconds to -27 seconds is identical to the range from 50 seconds to 53 seconds. The vertical axis denotes the interval average of the segment average speed as shown in Figure 6. The bottom and the top of vertical lines on a box mean the fastest and the slowest segment average speeds in the interval respectively. The upper and the lower base of a box are 85 percentile and 25 percentile speeds respectively. The size of a box shows variability of the segment average speed of the selected vehicles within the interval. The dot on the box denotes the median of the segment average speeds. The color line connecting these dots shows the signal state. In order to reduce an effect of a particular vehicle movement such as running extremely higher or lower and left or light turning, the median seems to be appropriate to analyze the vehicle movements.

The wavy form of the median line can be seen in Figure 7 as same as Figure 6. The highest median of the segment average speed appears immediately after the signal change from

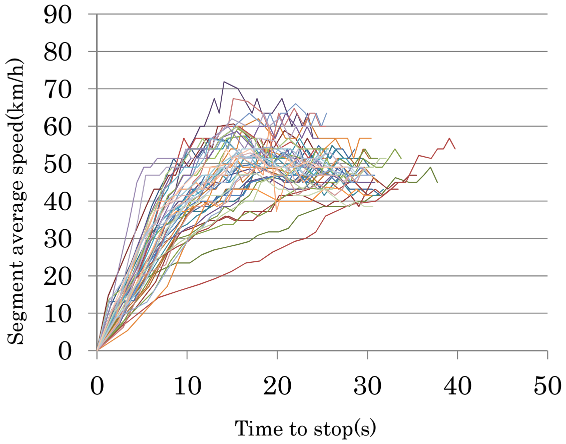

Figure 8 – Changes of segment average speed based on time to stop at Nishiura-intersection (all red signal)

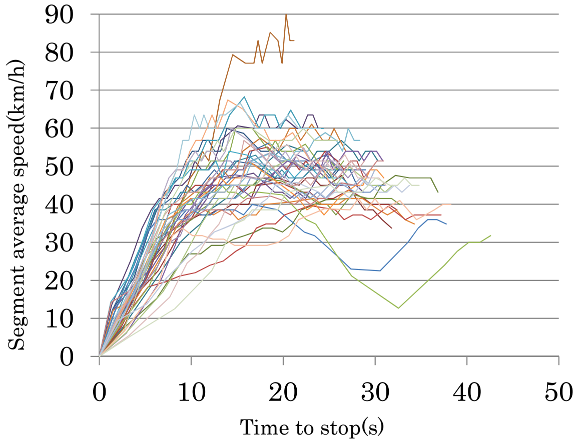

Figure 9 – Changes of segment average speed based on time to stop at Nishiura-intersection (changing signal)

green to amber. On the contrary, the lowest median appears just before the signal change from red to green. Variability in the segment average speeds is the smallest around an amber signal. The variability of other intervals is almost the same.

The signal change impacts the vehicle movements after about 20 seconds. Since the median just after the signal change to red is higher than that after the signal change to green, drivers seeing a signal seem to change their driving behaviors. When a signal ahead is green, a driver keeps the speed constant. On the other hand, a driver decelerates when a signal ahead is amber or red. If a driver keeps the speed constant at the signal change from green to red, an idling time increases at a signalized intersection. Consequently, environmental load such as CO_2 emissions is increased by such unnecessary vehicle movements.

Figure 8 and Figure 9 show changes of the segment average speeds in accordance with the time until stopping of each vehicle. The horizontal axis of Figure 8 and Figure 9 is the time until stopping and the vertical axis is the segment average speed. Each vehicle runs with the speed indicated by the line from right to left in these figures. Figure 8 is drawn by the vehicles which run a whole observed section during red. On the other hand, Figure 9 is drawn by vehicles running the observed section when a signal ahead changes from green to red. The segment average speed of vehicles in Figure 8 slightly increases according to the time or is kept constant for 20 seconds and later. Then, deceleration behavior appears from 20 seconds before stopping. Some vehicles start decelerating just after entering the observed section. These vehicle movements can make an idling time short so that the movements may reduce CO_2 emissions from vehicles.

The vehicle movements shown in Figure 9 are similar to those in Figure 8. However, there are some vehicles accelerating at around 30 second before the stopping. These unnecessary vehicle movements make an idling time longer at the intersection during a red signal. Consequently, CO_2 emissions are increased from vehicles.

Unnecessary vehicle movements such as repeating stopping and going seem to occur by stopping at a signalized intersection. Therefore, we analyze the vehicle movements focused on stopping. A signal cycle is divided into 10 seconds intervals, for instance, the interval 1 is a range from -40 to -30 seconds and the interval 2 is from -30 to -20 seconds. The signal states of the interval 1 to 4 and the interval 8 is red. The interval 8 is the time immediately after the signal change from green to amber and red. The interval 5 and 6 is green. All vehicles entering the observed section at each interval are aggregated by stopping or

Table 2 – A number of entering vehicles and a passing vehicles and segment average speed

Interval	1	2	3	4	5	6	7	8
Entering time	-40s ~ -30s	-30s ~ -20s	- 20s ~ -10s	-10s ~ 0s	0s ~ 10s	10s ~ 20s	20s ~ 30s	30s ~ 40s
Number of vehicles	19	18	16	15	14	16	20	17
Number of vehicles stopping	17	12	2	3	4	16	20	17
Stop ratio	89%	67%	13%	20%	29%	100%	100%	100%
Segment average speed at 325m (km/h)	47.30	48.51	48.00	45.24	47.75	50.75	49.42	48.89

passing at a signalized intersection. Moreover, an average speed of vehicles entering the observed section is calculated for 10 meters from the start of the observed section, i.e. from 330 to 320 meters. These data are summarized in Table 2.

The stop ratios of vehicles entering at the interval 1 and 2 are higher than those at the other intervals. This means stopping behavior is occurred frequently at a signalized intersection by the vehicle entering the section for these time intervals. However, a part of drivers pass through the intersection without stopping by low-speed running. This shows the possibility to reduce unnecessary vehicle movements by providing appropriate information on the signal change to drivers.

The stop ratios of vehicles entering at the interval 3 to 5 are lower than those at the other intervals. Unnecessary vehicle movements are not occurred at these intervals. On the contrary, no vehicles entering at the interval 6 to 8 passes through the intersection without stopping. Furthermore, the average speeds at the interval 6 to 8 are faster than those at other intervals. Unnecessary vehicle movements are occurred frequently at these intervals. If the vehicles entering the section at these intervals are recommended to decelerate not to stop at an intersection, vehicles run with extremely low-speed and may cause traffic congestion. These vehicles should therefore be recommended to decelerate gradually so that an idling time can be shortened. This means CO_2 emissions are also reduced.

Vehicle movements of Shiyakusyo-Higashi-Intersection

The samples of 105 are selected form the observed vehicles approaching Shiyakusyo-Higashi-Intersection as object vehicles based on the condition mentioned above. In the same way as Figure 6, the continuous segment average speeds of the vehicles are obtained as shown in Figure 10 in which pedestrian signal state is also shown as a part of background color in addition to vehicle signal states. In this figure, the time axis returns to origin point when the signal changes to green by every 120 seconds. The overall tendency of the segment average speeds forms a wavy and the periods when a pedestrian signal is flashing green and a vehicle signal is green and when a pedestrian signal is red and a vehicle signal is green painted in Figure 10 as green and purple respectively.

Figure 11 is a box plot in which some statistics are calculated from the vehicle movements in Figure 10. The lowest median appears just before the signal change from red to green as same as the case in Figure 7. However, the highest median of the segment average speed appears in the middle of pedestrian flashing green. The pedestrian flashing signal seems to be prior notice of vehicle signal change from green to amber and red for a driver. Therefore, driver might accelerate in order to pass through the intersection.

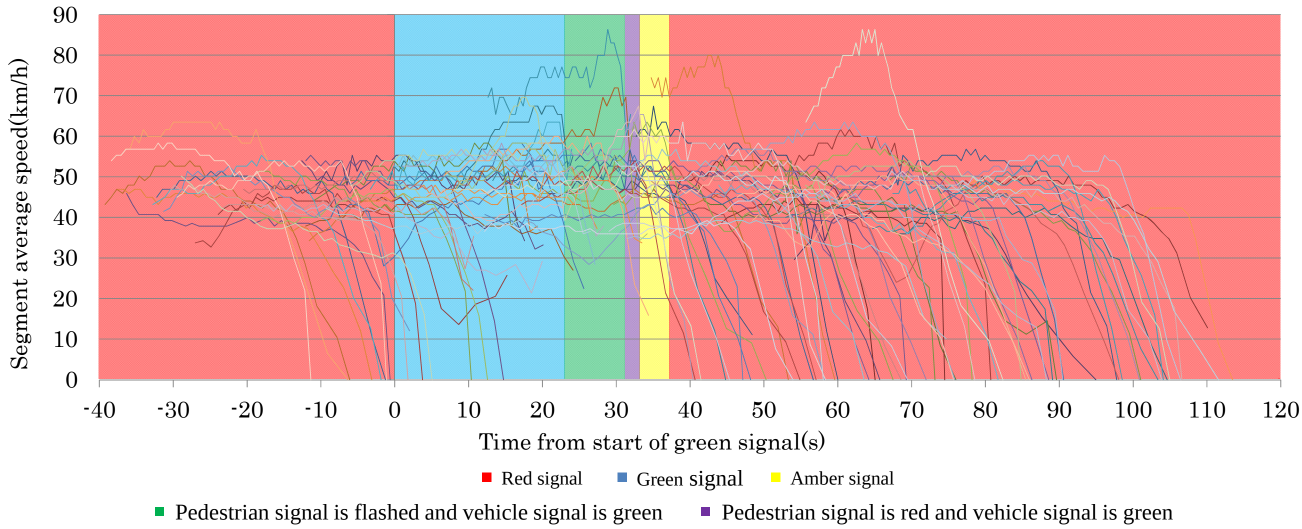

Figure 10 – Changes of segment average speed by each vehicle at Shiyakusyo-Higashi-Intersection

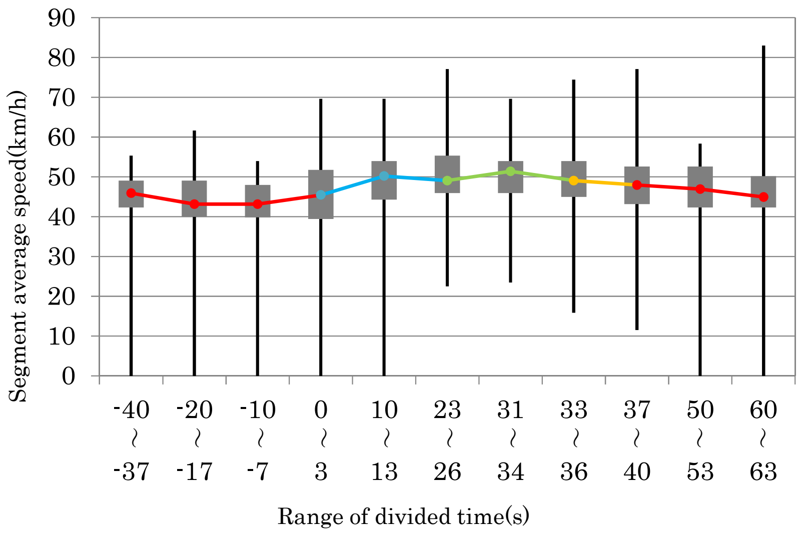

Figure 11 – Box plot of segment average speed by divided time at Shiyakusyo-Higashi-Intersection

Figure 12 and Figure 13 show changes of the segment average speeds in accordance with the time until stopping of each vehicle at Shiyakusyo-Higashi-Intersection. Figure 12 is drawn by the vehicles running a whole observed section during red. Figure 13 is drawn by vehicles running when a signal ahead changes from green to amber and red. Deceleration behavior appears from 10 seconds before stopping in Figure 12. However, deceleration behavior in Figure 13 appears earlier (more left) than that in Figure 12.The segment average speeds in Figure 13 tend to be higher than those in Figure 12. Therefore, it is found that drivers who approach the intersection and predict the vehicle signal change from pedestrian flashing green do not decelerate regardless of the distance from the intersection and intend to keep their speed constant.

Comparison of vehicle movements

The result of analysis of variance (ANOVA) for two signalized intersections is shown in Table 3, in which the vehicle movements immediately after the signal change are focused. It is

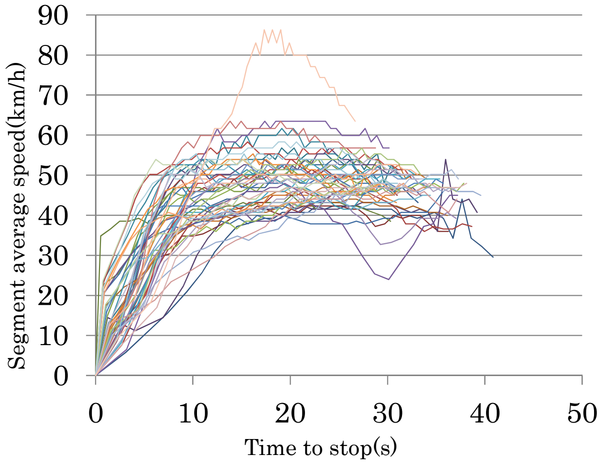

Figure 12 – Changes of segment average speed based on time to stop at Shiyakusyo-Higashi-Intersection (all red signals)

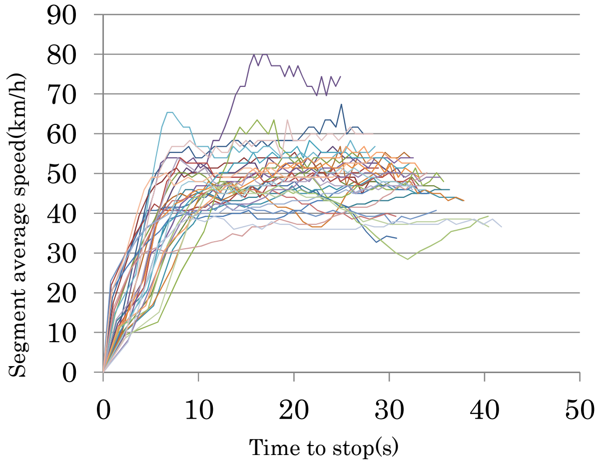

Figure 13 – Changes of segment average speed based on time to stop at Shiyakusyo-Higashi-Intersection (changing signal)

Table 3 – Analysis of variance on vehicle movement at Nishiura and Shiyakusyo-Higashi after signal changing

		3 seconds after changing to green	3 seconds after changing to amber	3 seconds after changing to red
Average speed	Nishiura-Intersection	41.09	50.27	48.82
	Shiyakusyo-Higashi-Intersection	43.53	49.95	47.76
P-value		0.236	0.770	0.379

* 5% significance ** 1% significance

Table 4 – Analysis of vaiance on vehicle movement at Nishiura and Shiyakusyo-Higashi focused on distance at amber signal

		3 seconds after changing to amber		
		Short-distance	Medium-distance	Long-distance
Average speed	Nishiura-Intersection	46.61	52.54	51.64
	Shiyakusyo-Higashi-Intersection	48.60	47.75	52.30
P-value		0.399	2.55E-04 **	0.667

* 5% significance ** 1% significance

found that there is no significant difference between the vehicle movements approaching the signalized intersection with/without a pedestrian signal. It is adequate that no significant difference is shown in the vehicle movements at the signal change from red to green. On the other hand, the pedestrian flashing green may have any influences on the vehicle movements at the signal change from green to amber and red. Despite of the pedestrian flashing green, there is no significant difference. This is probably because the analysis shown in this paragraph ignores the distance of the vehicle from the intersection.

The result of ANOVA is shown in Table 4, which takes account of the distance of the vehicle when the signal for a vehicle changes from green to amber. In Table4, the range of short-distance is 0 meter to 100 meters, medium-distance is 100 meters to 250 meters and long-distance is 250 meters and longer. From Table 4, it is found that there is significant difference in the vehicle speeds at medium-distance. The pedestrian flashing green seems to affect the vehicle running at medium-distance from the intersection.

In order to analyze the change in vehicle movements, the vehicle movements are compared focused on the period of pedestrian flashing green. The period of 14 seconds from 23 to 37 as shown in Figure 4 is focused for the analysis at Shiyakusyo-Higashi-Intersection, which includes pedestrian flashing green, pedestrian red and vehicle green, and pedestrian red and

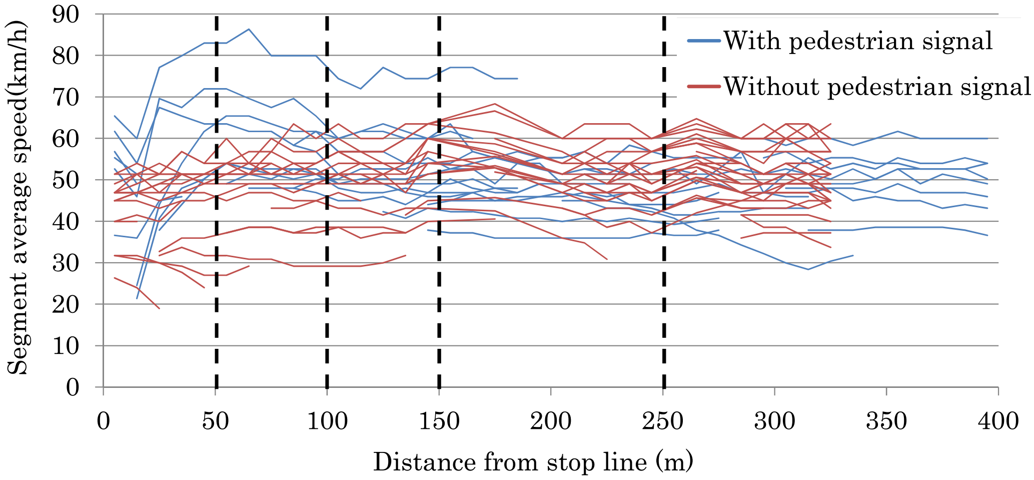

Figure 14 – Vehicle movement approaching intersection with/without pedestrian

Table 5 – Changes of vehicle speed approaching intersection with/without pedestrian signal

Section length	0m - 50m		50m - 100m		100m - 150m		150m - 200m		250m later	
Pedestrian signal	with	without	with	without	with	without	with	without	with	without
Number of samples	35	80	43	81	55	87	116	114	150	163
Average speed	54.14	43.95	59.53	48.03	53.34	50.36	49.00	51.18	50.24	50.99
Difference in average speed (km/h)	10.19 **		11.50 **		2.98		-2.17 *		-0.75	
Variance	183.93	82.41	113.88	66.55	81.25	68.26	62.54	46.42	72.97	45.25

* 5% significance ** 1% significance

vehicle amber. The period of 14 seconds from 13 to 27 as shown in Figure 2 is focused at Nishiura-Intersection. Vehicles entering the observed section for these 14 seconds are selected to be analyzed for the comparison. Those vehicle movements for the 14 seconds at both intersections are drawn in Figure 14. In proportion to the distance from the intersection, the segment average speed at the intersection with a pedestrian signal (blue line) becomes lower as compared with the speed at the intersection without a pedestrian signal (red line). On the contrary, the vehicles near the intersection with a pedestrian signal run faster.

Figure 14 is divided into 5 segments shown by dashed lines in the figure. They are divided into 0 meter to 50 meters, 50 meters to 100 meters, 100 meters to 150 meters, 150 meters to 250 meters and over 250 meters. The result of t-test of the average vehicle speeds by each segment is shown in Table 5

From Table 5, it can be seen that the vehicle speed with a pedestrian signal within 100 meters from the intersection becomes faster than that without a pedestrian signal. However, the vehicle speed with a pedestrian signal over 150 meters becomes lower. Furthermore, there is no significant difference in the average speed in the section of 100-150 meters.

As each driver reacts differently to a pedestrian signal, it is thought that the variance of vehicle speeds with a pedestrian signal may be larger than that without one.

Figure 15 illustrates each average speed in Table 5 as a line. Drivers seeing pedestrian flashing green tend to accelerate near an intersection and also to decelerate far from an intersection. However, tendency of drivers running at middle-distance from an intersection are still unclear because drivers accelerating and decelerating are mixed for middle-distance. This acceleration occurs by driver's decision to pass an intersection in a hurry. The deceleration also occurs by driver's decision to give up passing an intersection before signal

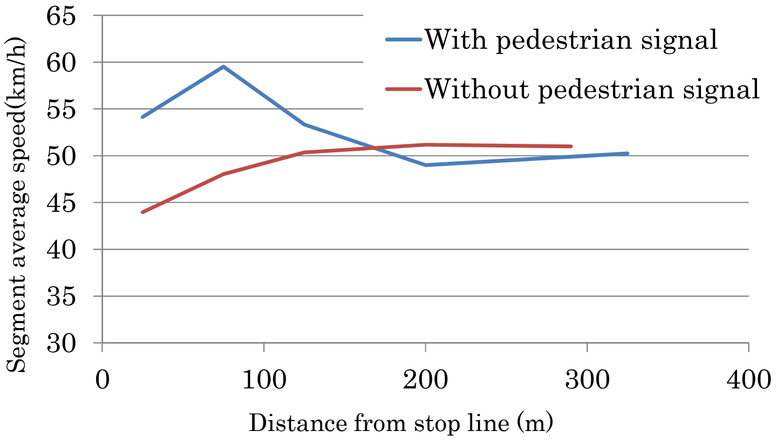

Figure 15 – change of segment average speed approaching intersection with/without pedestrian signal

change. On the other hand, driver's decision around 150 meters from an intersection varies based on the characteristics of each driver rather than the existence of a pedestrian signal.

CONCLUSION

Actual vehicle movements were observed around signalized intersections with/without a pedestrian signal by digital video cameras. The pedestrian signal can be regarded as prior information on signal change for vehicles. Therefore, we analyzed the influence of a pedestrian signal on vehicle movements. The influence can be regarded as same as the influence when signal change information is provided to drivers by the ITS technology.

Vehicles running freely were selected to be analyzed in this study. The 137 samples were selected for an intersection without a pedestrian signal and 105 were selected for one with a pedestrian signal. Continuous average speeds of each vehicle for the observed section were calculated for both intersections.

The average speeds formed wavy at the intersection without a pedestrian signal. This shows a red signal makes the average speed higher and a green signal makes the average speed lower. There were some vehicles decelerating slowly just after entering the observed section and stopping at the intersection. This movement reduces idling time.

The average speed was highest during pedestrian flashing green for the intersection with a pedestrian signal. This meant that the pedestrian flashing green might make some drivers hurry to pass through the intersection.

From the comparison of both results with/without a pedestrian signal, it was found that drivers approaching a signalized intersection did not decelerate to stop during pedestrian flashing green regardless of the distance from the intersection and kept their speed constant.

Some vehicles stopping at the intersection decelerated slowly in advance when the signal is red for all time. Drivers started to decrease nearer the intersection at pedestrian flashing green. This means pedestrian flashing green can be regarded as prior information for drivers that the signal changes shortly from green to amber and red.

To analyze the influence of providing information that a signal changes to red, we compared vehicle movements during pedestrian flashing green with a pedestrian signal and the time before changing from green to amber without a pedestrian signal. As a result, it was found that vehicle movements near the intersection during pedestrian flashing green tended to

accelerate. Since this movement may lead to traffic accidents, it is thought that the signal change information to drivers running near the intersection should not be provided.
Acceleration and deceleration were mixed in the vehicles running at middle-distance from the intersection, because driver's decision whether to accelerate or decelerate differed by each driver at middle-distance. This may also lead to traffic accidents. Therefore, careful consideration is needed to develop a method for providing the signal change information. On the other hand, drivers running far from the intersection decelerated slightly. This movement reduces idling time. Therefore, providing the signal change information to drivers far from an intersection is effective to reduce CO_2 emissions.
For further work, more observations at other intersections are required to obtain general influence of a signal on vehicle movements. Furthermore, it is desired that the effect of providing signal change information to drivers is analyzed by using a driving simulator.

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