ANALYSES ON THE LANE CHOICE BEHAVIOR FOR EVALUATING TRAFFIC SAFETY MEASURES AT SIGNALIZED INTERSECTIONS WITHOUT RIGHT-TURN-ONLY LANE ON ARTERIAL ROADS

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ABSTRACT

At signalized intersections without right-turn-only lane on two-lane (per one direction with left-hand traffic) arterial roads, the significant number of rear-end accidents might be caused by frequent and sudden lane changes of the straight-through vehicles to pass the right-turn vehicles waiting for right turn chance. To discuss traffic safety measures at such places, this paper, basing on data obtained at signalized intersections on National Route 1 in Toyohashi, JAPAN, analyses traffic flow and vehicle behavior.

Firstly, by using the data from traffic flow counts, it was confirmed that the frequency of lane changes is significantly correlated with the number of rear-end accidents. Secondly, by using the data from video observation conducted at the segment of two signalized intersections, it was found that a certain number of straight-through vehicles change their running lane at the segment far before the intersection. From this result, it was suggested that the drivers of the straight-through vehicles always consider the possibilities of the presence of the right-turn vehicles in the downstream segment. Due to this assumption, factors affecting the lane choice behavior were finally examined by estimating the disaggregate lane choice behavior model. The differences in behavior between standard-sized vehicles and heavy vehicles were also discussed.

Keywords: Traffic Safety, Rear-end Accidents, Lane Changes, Lane Choice Behavior

1. INTRODUCTION

Traffic accidents have been still serious social problem. In Japan, the number of traffic fatalities fell below 10 thousands in 1996 and have been decreasing rapidly. However, there were still extremely high number in 2009: 736,160 accidents; 4,914 fatalities; and 908,874 injuries (National Police Agency, Japan, 2010). At the arterial roads (i.e. national roads and prefectural roads), particularly, the half number of total accidents occur and to facilitate safety measures are needed. With limited financial resources, effective and efficient implementations of traffic safety measures are needed, which require appropriate evaluations of safety measures. However, the method of evaluating traffic safety measures has not been sufficiently established. The reason may come from the fact that there are quite a lot of high-accident locations with various traffic environments. Therefore, the accumulation of knowledge corresponding to respective high-accident locations is needed.

The targeted high-accident locations in this paper are signalized intersections without right-turn-only lane on two-lane (per one direction with left-hand traffic) arterial roads (see Figure 1). At such locations, the way of the straight-through vehicles running on the overtaking lane is blocked off by the vehicles waiting for right turn chance, and then sudden lane changes which induce disordered traffic flow is arisen. The disordered traffic flow may cause the rear-end accidents. In such situations, it is effective to set a right-turn-only lane but there are many places where are not to be able to do because of the lacks of space or financial resources. There have been cases that traffic managers make the overtaking lane be right-turn-only in order to prevent in advance the straight-through vehicles from running on the overtaking lane. In this case, however, the overtaking lane is not available even if there are no right-turn vehicles. Thus, those measures are inefficient at the places where the numbers of right-turn vehicles are fewer than those of straight-through vehicles. In the future, on the other hand, it is hoped to prompt the straight-through vehicles running on the overtaking lane to change lane early by providing the information on the presence or absence of the right-turn vehicles in the downstream segment using ITS or by forcing the right-turn vehicles to signal early. When these treatments are implemented, of course, an appropriate prediction of the impacts should be conducted because the impacts on safety or efficiency will differ depending on the characteristics of the traffic flow. This will firstly require enough analyzing the in-depth analyses of the lane choice behavior of the straight-through vehicles.

In this paper, as a fundamental study for evaluating traffic safety measures at signalized intersections without right-turn-only lane on two-lane (per one direction with left-hand traffic) arterial roads, there are three aims:

1. to confirm that the lane changes just before signalized intersections are related to the occurrence of rear-end accidents, by using data from traffic flow count;

2. to analyze the actual condition of traffic flow and the lane choice behavior on the segment between two signalized intersections by using data from video observation;

3. and to find out the factors of lane choice behavior by estimating the disaggregate lane choice behavior model.

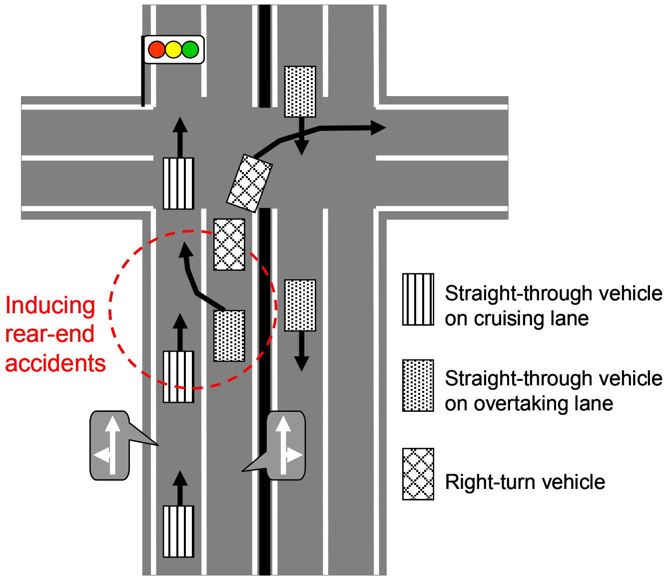

Figure 1 – Inducement of rear-end accidents by the vehicles waiting for right turn chance
(with left-hand traffic in Japan)

2. REVIEW OF PREVIOUS STUDIES

2.1 Previous Studies on Rear-end Accidents at Signalized Intersections

There are many previous studies pointing out dangerousness of rear-end accidents at the signal change timing (e.g. Kataoka et al. 2005; Sharma et al. 2007; Suzuki et al. 2008). Kataoka et al. (2005), for example, analyzed "Different Zone" where drivers' decisions of passing or stopping at the signal change timing are actually varying, and they found that the "Different Zone" is different from "Dilemma Zone" or "Option Zone" which had been established traditionally. On the other hand, there are few studies pointing out dangerousness of rear-end accidents *not* at the signal change timing. Wang et al. (1999) statistically analyzed the relationships between the number of rear-end accidents and the traffic environment factors at signalized intersections, and they suggested that frequent lane changes increase the frequency of abrupt slowdowns. They also suggested that, at signalized intersections without right-turn-only lane or left-turn-only lane, the risk of rear-end accident is increased by the number of stop behavior of the straight-through vehicles which are induced by the right-turn vehicles or left-turn vehicles. However, these matters have not been proved empirically.

Therefore, there are few accumulation of the information on the relationship between rear-end accidents and lane changes at the locations just before the signalized intersections, and this paper will focus on that relationship.

2.2 Previous Studies on Lane Choice Behavior

There are lots of previous studies dealing with the lane change behavior or the lane choice behavior. For weaving sections, Nakamura et al. (1992) modelled the lane change behavior with special indicator – the relative change rate of the distance from the leading vehicles or following vehicles. Also, Uno et al. (2001) modelled the lane change behavior by applying fuzzy theory considering the distance from the leading vehicles or following vehicles. Moreover, Nakamura et al. (2001) modelled the lane change behavior with 2-step process. The first step of the model is related to the decision to start seeking the gap for lane-changing. The second step is related to the acceptance of the gap. They also applied the model to microscopic traffic simulation with town street network.

These models have considered only traffic environment conditions just around the vehicles. In the case where it is desired to predict impacts of providing the information on the presence or absence of the right-turn vehicles in the downstream segment, a model which can express the lane change behavior considering traffic environment conditions not only around the vehicle but also in the far downstream is needed. This will require the observations and the analyses in the long segment. Kita et al. (2000) observed traffic flows in the segment between 500m behind the expressway merging section and 25m ahead of it by using the radio control helicopter's-eye. Then they found that although the drivers cannot know the presence or absence of the merging vehicles before the merging section, they move to the overtaking lane in order to avoid the conflict with the merging vehicles based on their driving experiences. However, there are few studies dealing with the lane change behavior or the lane choice behavior in the long segment on arterial road.

This paper will analyze the lane choice behavior in the long segment between two signalized intersections by implementing the video observation. Then, by estimating the disaggregate lane choice behavior model, the effects of traffic environment conditions in the downstream segment on the lane choice behavior will be discussed.

3. RELATIONSHIP BETWEEN REAR-END ACCIDENTS AND LANE CHANGES

3.1 Data Collection

In order to confirm that the frequency of lane changes just before the signalized intersections is related to the number of rear-end accidents, the simple traffic flow count was conducted at 10 signalized intersections on national route 1 in Toyohashi, Japan (see Figure 2). There are two directions (namely, leading to Nagoya and to Hamamatsu) at each intersection. Thus there are 19 targeted approaches without right-turn-only lane except for one approach with right-turn-only lane. At each approach in two periods (8:00~9:00 and 17:00~18:00) on Jun. 24th, 2008 ~ Jul. 14th, 2008, the numbers of straight-through vehicles, right-turn vehicles, left-turn vehicles, and lane-changing vehicles (only from the cruising lane to the overtaking lane) in the segment between each intersection and 100m behind it are counted for 3 cycles. The characteristics of each intersection are shown in Table 1. Note that the number of rear-end accidents are in the segment between each intersection and 100m behind it, for 3 years (2005~2007). Also note that the ratios of left-turn vehicles, right-turn vehicles, and lane-changing vehicles are the values that the number of left-turn vehicles, right-turn vehicles, and lane-changing vehicles are divided by the number of all vehicles, respectively. There are not large changes of traffic environment conditions between the time point of collecting the number of accidents and that of counting the traffic flow.

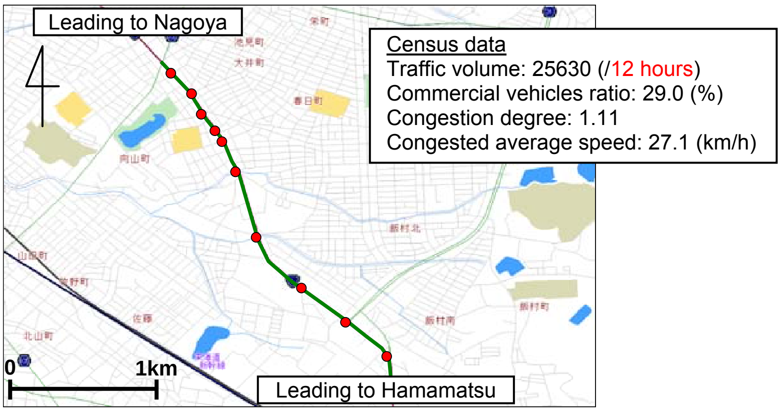

Figure 2 – Targeted Intersections

Table 1 – Characteristics of each intersection

Approach No.	Road width (m) (/ two lane)	Left turn	Right turn	Rear-end accidents	Number of all vehicles (/ one cycle)	Ratio of left-turn vehicles (%)	Ratio of right-turn vehicles (%)	Ratio of lane-changing vehicles (%)
1	7.2	○	○	7	56	4.8	4.9	20.1
2	8.2	○	○	3	48	0.0	3.6	12.9
3	8.4	–	○	1	52	6.7	0.0	1.4
4	7.3	○	○	2	44	0.0	0.0	2.2
5	6.9	○	○	1	43	0.7	2.0	8.0
6	7.0	–	○	12	45	0.0	2.1	15.3
7	7.9	○	○	3	46	17.5	0.4	4.6
8	7.9	○	○	7	44	0.7	1.7	6.2
9	7.3	○	○	4	52	0.0	7.1	17.3
10	8.1	○	○	2	46	5.3	0.3	1.1
11	8.0	○	○	2	52	23.8	0.0	1.9
12	7.5	○	–	4	43	0.0	0.8	10.0
13	6.5	○	○	2	47	7.9	0.0	3.5
14	6.7	○	○	1	46	2.1	1.1	5.9
15	6.8	○	–	6	43	6.6	0.0	1.2
16	7.1	○	○	11	35	2.9	8.7	12.6
17	7.1	○	○	2	37	0.5	3.8	8.2
18	10.1	○	–	3	36	5.8	0.0	0.4
19	6.9	○	○	4	41	1.3	6.6	14.2
Average	7.5			4.1	45.1	4.6	2.3	7.7
Variance	0.8			3.2	5.6	6.4	2.8	6.1

3.2 Analyses on Number of Rear-end Accidents

In Figure 3, the number of rear-end accidents at each intersection are plotted against the number of all vehicles as a scatter chart. This chart indicates that there is not clear correlation between the number of all vehicles and the number of rear-end accidents. The reason may come from the fact that the variability of the number of vehicles is small because the targeted intersections are all on the same route. This fact implies that, conversely, the differences in the characteristics between among these intersections are related to the number of rear-end accidents.

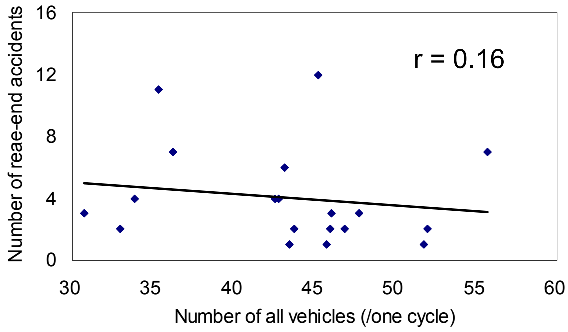

Figure 3 – Relation between the number of all vehicles and that of rear-end accidents

In Figure 4, the number of rear-end accidents at each intersection are plotted against the ratio of left-turn vehicles as a scatter chart. This chart indicates that there is not clear correlation between the ratio of left-turn vehicles and the number of rear-end accidents. This result is different from the result of Wang et al. (1992) which indicated that the increase of the number of left-turn vehicles increases the rear-end accident risk. The reason may come from the fact that the data in Wang et al. (1992) was also collected at a substantial number of intersections with three lanes or more where the lane changes may occur more frequently, whereas the data used in this paper were collected at the intersections with two lanes.

In Figure 5, the number of rear-end accidents at each intersection are plotted against the ratio of lane-changing vehicles as a scatter chart. This chart indicates that there are lots of rear-end accidents at some intersections with high ratio of lane-changing vehicles (with the significance probability of 0.02). It is not so strong relation with correlation coefficient of 0.53. Considering a large eventuality of accident occurrence, however, this result may indicate that frequent lane changes just before the intersections are the factors which increase the rear-end accident risk.

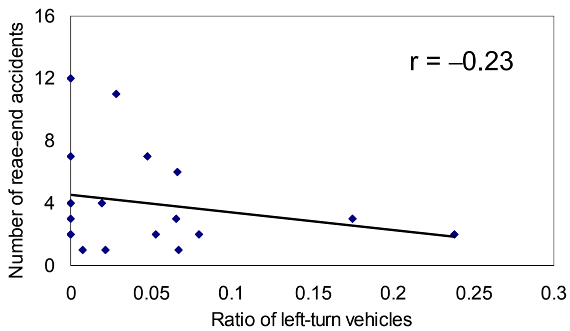

Figure 4 – Relation between the ratio of left-turn vehicles and the number of rear-end accidents

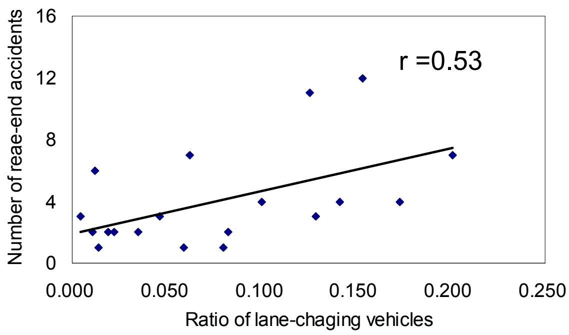

Figure 5 – Relation between the ratio of lane-changing vehicles and the number of rear-end accidents

Figure 6 and Figure 7 show the relation between the ratio of right-turn vehicles and the number of rear-end accidents, and the relation between the ratio of right-turn vehicles and the ratio of lane-changing vehicles, respectively. Figure 6 suggests that the rear-end accidents occur more frequently at the intersections with comparatively high ratio of right-turn vehicles. Considering that the correlation coefficient between the ratios of right-turn vehicles and that of lane-changing vehicles is 0.80, it is implied that the frequent lane changes to pass the vehicles waiting for right turn chance increase the rear-end accident risk. It may also be implied that, of course, some vehicles crash to the vehicles waiting for right turn chance, and it is needed more detailed surveys and analyses. Even if the accidents occur by both factors, however, accident risk may be decreased by providing the information on the presence or absence of the right-turn vehicles in the downstream segment.

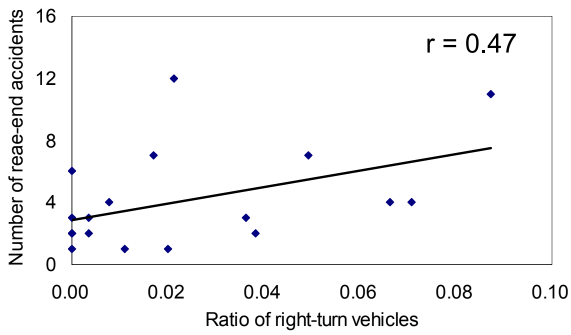

Figure 6 – Relation between the ratio of right-turn vehicles and the number of rear-end accidents

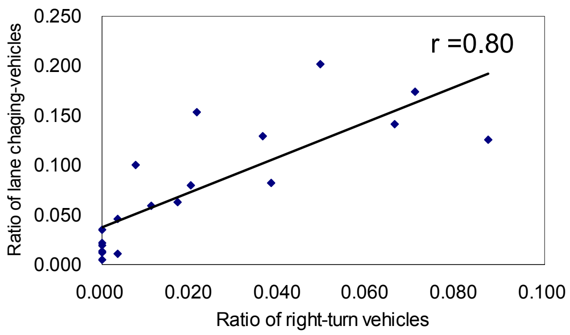

Figure 7 – Relation between the ratio of right-turn vehicles and that of lane-changing vehicles

4. ANALYSES OF TRAFFIC FLOW BETWEEN TWO SIGNALIZED INTERSECTIONS

4.1 Targeted Approach

In order to analyze the lane choice behavior in the segment between two signalized intersections, a video observation was conducted. The targeted approach to the signalized intersection was the approach to Tonodabashi intersection leading to Hamamatsu (No. 16 in Table 1; see Figure 8). This approach has high accident risk because 11 rear-end accidents occurred in this approach in 2005~2007. There is no right-turn-only lane at the targeted approach. The cruising lane is allowed for going straight and left turn, and the overtaking lane is allowed for going straight and right turn. A road is derived leftward from 50m behind the targeted intersection, and most left-turn vehicles do not turn left at intersection but at the derived road. Lots of the traffic volume at the targeted approach is quite a high, and commercial vehicles ratio is more than 30 % (see Table 2).

4.2 Video Observation Method

At first, the segment between the targeted intersection and the predecessor intersection was divided into 6 small sections. Then, traffic flow was observed at the 6 sections dynamically by using 6 video cameras. From synchronized movie, after that, each vehicle's data were collected: the time of passage at each section; the running lane at each section (i.e. cruising lane or overtaking lane); the vehicle type (i.e. normal vehicle or heavy vehicle); and the direction at the targeted intersection (i.e. going straight; left turn; or right turn). Table 3 shows an observation date, an observation term, and the number of observed cycles.

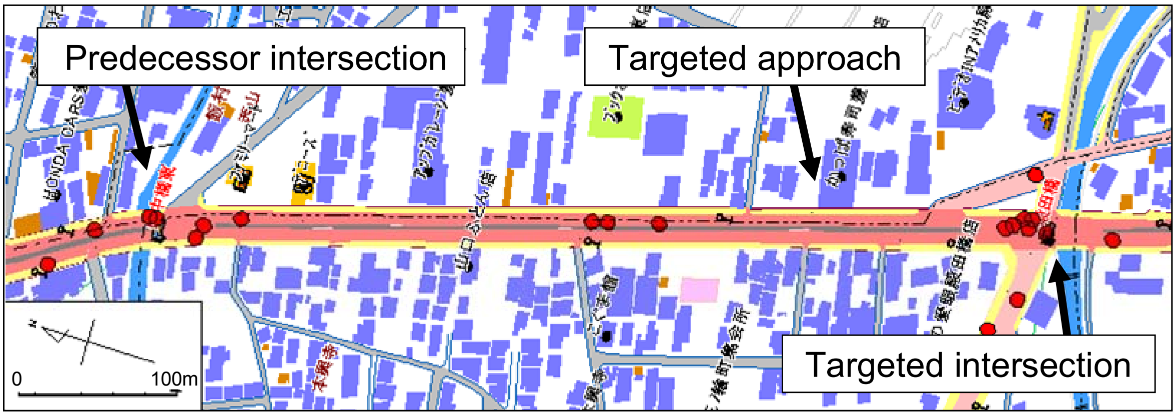

Figure 8 – Targeted segment (○ is the location of rear-end accident)

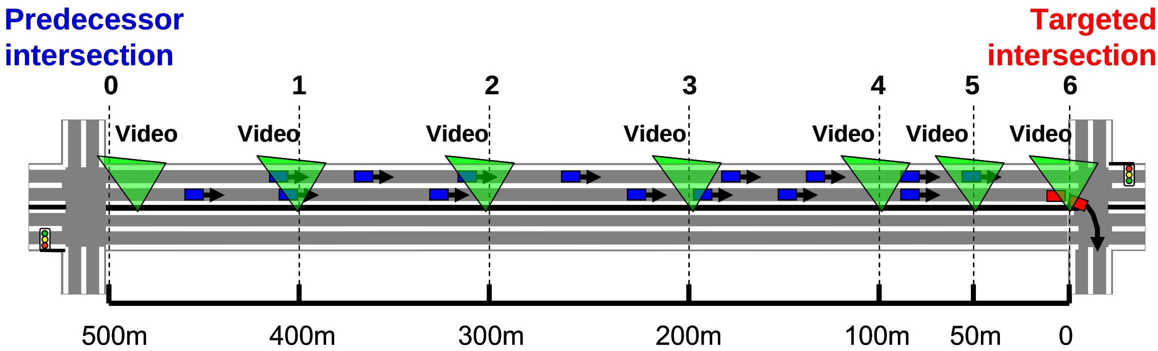

Figure 9 – Method of the video observation

Table 2 – Traffic volume at the targeted approach

Traffic volume	44.0 (/ one cycle)	
Straight-through traffic	34.7 (/ one cycle)	(78.8%)
Left-turn traffic*	6.8 (/ one cycle)	(15.4%)
Right-turn traffic	2.6 (/ one cycle)	(5.8%)
commercial vehicles ratio	31.1 (%)	

*Left-turn traffic is the total number of vehicles which turned left in the segment between the predecessor intersection and the targeted intersection
*One cycle: 150 (sec) – blue: 73 (sec); yellow: 3 (sec); red: 74 (sec)

Table 3 – Observation date, time period, and cycles

Observation date	Dec. 18th, (Thu)
Observation period	13:45~14:10 (25 minutes)
The number of observed cycles	9 cycles

4.3 Relationship between the Number of Lane-changing Vehicles and Traffic Volume

Figure 10 shows the number of lane-changing vehicles in the segment of 100m ~ 50m behind the targeted intersection and in the segment of 50m ~ 0 behind the targeted intersection, and the number of all vehicles and right-turn vehicles, for each observed cycle. Whereas there is not clear relation between the number of all vehicles and that of lane-changing vehicles, there is tendency that the number of lane-changing vehicles increases as the number of right-turn vehicles increase. Figure 10 also shows that the number of lane-changing vehicles in cycle 5 was different from that in cycle 8 although each of these cycles has one right-turn vehicle. The reason comes from the fact that the right-turn vehicle in cycle 5 was ahead of the group of vehicles and affected them obviously whereas the right-turn vehicle in cycle 8 was behind the group of vehicles and did not affect them. In addition, Figure 10 shows that lane changes occur in cycle 3 in spite of no existence of right-turn vehicles. The reason may come from the fact that, the density of vehicles on the overtaking lane were provisionally high because the overtaking lane had been chosen by a certain number of the straight-through vehicles noticing that there was no right-turn vehicles ahead of themselves, and then the following vehicles facing the provisional situation chose the cruising lane.

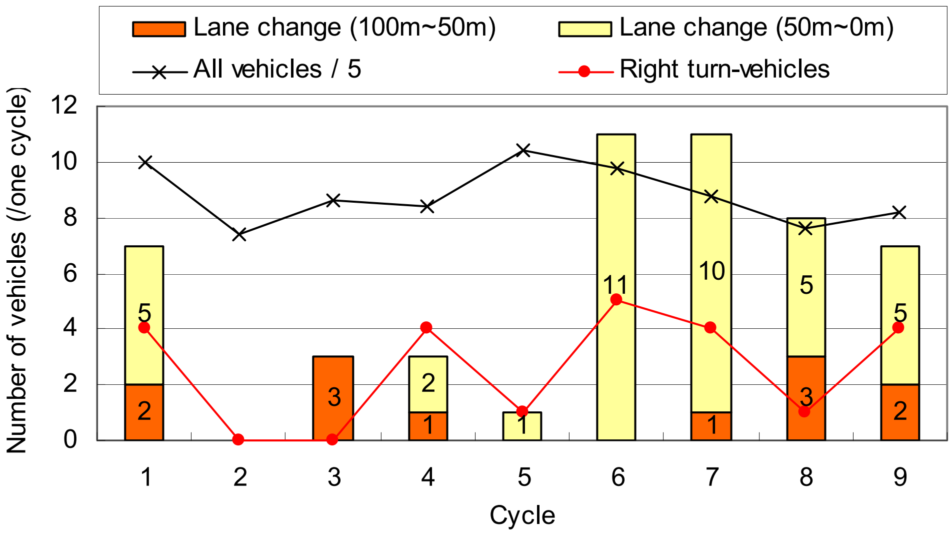

Figure 10 – Number of lane-changing vehicles, all vehicles, and right-turn vehicles for each observed cycle

4.4 Comparing Traffic Flows with/without Right-turn Vehicles

Observed cycles include both the cycles with right-turn vehicles and the cycles without right-turn vehicles. In this section, thus, the characteristics of traffic flows in the two kinds of cycles will be compared. Note that cycle 5 is included in the cycles without right-turn vehicles in spite of the existence of right-turn vehicle because it did not affect the group of vehicles in the cycle.

Figure 11 and Figure 12 show the average speeds in respective observed sections on the cruising lane and that on the overtaking lane. These figures are for the cycles with and without right-turn vehicles, respectively. These figures indicate that the average speeds tend to slow down as coming closer to the targeted intersection. These are the effect of the queue around the intersection made by red light. Figure 11 also indicates that the average speed on the cruising lane is not so much slow even around the targeted intersection whereas the average speed on the overtaking lane is largely slow around the targeted intersection due to the effect of the vehicles waiting for right turn chance. Therefore, it will be dangerous when the vehicles on the overtaking lane, which have temporarily been slowed down in order to follow the right-turn vehicles, move to the cruising lane.

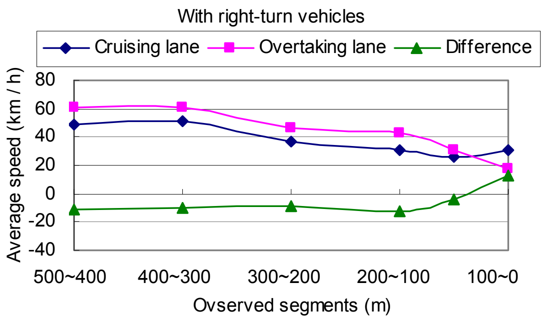

Figure 11 – Transition of average speed in each observed segment by lane (with right-turn vehicles)

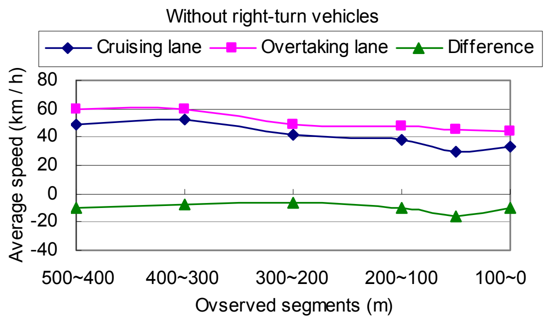

Figure 12 – Transition of average speed in each observed segment by lane (without right-turn vehicles)

Figure 13 and Figure 14 show the transition of the number of straight-through vehicles on the cruising lane and those on the overtaking lane. These figures are for the cycles with and without right-turn vehicles, respectively. Note that the left-turn vehicles and the right-turn vehicles are excluded here because both the vehicles will choose one lane independently of traffic condition in the downstream segment (i.e. the left-turn vehicles will choose the cruising lane and the right-turn vehicles will choose the overtaking lane respectively). Figure 13 (with right-turn vehicles) shows that some vehicles move from the overtaking lane to the cruising lane in the segment 50m ~ 0m behind the targeted intersection in order to pass the right-turn vehicles whereas Figure 14 (without right-turn vehicles) shows that there is not lane-changing in the same segment. As an interesting result, both Figure 13 and Figure 14 indicate the same aspect in the 5 segments, 500m ~ 50m behind the targeted intersection, where the ratio of vehicles on the cruising lane is gradually getting much. This fact implies that a certain number of straight-through vehicles change their running lane at the segment far before the targeted intersection based on their own experiences although they have no information on the presence or absence of the right-turn vehicles in the downstream segment. This implication corresponds to Kita et al. (2000)'s result in the segment behind the expressway merging section. However, a priori changing lane from the overtaking lane to the cruising lane at the segment far before the targeted intersection leads to excessive decrease of the efficiency when there are no right-turn vehicles in the downstream segment. It is suggested that, therefore, providing the information on the presence or absence of the right-turn vehicles in the downstream segment will contribute to not only the increase of the safety but also repression of the excessive decrease of the efficiency.

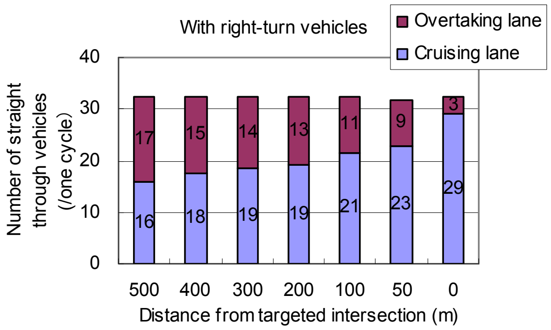

Figure 13 – Transition of the number of straight-through vehicles on each lane (with right-turn vehicles)

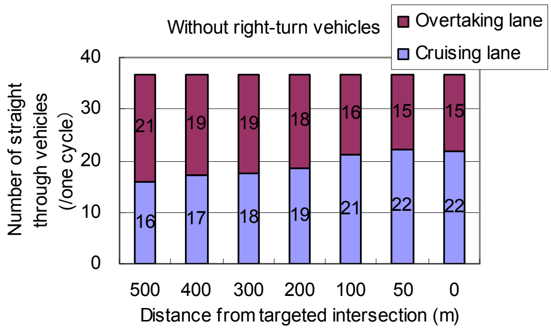

Figure 14 – Transition of the number of straight-through vehicles on each lane (without right-turn vehicles)

5. ESTIMATION OF THE LANE CHOICE BEHAVIOR MODEL

5.1 Assumption of the Lane Choice Behavior

In this section, the assumption of how a driver chooses his or her running lane will be expressed.

Supposing a case that a driver of a straight-through vehicle chooses the cruising lane, the driver will not incur the delay caused by the vehicles waiting for right turn chance and will not need the risky lane change in order to pass them. Thus, the driver has a merit in terms of both safety and convenience without possibility of crashing into the vehicles waiting for right turn chance. But, the driver also has a demerit in convenience with less smoother driving than the overtaking lane by the effects of the slow vehicles or left-turn vehicles.

Supposing a case that the driver chooses the overtaking lane, on the other hand, the driver has a merit in convenience with smoother driving than the cruising lane. But, the driver also has a demerit in terms of both safety and convenience with possibility of crashing into the vehicles waiting for right turn chance.

It is assumed in this paper that, therefore, a driver chooses the lane which has the highest evaluated total benefit by considering the trade-off between safety and convenience. Based on this assumption, the lane choice behavior model will be formulated in next section.

5.2 Formulation of the Lane Choice Behavior model

The lane choice behavior is defined as the discrete choice behavior that a driver chooses either the cruising lane or the overtaking lane under certain conditions. In this paper, thus, a disaggregate binomial logit model is applied to the lane choice behavior model. Namely, the utility of each lane corresponds to the evaluated total benefit mentioned above. Specifically, the choice probability of the cruising lane at the section (l) for driver n is formulated as follows:

$$P_{C,n}^{(l)} = \frac{1}{1+e^{-\left(V_{C,n}^{(l)}-V_{O,n}^{(l)}\right)}} = \frac{1}{1+e^{-\Delta V_n^{(l)}}} \quad (1)$$

$$\Delta V_n^{(l)} = a_0 + \sum_k a_k \cdot x_{nk}^{(l)} \quad (2)$$

where $x_{nk}^{(l)}$ are explanatory variables and a_0, a_k are parameters. The explanatory variables included in the model are shown in Figure 15 and expressed as follows:

1. $\delta_{C,n}^{(l-1)}$: a dummy variable that takes value 1 if driver n has chosen the cruising lane at the section ($l-1$), otherwise 0, this variable is included because the lane choice behavior may strongly depend on chosen lane at the predecessor section;
2. $d^{(l)}$: the distance between the section (l) and the targeted intersection, this variable is included because the margin to change from overtaking lane to the cruising lane in order to pass the vehicles waiting for right turn chance may decrease as the distance from the targeted intersection becomes shorter;
3. and $\Delta S_n^{(l-1,l)}$: the difference of average speed between the cruising lane and the overtaking lane in the segment ($l-1, l$) for driver n (average speed on the cruising lane – that on the overtaking lane), this variable is included because drivers may tend to wish to drive more smoothly.

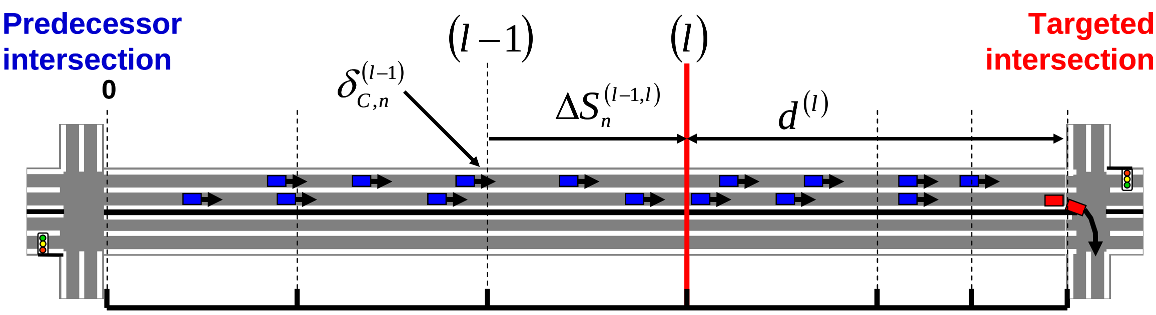

Figure 15 – Explanatory variables included in the lane choice behavior model

5.3 Results of Estimating the Lane Choice Behavior Model

Table 4 shows the result of estimating the parameters of the lane choice behavior model by using the data collected in Chapter 4. Since only straight-through vehicles are included in the data due to the reason mentioned in Chapter 4, the number of cases is a product of the number of straight-through vehicles and that of sections.

The parameter of $\delta_{C,n}^{(l-1)}$ is significantly positive value. Namely, the choice probability of the cruising lane is high if the driver has chosen the cruising lane at the predecessor section. This result indicates that a driver who has chosen the cruising lane once is less likely to choose the overtaking lane after that.

The parameter of $d^{(l)}$ is significantly negative value. Namely, the choice probability of the cruising lane will be higher as the distance from the targeted intersection becomes shorter.

This result implies that although drivers who are at the segment far before the targeted intersection have bigger margin to change from overtaking lane to the cruising lane until the intersection, the margin felt by the drivers is getting smaller as the distance from the intersection becomes shorter. Thus, $d^{(l)}$ may be called "the margin distance to change to the cruising lane". This result also indicates that drivers choose lane by considering traffic environment conditions not only just around the drivers but also in the far downstream segment.

The parameter of $\Delta S_n^{(l-1,l)}$ is significantly positive value. Namely, the choice probability of the cruising lane will be higher as the average speed on the cruising lane becomes relatively-faster. This result indicates that drivers wish to drive on smoother lane.

Table 4 – Result of estimating parameters

Explanatory variable	Sample mean	Estimated parameter	(t-value)
Constant		–1.11	(–7.01)
Dummy variable of choosing the cruising lane at the predecessor section: $\delta_{C,n}^{(l-1)}$	0.52	6.14	(23.2)
Distance from the targeted intersection: $d^{(l)}$	133.3	–0.0019	(–2.39)
Difference of average speed between the cruising lane and the overtaking lane: $\Delta S_n^{(l-1,l)}$	–7.27	0.078	(6.63)
Hit ratio		0.94	
ρ^2		0.71	
Number of cases		1850	

5.4 Results of Estimating the Lane Choice Behavior Model by Vehicle Type

Between standard-sized vehicles and heavy vehicles, there are the differences in conditions such as driving performance, field of front vision, severity of accidental damage and others. Since the characteristics of driving behavior between the two types of vehicles, the lane choice models are also estimated for respective types of vehicles. Table 5 shows the result by the vehicle type, where the parameter of $d^{(l)}$ with heavy vehicles is not significant, and the parameter of constant with heavy vehicles is larger than that with standard-sized vehicles. This fact suggests that heavy vehicles have fewer recognition of the possibility of the presence of the right-turn vehicles in the downstream segment than standard-sized vehicles. The reason may come from the facts that heavy vehicles are able to perceive the vehicles waiting for right turn chance earlier than standard-sized vehicles because of the wide vision, or that most drivers of the heavy vehicles are the professional drivers and are hence more likely to take risky behavior than standard-sized vehicles. In order to confirm this implication, it is needed to conduct more surveys and analyses using questionnaires or anything. In this paper, however, it can be concluded that there is obvious differences of lane choice behavior between standard-sized vehicles and heavy vehicles.

Table 5 – Result of estimating parameters by vehicle type

Explanatory variable	Estimated parameter (t-value)			
	Standard-sized vehicles		Heavy vehicles	
Constant	–0.94	(–4.69)	–1.38	(–5.26)
$\delta_{C,n}^{(l-1)}$	5.96	(18.5)	6.49	(13.7)
$d^{(l)}$	–0.0026	(–2.58)	–0.00068	(–0.52)
$\Delta S_n^{(l-1,l)}$	0.069	(4.71)	0.094	(4.71)
Hit ratio	0.94		0.94	
ρ^2	0.71		0.72	
Number of cases	1142		708	

6. CONCLUSIONS

In this paper, as a fundamental study for evaluating traffic safety measures at the signalized intersections without right-turn-only lane on two-lane (per one direction with left-hand traffic) arterial roads, simple traffic flow count and video observation were conducted. Firstly, by using the data from traffic flow count at 19 signalized intersections, it was confirmed that frequency of lane changes is significantly correlated with the number of rear-end accidents. Secondly, by using data from video observation conducted in the long segment between selected signalized intersection and predecessor signalized intersection, it was found that a certain number of straight-through vehicles change their running lane at the segment far before the targeted intersection, based on their own experiences, although they have no information on the presence or absence of the right-turn vehicles in the downstream segment.

By estimating the lane choice behavior model, it was confirmed that the straight-through vehicles choose their lane by evaluating safety and convenience based on “the difference of average speed of each lane”, “the possibility of the presence of the right-turn vehicles in the downstream segment”, and “margin distance to change to the cruising lane”. It is also found that there are differences of lane choice behavior between standard-sized vehicles and heavy vehicles: namely, heavy vehicles are more likely to take risky behavior than standard-sized vehicles.

In further studies, it will be needed to generate the lane choice model with the observation at more signalized intersections, particularly, intersections where the frequencies of right-turn vehicles largely differ each other.

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