Modeling the Maneuver of Left-turning Vehicles Considering the Interaction with Pedestrians at Signalized Intersections

Nan Kang[1], Wael Alhajyaseen[2], Axel Wolfermann[3], Miho Asano[4] and Hideki Nakamura[5]

[1]Student Member of JSCE, M. Eng., Doctor Course Student, Dept. of Civil Eng., Nagoya University
(Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan)
E-mail:kang@genv.nagoya-u.ac.jp
[2]Member of JSCE, Dr. Eng., Postdoctoral Research Fellow, Dept. of Civil Eng., Nagoya University
(Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan)
E-mail:wael@genv.nagoya-u.ac.jp
[3]Non-Member of JSCE, Dr. -Ing., German Aerospace Center
(Rutherfordstraße 2, 12489 Berlin, Germany)
E-mail: axel.wolfermann@dlr.de
[4]Member of JSCE, Dr. Eng., Assistant Professor, Dept. of Civil Eng., Nagoya University
(Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan)
E-mail:asano@genv.nagoya-u.ac.jp
[5]Member of JSCE, Dr. Eng., Professor, Dept. of Civil Eng., Nagoya University
(Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan)
E-mail:nakamura@genv.nagoya-u.ac.jp

Traffic collisions involving pedestrians compose a significant part of total traffic collisions at intersections. The threat to pedestrian safety comes mainly from the interaction with turning vehicles, especially left-turners (left-hand traffic). This paper aims at developing a methodology to reproduce the speed profile of left-turning vehicles considering the interaction with pedestrians. A mechanism is developed to represent the decision making of left turners inside signalized intersections. The developed methodology mainly consists of ideal speed profile model and empirical gap acceptance model. It is concluded that the speed profiles of left-turners are significantly affected by the characteristics of pedestrian movement.

Key Words: *signalized intersection, conflict, left-turning vehicle, pedestrian, speed profile*

1. INTRODUCTION

Intersections are key components of road network. Their operations significantly affect the performance of the whole road system. Intersections are places where various movements from different directions cross each other. Pedestrian-vehicle conflicts are considered as one of the most common safety problems at signalized intersections since pedestrians are less protected than drivers. According to the report by Japan National Police Agency[1)] in 2010, one-third of the total traffic accident fatalities are pedestrians at signalized and unsignaized crosswalks. There are many reasons behind such kind of collisions for instance visibility, intersection geometry layout, traffic signal control policy and behavior of turning vehicles and pedestrians.

The safety performance of intersection is usually evaluated through two approaches: before-after studies and traffic conflict analysis. Before-after studies are accident records which are in most of the cases difficult to get. On the other hand traffic conflict analysis uses empirical data to evaluate the safety conditions. This approach requires collecting sufficient empirical data which is usually not available and costly as well. Simulation tools are often used in practice as an alternative analysis tool to overcome the limitations of existing procedures, further they are more flexible and promising. However existing simulation software is basically aimed for the mobility assessment thus it simplifies traffic flow inside intersections to an extent that safety assessment is not reliable. The models described in this paper are one part of a comprehensive research project aimed at developing a simulation tool for the safety assessment of signalized intersections.

Generally, the main threat to pedestrian safety comes from the interaction with turning vehicles. Since left turners (left-hand traffic) have more frequent conflicts with pedestrians in common signal phasing plans, thus this study concentrates on their maneuver and aims at developing a methodology to represent the decision making mechanism of left-turners considering intersection geometry and crossing pedestrians.

This paper starts with introduction and literature review followed by the methodology where a procedure to represent the maneuver of left-turners considering pedestrians is proposed. The proposed methodology contains several sub-models which are modeled empirically. A comprehensive discussion and verification for the proposed mechanism is presented. Finally, this paper ends up with conclusions and future works.

2. LITERATURE REVIEW

In order to analyze the interaction between pedestrians and vehicles, it is important to gain better insight into both the behavior of pedestrians and vehicles. Since this research focuses on the left-turners behavior, thus the literature review will concentrate on their maneuver and decision making.

Ishikawa[2] analyzed the characteristics of vehicle-pedestrian crashes by classifying the crashes as "fatal crash", "seriously injured" and "minor injured". They concluded that drivers' behavior is the main influencing factor in pedestrian-vehicle crashes. Furthermore, they found that crashes were strongly related to the drivers' misjudgment on pedestrian activities such as misjudging the distance between vehicles and pedestrians or ignoring the effect of visibility limitation. Therefore for safety analysis, it is essential to focus not only on the average trend of drivers' decision making but also on their variation.

The maneuver and decision making of left-turners can be represented as a combination of driver lag/gap acceptance and yielding behavior (Schroeder and Rouphail[3]). However it is very difficult to distinguish between these two components, since both of them are binary choice models. Thus this approach in modeling the decision making of left-turners cannot reproduce the whole vehicle maneuver (path and speed profile) which is essential for the safety assessment.

The likelihood of drivers to yield (give priority to pedestrians) in a macroscopic sense has been linked empirically to vehicle speeds and the relative positioning of the pedestrians to the curb (Geruschat and Hassan[4]). In an attempt to analyze yielding patterns more closely, Sun et al.[5] applied logit and probit models to observed data from an unsignalized pedestrian crossing site. The authors used a discrete choice modelling approach and found that drivers are more likely to yield to a group of pedestrians, and drivers of heavy vehicles were more likely to yield than drivers of passenger cars.

Traditionally, literature on vehicle gap acceptance has used a constant value of critical gap CG that is calibrated for local conditions (Troutbeck and Brilon[6]). The critical gap CG is defined as the time between consecutive vehicles on the major road at which a vehicle waiting at the minor approach is equally likely to accept the gap or reject it. The critical gap can differ depending on the type of movement and the type of vehicle. These types of gap acceptance models are referred to as deterministic models which assume that drivers are homogeneous and consistent. In a homogeneous driver population, all drivers have the same critical gap while the consistency assumption means that the same gap acceptance situation will always cause a driver to make the same (consistent) decision. In reality such assumptions are not realistic, thus a probabilistic approach for gap acceptance is necessary to consider the variation in driver decisions.

Beside the deterministic gap acceptance models, probabilistic ones are also discussed in the literature. In a report by Federal Highway Administration (FHWA)[7] in 2004 regarding the Next Generation Micro-simulation (NGSIM) research effort, probabilistic gap acceptance models are proposed. Following a Probit or Logit approach, these models assume a mean CG with a random variance term depending on the specific coefficients defined for a driver and/or situation. This means that these models consider the inconsistency or randomness in the critical gap value only. Such assumption is sufficient for capacity analysis but not for the safety assessment. Following the same approach, Logit gap acceptance models have been proposed by Ben-Akiva and Lerman[8], and Cassidy et al.[9], and Probit models were suggested by Mahmassani et al.[10] and Madanat et al.[11]. Conceptually, these models could represent inconsistent driver behavior and a heterogeneous population by using random distributions. Generally, the main objective of existing lag/gap acceptance models is to analyze driver decision when facing pedestrian without reproducing the whole vehicle maneuver which is the goal of this paper.

3. METHODOLOGY

Left turning traffic commonly has to yield to crossing pedestrians in order to avoid colliding with them. It is assumed that if there is no pedestrians are present, the driver will follow an ideal speed profile which is defined for turning traffic not influenced by signals, other vehicles, or pedestrians. On the contrary, the drivers approaching the crosswalk have to observe pedestrians and react according to the assessment of the situation. Such kind of reaction to pedestrians is represented by the acceptance of the lags/gaps between crossing pedestrians.

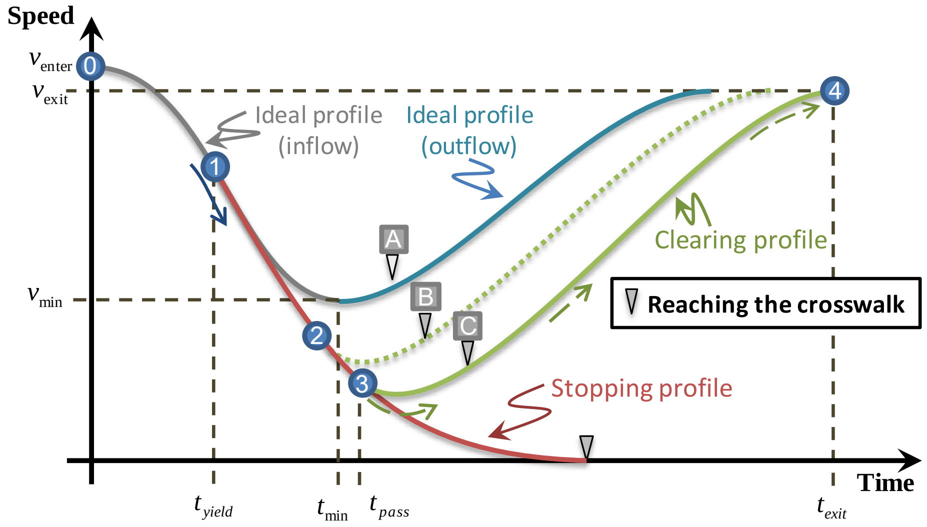


Fig.1 Ideal speed profile, stopping profile, and clearing profile in reaction to pedestrians

In this paper, the reaction time is defined as the time when the driver starts reacting to pedestrian. For simplification it is assumed that the driver reacts to pedestrians once he/she passed the stop line of the entering approach (point 1). From this time on, the driver will scan the crosswalk and assess the gaps in the pedestrian stream. This decision making process is updated every 0.5sec. Moreover car-following behavior and reaction to signals are not considered in this paper. Three categories of speed profiles will be proposed in the decision-making process: "ideal speed profile", "clearing profile" and "stopping profile" as shown in **Fig.1**. Stopping profile is the speed profile by which vehicles can safely stop in front of the crosswalk. Clearing profile is the speed profile of the vehicles which chose to slow down due to the existence of pedestrians without a complete stop before the crosswalk. The drivers are assumed to choose the speed profile during turning as the reaction to pedestrians by anticipating the situation when they reach the crosswalk. The decision-making process is proposed as following.

The driver starts approaching to the intersection at point 0. At point 1 he/she scans the crossing pedestrians for the first time. If this driver follows the ideal speed profile, he/she will reach the crosswalk at time A. Therefore, he/she checks whether the lag/gap between pedestrians is acceptable by predicting pedestrian positions at time A. In this example, he/she decides to yield as the lag/gap is not suitable at time A.

During each time step he/she re-assesses the situation at the crosswalk. This re-assessment is highlighted for point 2. Since the driver wants to safely pass as early as possible, he/she assumes the clearing profile for the acceleration and predicts his/her arrival at the crosswalk to be at B. If he/she rejects the lag/gap available at this time, then he/she follows the stopping profile further. At point 3 the assessment leads to the acceptance of the lag/gap at C. As the driver found the lag/gap was acceptable this time, he/she switches to the clearing profile (t_{pass}), passes the crosswalk at C, accelerates to the desired exiting speed and finishes the turning maneuver at point 4.

The available lag/gap is checked using the lag/gap acceptance model. The driver assumes constant walking speed of the pedestrians.

Mainly two sub-models are required to reproduce the maneuver of left-turners; speed profile model and lag/gap acceptance model. However to develop these models, empirical data is necessary.

4. DATA COLLECTION AND PROCESSING

(1) Study sites

Video data was collected at several signalized intersections in Japan with different geometric characteristics, pedestrian and vehicle traffic conditions. Twelve approaches at eight signalized intersections are videotaped. All these sites are in Nagoya City except Aoyama intersection which is located in Tokyo. The definitions of the parameters related to intersection geometry are illustrated in **Fig.2** while **Table 1** presents the geometric characteristics of observed sites. The observation sites have significantly different geometric layouts such as curb radii, intersection corner angles and crosswalk setback distances. The survey dates and the average demands of left-turning vehicles, pedestrians and cyclists are presented in **Table 2**. At all observed sites pedestrians share the same signal phase with the through and left turning traffic of the same direction. Thus left-turning traffic has frequent conflicts with cross-

Table 1 Geometry characteristics of observation sites

Intersection	Left-turners entering approach	Corner Radius R_c (m)	Intersection corner angle θ (deg)	Downstream crosswalk: setback distance D_s (m)	Downstream crosswalk: Width - Length (m)	No of exit (outflow) lanes N_o
Suemori-dori	East	9.7	88.3	6.5	7.3- 18.5	2
	West	19.0	65.4	16.5	7.7- 18.0	2
	North	17.0	117.0	11.0	6.7- 25.4	3
Taiko-dori	West	17.0	94.1	16.0	6.7- 15.4	3
Horita	East	14.0	94.1	5.0	5.3- 37.5	3
	South	12.0	88.3	14.0	5.9- 20.8	3
Hiroji-dori	West	5.0	95.0	2.0	6.7- 9.4	2
Imaike	North	16.0	79.0	16.5	4.7- 20.3	3
Nishiosu	East	17.0	76.9	17.0	4.6-35.1	3
Kawana	East	21.0	106	22.5	6.2- 14.8	2
Aoyama	North	11.5	92.0	7.6	6.2- 25.5	4
	West	12.0	90.0	7.8	6.3- 18.0	3

ing pedestrians depending on the demand and the arrival pattern of each of them.

(2) Trajectory tracking

Left-turning vehicle trajectories as well as pedestrians including the positions and timings are extracted from video data by using video image processing system *TrafficAnalyzer* (Suzuki and Nakamura[12)]). The positions were extracted every 0.5 second and then their video coordinates are converted to the global coordinates by projective transformation. Due to the position of video recording, the point where the right-front wheel is touching the ground is the reference observation point for all left-turning vehicles. By considering the dimension of each turning vehicle, the observed trajectories based on the right-front wheel are transformed to the trajectories which correspond to the center-front of the vehicles. The transformed trajectories are smoothened by Kalman smoothing method. Regarding pedestrians, the center point of their body is considered as the reference observation point.

5. DATA ANALYSIS AND MODELING

(1) Ideal speed profile

After processing the trajectory data, the observed speed and acceleration profiles can be estimated. The speed and acceleration profiles of unimpeded turning vehicles (not influenced by pedestrian, other turning vehicle and signal control) follow a regular shape as shown in **Fig.3** a) and b). The speed profile of the unimpeded vehicle is called ideal speed profile. The

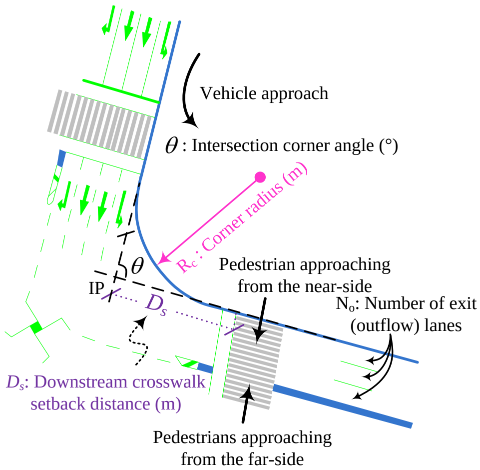


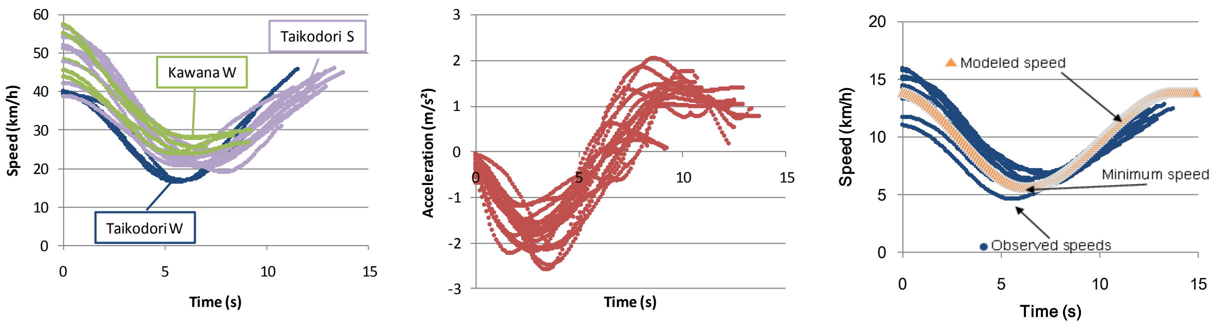
Fig.2 Definition of the parameters related to intersection layout

observed ideal speed profiles showed that they basically had the similar shape however at different study sites the position of the speed profiles changed. The difference indicates an influence of the geometry on the speed profile. Possible influences are, for instance, the curve radius, the angle between approach and exit, the presence of a raised median and its position.

Therefore the speed profile can be divided into two parts, an inflow part and an outflow part, and their boundary defined by the moment the vehicle reaches the minimum speed. It is assumed that the shape of the speed profile is determined by the geometry of the intersection and the position of the shape is determined by the minimum speed V_{min}. Since from the observed data, both of these two parts of the speed profile approximately follows a cubic shape, the speed profile is modeled assuming a polynomial of

Table 2 Traffic conditions at observation sites

Intersection	Left-turners entering approach	Survey time	Average left-turning vehicle demand (*veh/hr*)		Average pedestrian/Cyclist demand (*ped.* or *cyc./hr*)			
			PC	HV	Near-side		Far-side	
					Ped.	Cyc.	Ped.	Cyc.
Suemori-dori	East	9:00-12:00	312	6	28	60	28	28
	West		204	8	16	32	64	52
	North		304	9	8	32	12	36
Taiko-dori	West	7:30-10:30	84	–	73	20	50	19
Horita	East	9:00-10:30	84	11	20	64	172	76
	South		28	5	20	36	128	36
Hiroji-dori	West	7:00-10:00	156	10	81	146	60	90
Imaike	North	13:00-15:00	146	7	145	120	104	81
Nishiosu	East	9:00-12:00	344	14	20	76	20	44
Kawana	East	7:30-10:30	208	2	20	52	108	28
Aoyama	North	9:00-12:00	124	6	50	32	29	11
	West		142	11	60	75	20	15



a) Speed profiles b) Acceleration profiles c) Illustration of speed profile

Fig.3 Observed Speed and acceleration profiles of left-turning vehicles

third degree as shown in Equation (1). Moreover first derivative of this function can also reflect the shape of acceleration shape.

$$v = c_1 t^3 + c_2 t^2 + c_3 t + c_4 \qquad (1)$$

The congruency of the shapes of observed and model speed profile following Equation (1) is highlighted in **Fig.3**c).

Table 3 shows the constraints for the two parts of the ideal speed profile (inflow and outflow) and the parameters/coefficients empirically modeled. "in" denominates the constraints at the beginning of the profile, while "out" denominates the constraints at the ending of the profile. The equation of the inflow ideal speed profile model has the following unknown parameters; $c_{1,in}$, $c_{2,in}$, $c_{3,in}$, $c_{4,in}$, t_{min} and v_{min} (as shown in **Fig.4**). This equation can be solved by using the constraints at the beginning of the inflow speed profile curve (v_{enter} and a_{enter}), the constraints at the end of the inflow speed profile curve (v_{min} and a_{min}), and the empirical models for c_1 and v_{min}. The same procedure is followed in solving the equation of the outflow ideal speed profile.

Table 3 Constraints and modeled parameters for the ideal speed profile of left-turning vehicles

Parameters	Ideal profile (inflow)	Ideal profile (outflow)
Speed *v* (in)	v_{enter}	v_{min}
Speed *v* (out)	(v_{min})	v_{exit}
Acceleration *a* (in)	a_{enter}	0
Acceleration *a* (out)	0	a_{exit}
Time *t* (out)	(t_{min})	$(t_{exit} - t_{min})$
Degree of freedom/constraints	5/3	5/4
Modeled parameter	v_{min}, $c_{1,in}$	$c_{1,out}$

The speed function can also be applied to other situations (stopping, accelerating after a stop etc.), which will lead to different constraints. The constraints and coefficients are illustrated in **Fig.4**.

In addition to v_{min} and c_1, the position of the speed profile relative to the path, and thus to the intersec-

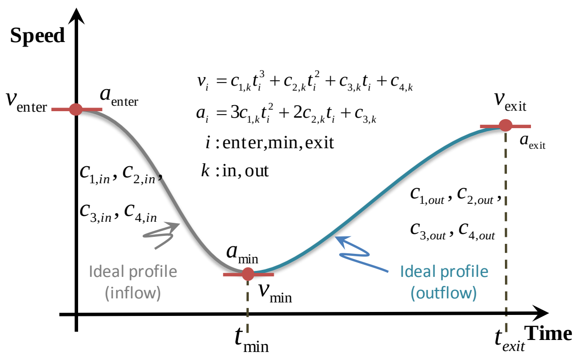


Fig.4 Constraints and coefficients of the speed profile

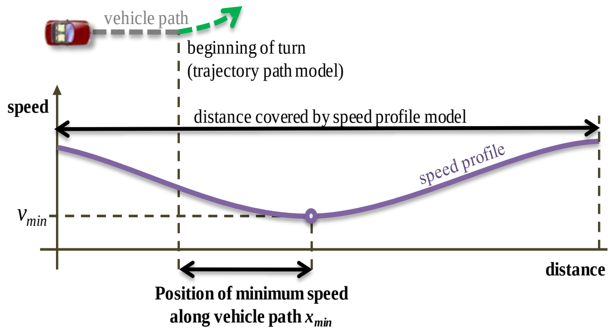


Fig.5 Illustration of the position of the minimum speed, x_{min}, relative to the vehicle path

Table 4 Models of the speed profile coefficients

Distribution	Parameters	$c_{1,in}$ $X\sim\Gamma(\alpha,\beta)$* Estimates(sig.)	$-c_{1,out}$ $X\sim\Gamma(\alpha,\beta)$* Estimates(sig.)	v_{min} N(μ, σ)** Estimates(sig.)	x_{min} N(μ, σ)** Estimates(sig.)
α(μ)	Const	2.09(0.02)	1.41(0.01)	-0.301(0.496)	1.42(0.52)
	Entering speed (m/s)	0.256(0.00)	-	0.0908(0.00)	-
	Approach angle (deg)	-0.0155(0.05)	-	0.0387(0.00)	0.0896(0.00)
	Corner radius (m)	-	-	0.0607(0.00)	0.5868(0.00)
	Lateral exit distance (m)	-0.168(0.01)	0.0630(0.03)	0.233(0.00)	0.577(0.00)
	Heavy vehicle dummy (HV:1, PC:0)	-	-	-0.496(0.11)	
β(σ)	Const	0.0573(0.00)	0.0822(0.00)	0.665(0.00)	0.135(0.83)
	Entering speed (m/s)	-0.001729(0.00)	-	-	
	Corner radius (m)	-0.00109(0.00)	-	-	0.144(0.00)
	Lateral exit distance (m)	0.00219(0.02)	-	0.0419(0.02)	0.336(0.00)
	Exiting speed (m/s)	-	-0.00396(0.00)	-	-
Sample Size		199	187	199	199

* Gamma Distribution. ** Normal Distribution.

tion is modeled. Because the length of the total turning maneuver varies remarkably, but the location where the minimum speed is reached is in the first place related to the curve and therefore limited in variation, the latter position, x_{min}, was chosen to fix the location of the speed profile as shown in **Fig.5**. The position where the minimum speed is reached is closely related to the path that the driver follows. Therefore, the speed profile is related to the path, and thus, indirectly to the intersection geometry on which the path depends.

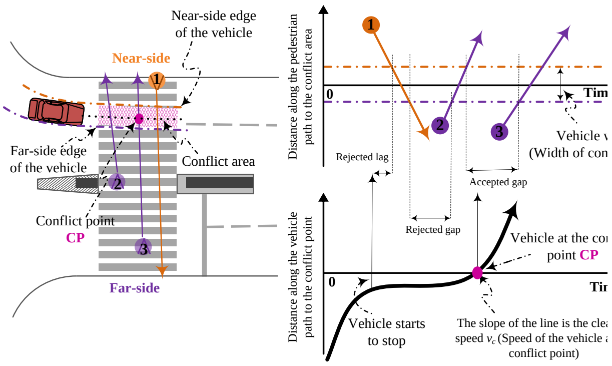
Therefore in order to model the ideal speed profile considering the geometry of the intersection and approaching speed regression analysis was used to estimate the influence of different factors on the characteristics of the speed function. After conducting regression analysis, **Table 4** shows the models of the speed function coefficients ($c_{1,in}$ and $c_{1,out}$) for the ideal speed profile, the min speed v_{min} and latter position x_{min}. The empirical analysis showed that $c_{1,in}$ and $c_{1,out}$ are influenced by the entering speed of the vehicle, the intersection corner angle angle θ, the corner radius of the curb R_c, and the lateral distance of the vehicle from the curb in the exit δ. They follow a distribution with positive skew, hence a Gamma Distribution was chosen for the model.

The results for the minimum speed v_{min} and the position of the minimum speed x_{min} are given in **Table 4**. The Normal distribution was chosen to model them.

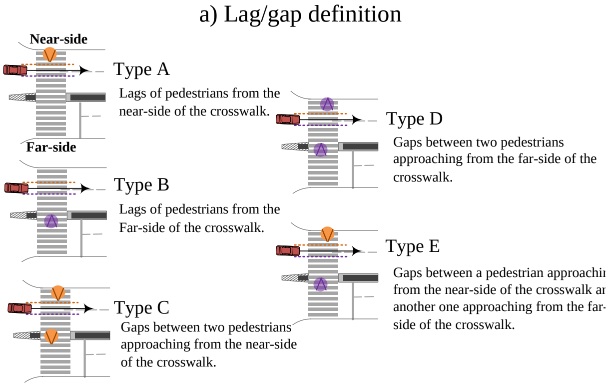
(2) Lag/gap acceptance model

In the vehicle-pedestrian conflicts, the available lags/gaps for drivers are defined as follows; a lag is defined as the time needed for a pedestrian to reach the conflict area while a gap is defined as the time difference between two successive pedestrians taken from the moment the first pedestrian has cleared the conflict area till the second one reaches the conflict area as shown in **Fig.6**a). The conflict area is defined as the area occupied by the body of the vehicle on the crosswalk. Since all potential conflicts with pedestrians occur within the conflict area, the calculated lags/gaps are precisely defined by excluding the time used by pedestrians to clear the area occupied by the vehicle body as shown in **Fig.6**a)

For the purpose of this study, it is assumed that pedestrian movements have their origin at either the



a) Lag/gap definition



b) Assumed types of lags/gaps

Fig.6 Pedestrian origin-destination and gap/lag definition considering vehicle size

near-side or the far-side of the crosswalk with reference to conflicting vehicles as shown in **Fig.6**a). To investigate the effect of pedestrian direction of movement on driver behavior near the crosswalks, lags/gaps are classified into five different types as shown in **Fig.6**b).

Gaps/lags of the same type are categorized into several pins. The gap/lag acceptance probability for category *i* of Type *j* is calculated according to Equation (2).

$$P(x)_{i,j} = \frac{No.\ Accepted\ gaps/lags}{Total\ No.\ of\ obsereved\ gaps/lags} \quad (2)$$

$$(in\ category\ i\ of\ Type\ j)$$

As mentioned in literature review, Logistic and Probit regression models are the most common approaches to represent the gap acceptance behavior. However mathematically, in Logit and Probit models, a positive value of acceptance probability can be estimated at zero second lag/gap. This is one of the main disadvantages of using this type of models. To overcome this problem, Cumulative Weibull distribution as shown in Equation (3) is used in this study to fit the observed lag/gap acceptance probability distributions. Weibull distribution is one of the widely used lifetime distributions in reliability engineering (Abernethy[13)]).

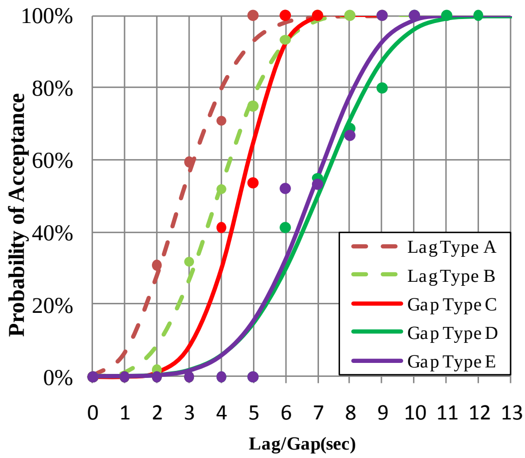


Fig.7 Observed gaps/lags acceptance probabilities and fitted Cumulative Weibull distribution

Table 5 Parameters of fitted gap acceptance distributions using Cumulative Weibull distribution

Lag/Gap Type	Parameters α (scale) & β (shape)	Estimates	Standard Error	Adjusted R^2	Sample size (A*/R**)	
A	α	3.269	0.169	0.977	64	80
	β	2.292	0.391			
B	α	4.405	0.092	0.993	131	137
	β	3.076	0.269			
C	α	4.966	0.183	0.959	40	92
	β	4.884	1.147			
D	α	7.615	0.200	0.968	53	165
	β	4.388	0.667			
E	α	7.346	0.268	0.934	52	124
	β	4.683	1.057			

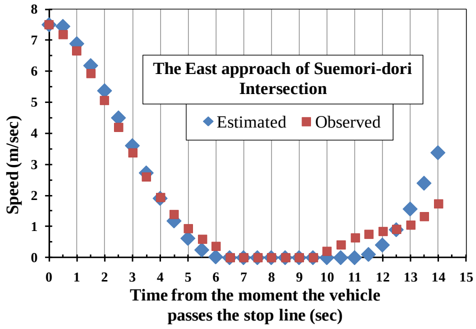
* Accepted lags/gaps. ** Rejected lags/gaps

$$P(x) = 1 - e^{-(x/\alpha)^{\beta}} \quad (3)$$

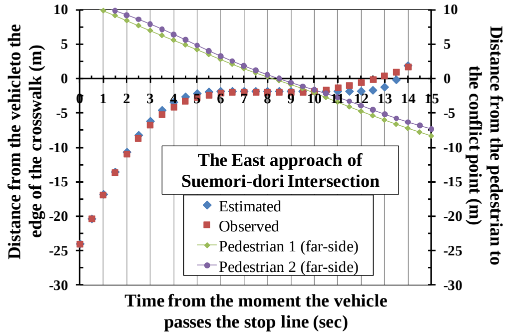
Where $P(x)$ is the acceptance probability of lag/gap x; α and β are Weibull distribution parameters.

The acceptance probability plots for the defined five types of lags/gaps are shown in **Fig.7**. Cumulative Weibull distribution is used to fit these plots. The parameters of the fitted distributions and the numbers of samples are listed in **Table 5**.

As shown in **Fig.7**, lags/gaps between pedestrians from the near-side (Type A and C) have significantly higher acceptance probability compared to the corresponding lags/gaps from the far-side (Type B and D) which can be referred to the lower visibility of the pedestrians coming from the near-side.

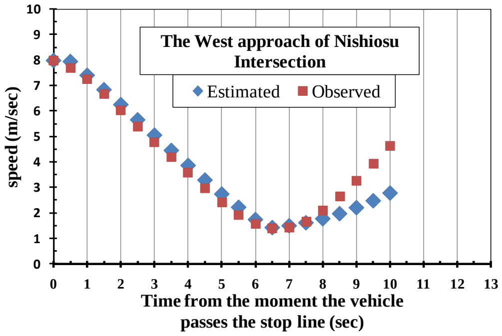


a) Time-speed diagram

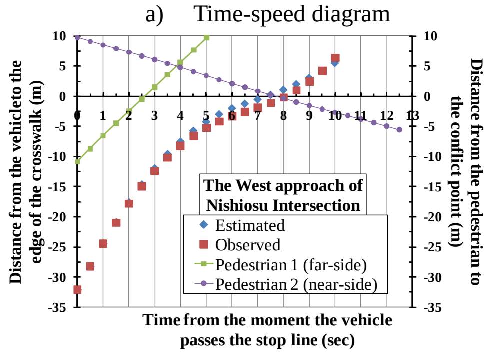


b) Time-space diagram

Fig.8 Estimated and observed maneuver profiles of a yielding left-turning vehicle



a) Time-speed diagram



b) Time-space diagram

Fig.9 Estimated and observed maneuver profiles of a stopping left-turning vehicle

5. VERIFICATIONS

By using the proposed mechanism and the developed empirical models which require intersection geometric characteristics and pedestrian trajectory information, the speed profile of left-turners can be generated. **Fig.8** and **Fig.9** compare the observed and estimated speed profiles of a sample of two left turning vehicles at the East approach of Suemori-dori Intersection and the west approach of Nishi-osu Intersection, respectively.

Fig.8 shows that the estimated speed profiles of the stopping left-turning vehicle matched well the observed one. However in the part of the speed profile after clearing the downstream crosswalk, there are significant differences between the observed and estimated profiles. This difference is referred to the randomness in driver behavior which is reflected in the developed empirical models. However in the first half of the speed profile, before reaching the crosswalk, lag/gap acceptance behavior plays the main role in defining the shape of the speed profile.

Fig.9 shows the same comparison shown in **Fig.8** but for a yielding vehicle which did not stop because of pedestrians. The observed time difference between the pedestrian and the vehicle passing the conflict point is 0.9 sec, which indicates that the probability of having a collision is very high. It is clear that the estimated profile matches the observed one. However in the part of the speed profile after clearing the downstream crosswalk, significant differences exist

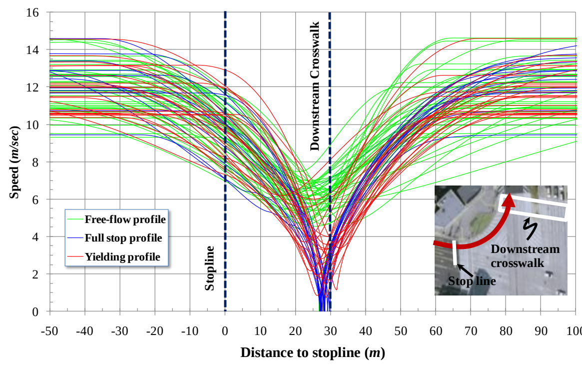


Fig.10 Simulated speed profiles of left-turning vehicles at the west approach of Nishi-osu Intersection

between the observed and estimated profiles, which are similar to the differences shown in **Fig.8**a). Generally, it is concluded that the proposed decision-making process can reasonably reproduce the maneuver of left-turners considering intersection geometry and pedestrians.

For a better insight, how the proposed mechanism can reproduce the maneuver of left-turners, **Fig.10** is presented. A Monte Carlo simulation is conducted to generate the speed profiles of left-turners from the West approach of Nishi-osu Intersection by using the geometric information (**Table 1**) and the observed demands of left-turning vehicles and pedestrians (**Table 2**). **Fig.10** presents the generated speed profiles of free-flow, stopping and yielding left-turning vehicles. Stopping and yielding profiles reflect the interaction with pedestrians. Generally, generated speed profiles are reasonable. Furthermore, it is ob-

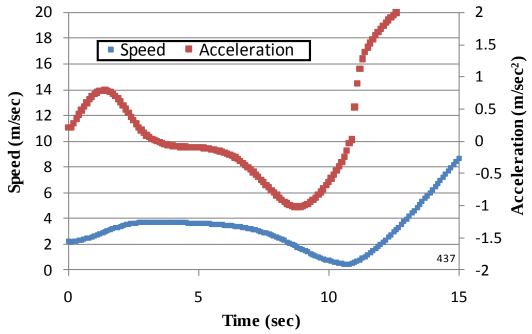


Fig.11 Example of an observed irregular speed profile

vious that the developed methodology can capture the stochastic behavior of left-turners. It is important to note that when analyzing observed speed profiles it can be seen that under certain circumstances driver behavior follows more complex patterns and irregular forms such as the profile shown in **Fig.11**. These more complex patterns have to be analyzed and incorporated into future versions of the decision making mechanism.

6. CONCLUSIONS AND FUTURE WORKS

Through this study a methodology to reproduce the speed profile of left-turners considering intersection geometry and the interaction with pedestrians was proposed. The developed methodology is a unique mechanism that can provide a realistic representation of left-turning vehicles' maneuver and it considers the stochastic characteristics of driver behavior as well. The proposed procedure depends mainly on two components; the ideal speed profile model and the lag/gap acceptance model. The two models were developed empirically considering intersection geometry and pedestrian dynamics.

The verification of the proposed methodology showed that estimated profiles matches well the observed ones. However in data analysis, under specific conditions drivers' behavior follows complex patterns and irregular forms. Such profiles have to be analyzed and incorporated into updated versions of the proposed methodology.

The proposed model was developed as part of an extensive project dealing with the safety assessment of signalized intersections. Further models, for instance, for the path of vehicles, the speed of pedestrians on the crosswalk, have been developed. Incorporated into simulations they will lead to a realistic representation of turning vehicles' speeds which can be used for the safety assessments of signalized intersections.

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