DEVELOPMENT OF MICRO TRAFFIC FLOW SIMULATION SYSTEM AT MERGING SECTION FOR EVALUATION OF ADVENCED AND CRUISE-ASSIST HIGHWAY SYSTEMS (AHS)

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走行支援システム評価を目的とした
高速道路ランプ合流部のミクロ交通流シミュレーションシステムの開発

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本研究では，首都高速道路ランプ合流部を対象に，安全かつ円滑な合流を支援する走行支援システムの効果分析を行うための従来にないミクロ交通流シミュレーションシステムを開発した．はじめに，走行支援システムを導入した場合の運転挙動の意思決定プロセスについてモデルの定式化を行った．次に，いくつかの合流部において簡易な走行支援システムの模擬実走実験を行い，モデルのパラメータを取得した．最後に，モデルを統合して効果分析システムとしてのシミュレーションシステムを開発し，走行支援システムの導入が合流部の安全性や円滑性の向上に与える影響を分析した．

1. INTRODUCTION

The merging sections of Tokyo Metropolitan Expressway (MEX) have various problems in terms of safety, efficiency and comfortability. To solve such problems was considered to be unable because of highly traffic flow rate and the difficulty in improving their geometric condition due to urban space constraint.

Recently, the R&D of Advanced and cruise-assist Highway System (AHS) is ongoing to realize safer and more efficient condition at road sections, but conceptualization of the AHS for merging section (AHS-M) was put off because of lack of methodologies and tools of traffic flow analysis, in addition that AHS-M didn't meet the government's policy for reducing number of accidents. However, to achieve efficient management at merging section is now required by AHS-M, this indicates the need of development of methodologies and tools of traffic flow analysis there.

Several micro simulation models[1),2)] to analyze merging behavior were developed previously. However, all models have several week points that their algorithm cannot reflect the effect of AHS-M, determination of merging behaviors are simplified and give-way behavior cannot be expressed which is considered to be very important to achieve safer and more efficient flow there. In addition, the experiment of driving behavior under the installation of AHS-M at merging section should be done in order to obtain more exact model parameters.

The objective of this study is to examine the effect of AHS-M in actual merging sections to confirm the behavioral principle and to construct a micro simulation system at merging section. Finally, the effect of several AHS-Ms is analyzed.

2. FOCUSED AHS-M SYSTEM

In this study, 3 types of AHS system mentioned below are considered.

ASV is a vehicle with the advanced technologies for safety driving, such as warning system, adaptive cruise control system and so on. The difference between ASV and AHS mentioned below is that there is no intra vehicle and infrastructure

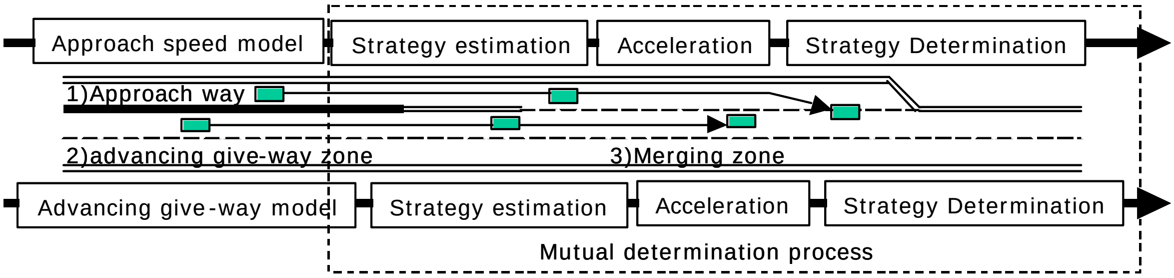

Fig. 1 Driver's behavioral process

communication for ASV. In this study, simple adaptive cruise control system is only reflected for both merging vehicle and vehicle on main lane.

AHS-i gives traffic flow information to both merging vehicle and vehicle in main lane before entering into merging section to help drivers determine their behavior. The system can detect the infra-related data such as traffic flow and incident (e.g. accident, obstruction). In this study, three AHS-i types are considered, information for existence, information for position and behavior guidance.

AHS-c assists a part of driving operations in addition to AHS-i functions. At merging section, we can assume that merging vehicle is controlled to enter into optimum gap, and vehicle on main lane

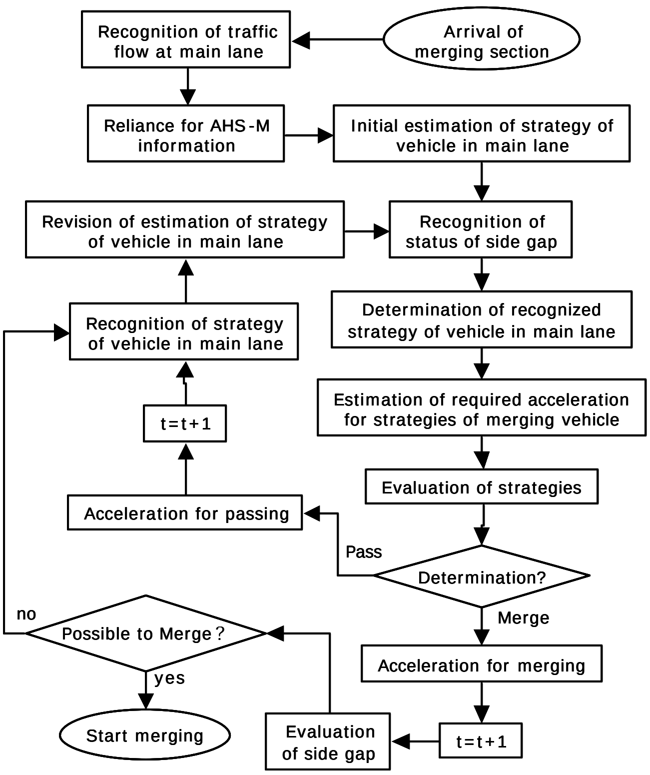

Fig. 2 Flow of gap choice and acceleration model for merging vehicle

change their lane (Give-way) or reduce their speed in advance. In this study, AHS-c vehicle is programmed like mentioned above.

3. FORMULATION OF BEHAVIOR AT MERGING SECTION

(1)Model Framing

Fig. 1 shows the summary of time series driver's behavioral process in this study. Merging section is divided into 3 zones, merging approach way, advancing give-way zone and merging zone. The most distinctive functions of this model are advancing give-way model and approach way model that were never considered in previous models, and consideration of mutual behavior expression between merging vehicle and related vehicle in main lane.

(2)Principle of Driver's behavior

We assume that the three kind of driver's utilities at merging section, utility for safety, comfortability, and efficiency. We assume that safety is expressed by time to collision (TTC) or gap length, comfortability is explained by change of acceleration and efficiency is explained by gap from expected time to pass merging section. Actually, Each driver is considered to have different weights among 3 utilities depending on humanity, age, vehicle performance and so on.

(3) Model Explanation (Gap Choice and Acceleration Model for Merging Vehicle)

The gap choice and acceleration model for merging vehicle is only formulated below because of page constraint. **Fig. 2** shows the flow of the model.

We assume that driver chooses his/her strategy of 2 alternatives (merge or pass) at every scanning time Δt (=reaction time set to be 1.0 second) in merging zone by considering these utilities. The utilities of merge and pass at time t are determined by expected utility as follows,

$$s(t) = \max(EU_m(t), EU_p(t)) \quad (1)$$

$$EU_m(t) = P_g(t)U_{mg}(t) + P_n(t)U_{mn}(t) + P_c(t)U_{mc}(t) \quad (2)$$

$$EU_p(t) = P_g(t)U_{pg}(t) + P_n(t)U_{pn}(t) + P_c(t)U_{pc}(t) \quad (3)$$

where s is chosen strategy, strategic suffix for merging vehicle m is "merge", p is "pass", strategic suffix for vehicle in main lane g is "give", n is "not give" and c is "give-way". Each utility $U_{ij}(t)$ (i is strategy of merging vehicle, j is strategy of vehicle in main lane) is expressed by traffic conditions such as gap length, required acceleration for strategy i and length to the end of merging section at time t. Required acceleration for strategy i is expressed by driving speed and TTC or gap length to obstacle and surrounding vehicles. $P_j(t)$ is estimated probability of strategy j at time t. It is assumed that every driver has initial recognized probability of strategy j and this is affected by information given and strategy j at time $(t-\Delta t)$. If strategy "merge" is chosen, driver judge whether he/she can enter side gap or not by considering some traffic parameters of side gap.

4. EXPERIMENT OF AHS-M AT MEX

(1)Focused Sites and Experimental Devices

Higashi-ikebukuro (Line 5) and Katsushima (Line 1) onramp were selected on several days of late September, 2000. Two experimental vehicles which can obtain not only data for vehicle movement such as speed, acceleration and headway, but also driving operation data such as handling and breaking in every 0.1 second. Several video cameras were set to record the movement of surrounding vehicles. In addition, traffic flow at focused merging section was recorded by several video cameras from roof of building. The investigator at roof of building detects traffic flow status by specific algorithms and gives information to driver in experimental vehicles using hands-free cellular phone previously when vehicle passes the merging section. 3 types of information, information for existence, information for position and behavior guidance were examined.

(2)Effect of AHS-M on Merging Behavior

Fig. 3 shows the example of the difference of time series relationship between driving operation and vehicle behavior for merging vehicle with and without AHS-M in the case of independent merging at Higashi-ikebukuro. Time passed 0(s) means the time when merging vehicle can watch the main lane first. Information was give at time –0.9(s) as driver can watch the main lane. This indicates that information helps driver brake slower, and after that, accelerate smoother.

(3)Effect of AHS-M on Entering Speed

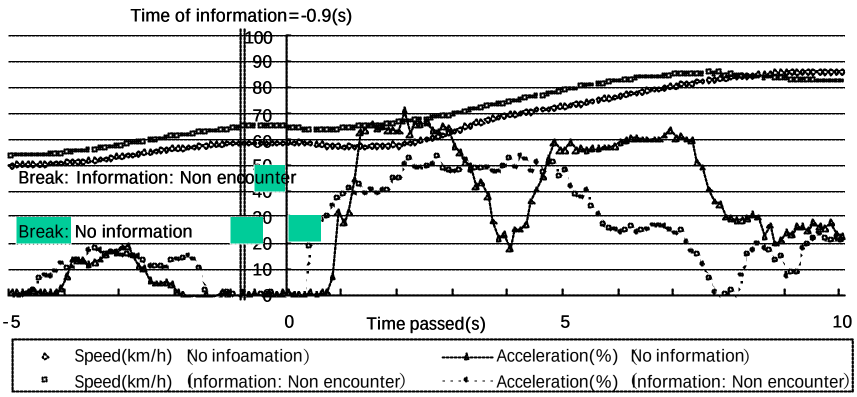

Fig.3 Time series of driving operation and vehicle behavior

Table 1 Entering speed with and without information

	Higier speed		Lower speed	
	Without	With	Without	With
Average(km/h)	54.9	58.0	44.9	44.2
Standard Deviation(km/h)	4.73	2.77	2.49	3.50

	Higier Reliance		Lower Reliance	
	Without	With	Without	With
Average(km/h)	52.1	54.4	50.3	51.3
Standard Deviation(km/h)	6.70	7.09	4.14	4.11

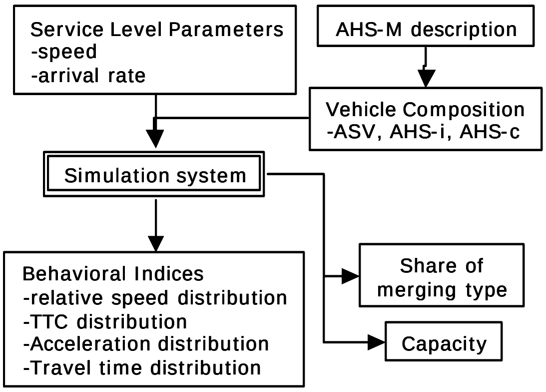

Fig.4 Input and output data of the system

Table 1 shows the average and standard deviation of entering speed with and without information. This indicates that information possibly increase entering speed for drivers who drive faster and rely information that helps smoother and safety merging.

5. DEVELOPMENT OF SIMULATION SYSTEM AT MERGING SECTION

(1)System Building and Model Estimation

Simulation system is described by Microsoft Visual C++ programming software. **Fig.4** shows the system flow. Some proposed models are estimated using tracked traffic flow data from video image though Karman smoothing algorithm. Some models that cannot obtain parameters are analyzed by sensitivity analysis.

(2)System Verification

Most important verification index is considered to be the share of merging type. **Table 2** shows the actual (3.5 hours observation) and simulated share of merging type. 2 simulation runs for 30 minutes at Higashi-ikebukuro ramp are conducted for verification. Better verification result is obtained for merging vehicle than vehicle in main lane. This indicated that driver of vehicle in main lane tends to feel more uncomfortable and unsafe to pass through merging section without lane changing in this system.

(3)Validation of AHS-M-i System

Table 3 shows the average travel time and number of conflicts of 30 minutes simulation at Higashi-ikebukuro ramp with different composition of AHS-i vehicle. This result indicates that comfortability and efficiency of merging section become higher when composition of AHS-i vehicle is lower and higher, whereas medium level of composition results in less comfortable and less efficient operation.

Table 2 Verification of merging type

Vehicle	Final strategy	Actual	Run 1	Run 2
Merging	Merge	0.550	0.561	0.646
	Pass	0.450	0.439	0.354
Main Lane	Non	0.551	0.439	0.354
	Give	0.095	0.041	0.089
	Give-way	0.355	0.490	0.557

Table 3 Effect of AHS-M-i system

Average travel time of merging section (sec.)

Lane	Composition of AHS-i vehicle				
	0%	10%	30%	50%	100%
Merging	2.47	2.43	3.02	2.48	2.52
Outer	2.25	2.09	2.81	2.06	2.06
Inner	2.19	2.38	2.55	2.08	2.05

Average number of conflict

Lane	Composition of AHS-i vehicle				
	0%	10%	30%	50%	100%
Merging	3.84	5.92	6.18	6.13	5.07
Outer	0.91	1.10	1.31	0.40	0.32
Inner	1.40	1.25	2.82	1.22	0.99

6. CONCLUSION

In this study, the behavioral process flow at merging section under AHS-M system is formulated, and micro simulation system is developed for evaluation of AHS-M. A field trial of AHS-M is conducted to confirm proposed process flow and to obtain some model parameters. Using this system, AHS-M-i system is verified and validated at Higashi-ikebukuro ramp.

For further study, successive data will be important to verify this model.

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