# Suggestions and Verification for Management of ITS for Driving Behaviour Decision Process Models

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***ABSTRACT*****:** In the present study, a driving behaviour decision process model, in which psychological phenomena and physical phenomena from hazard perception to vehicle behaviour are integrated, is suggested. Feasibility of the driving behaviour decision process was determined in simulation by evaluating a web questionnaire. From those results, it was verified that there was a change induced by the introduction of ITS for each set process in the driving behaviour decision process. In addition, from observing the chain process, it was possible to logically identify what to improve on.

***KEYWORDS***: ITS, evaluation, AHS, logic model

## 1. INTRODUCTION

### 1.1 Objective

At a road section named 'Unimproved Section', as it does not comply with the Road Construction Ordinance, there are dangerous places with adverse road conditions such as narrow, sudden curves and steep slopes. In regards to the sudden curves, which are one type of 'Unimproved Section', there are close to 470 such places in our country's urban expressway, and the accident rate there is 2.6 times more than average, said to cause an annual loss of 10 billion. As such it is evident that there is a need to address the safety measures regarding unfavorable road conditions such as sudden curves.

One such safety countermeasure is an ITS that uses the AHS forward obstacle information service to notify drivers of stationary vehicles ahead of sudden curves. In comparison to other, drastic countermeasures such as a construction to avoid sudden curves, there are big expectations regarding ITS as a realistic safety measure which does not require significant construction or a huge budget.

However, software like ITS aims to solve the problem without altering the existing road configuration, e.g. by removing problem-evoked sudden curves and other road structures. Therefore, depending on how drivers use the ITS, there is a difference in what extent the problem can be resolved. Thus the ITS safety countermeasures should include adequate operation to obtain the significant effect of ITS at the time of its introduction.

Generally, it is known that the driver is driving safely depending on the continuity of their cognition, judgment and application. Namely, in order to maximize the ITS results there is a need for an operation model taking into consideration the driving behaviour decision process from cognition to application.

In regards to the ITS effect evaluation, in Iida and Ikeda et al.'s lab test, it was made evident that the information provided by ITS leads to ensuring inter-vehicular distance and suppressing acceleration and deceleration in times of heavy fog. According to Okamura and Matsumoto et al. through their case studies on the introduction and verification of ITS in various locations, it was reported that the vehicle behaviour, traffic behaviour and driver's psychological element was affected by ITS. In the model using decay time effect of short term memory discussed by Kusubashi et al., the effect on alertness from information provided through vehicle mounted devices using ITS etc. was greater when compared to existing traffic safety facilities, On the other hand, according to Kusubashi et al. the effect of ITS appeared to have a limitation on the expressway while merging on highway interchanges, and as a result it can be imagined that ITS is not valid on all occasions. In this way, up until now, safety measures of the ITS have been reported to be effective (or non-effective) on the driving process from driver cognition to judgment. However, there has been close to no discussion on the management process of ITS such as how to evaluate the ITS.

In this study an ITS evaluation system modelled on the integrated driving behaviour decision processes from cognition to operation was constructed and its feasibility is verified. An evaluation process based on the driving behaviour decision processes will be performed in simulaion and from there, how ITS can be evaluated by this process will be examined.

## 1.2 Hypothesis

The evaluation system suggests how much the ITS has enhanced safety and what measures should be taken to make it even safer. In order to do this, it is necessary a structure to observe drivers' vehicle and driving behaviour, including "cognition", "judgement" "action", possibly leading to accidents, and to investigate how to improve them. In the present study, by treating the driving behaviour decision processes as a series of process model, to what extent the ITS is effective or how to improve it will be examined.

Renge presented the dangerous behaviour (Risk Taking) mechanism. It was concluded that, in a situation where humans are taking risks, personality, driving attitude, traffic situation and/or driving tasks may be a facilitation factor. The attention that is put towards traffic conditions by traffic participants is hazard perception, and when important hazards are noticed, risk perception is made. By activating risk perception, risk taking (decision making towards risks) occurs; it is the action being executed. In addition, risk perception is affected by driver's self-evaluation skills (e.g. the car became safe), and risk taking by the risk effect (e.g. the feeling that there is a need to hurry). In this study, drivers' driving behaviour decision process will be examined by referring to the mechanism of risk taking.

Figure 1 displays a driver's driving behaviour decision process model and the positioning of ITS. The driving behaviour decision process can be defined as follows:

"Surrounding traffic conditions" such as vehicles that move forward, "road structures" such as sudden curves and AHS and "driver's running state" that the driver's feeling from flowing scenery, make drivers perceive hazards such as "a sudden curve may be ahead" and "you may be speeding" and then risks such as "may not be able to turn". Accordingly they further evaluate the degree of risk.

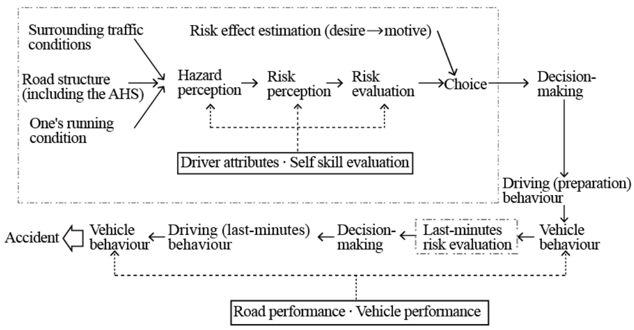


Figure1 Driving behaviour decision process

At these times, processes from hazard perception to risk evaluation will be affected by the driver's age, driving experience and self-recognition of driving skills. For example, a young driver with little/superficial driving experience may underestimate hazards and risks. Also, in addition to the results of the risk evaluation, based on “risk effect evaluations” such as “in a hurry”, decision making and then choices are made and executed from among the several options of driving behaviours “stepping on the break” and “holding the wheel properly” and actions e.g. “stepping on the break”. Therefore, depending on the driving behaviour, the vehicle being driven reaches a state such as “running speed of 40km” or “deceleration of $3m/s^2$”.

At this point, the “slipperiness of the road” and “break effectiveness” and such vehicle and road performance affect the behaviour. With the repetition of the processes that starts from hazard perception while actually entering a curve, either accidents happen or they are able to pass through the curve. Observing the results when there were accidents, the effects of the ITS are discussable. On the other hand, regarding to what extent ITS and other measures should be taken to prevent accidents, there is no choice but to analyze with the chain process from hazard perception to vehicle behaviour to make this clear. The present study aims to verify how to evaluate ITS against road traffic problems by using a driving behaviour decision process thought in this way.

In addition, how the driving behaviour decision process will be made should be important. In order to evaluate to what degree the ITS solved the problems by the driving behaviour decision process, there is a need for evaluators to understand what kind of processes ITS affects. In other words, there is a need to set the relationship between the functions that the ITS provides and the driving behaviour decision process in advance.

Therefore, the driving behaviour decision process is created using an evaluation process from logic models previously suggested by the authors. With this method, since the problem and its possible cause are visualized as a problem structure, drivers' awareness of hazards and risks that drivers recognize can be shown as a structure. In addition, because the corresponding relationship between problem construction and the functions that ITS provides can be simultaneously adjusted, it is easy to adjust the corresponding relationship between awareness construction against risks and ITS.

Here is an explanation, using the logic model evaluation process, about the procedure regarding the creation of the driving behaviour decision process: From the driver interview investigations, the structure of awareness composed from the cause and effect relationship of risk perception and hazard perception against the objected transport problems (hereafter risk awareness structure) is established. In addition, a logic model is constructed identifying the corresponding relationship between the risk awareness structure and the functions that ITS provides, and the intended logic model for the ITS is identified.

Next, development of the hazard and risk perception from the logic model into the driving behaviour decision process, together with arrangement of the relationship between driving behaviour and risk perception from the earlier interview investigation, are used to determine the driving behaviour decision process.

When actually evaluating ITS, an evaluation indication is organized for each of the processes. Regarding before and after implementation of the proposed measures, evaluation indexes are observed, and the driving behaviour decision process is analyzed. Depending on this, what degree of the results of the proposed measures is obtained, if each of the driving behaviour decision processes is going well, and which processes should be improved can be considered.

## 2. Experimental Method

To start with, the construction experiment of the driving behaviour decision process model will be implemented by using case studies of places where ITS was actually introduced. Next, an evaluation system's feasibility will be studied through a simulation of a series of evaluation processes including extracting the indicators, indicator measurements and analysis using the driving behaviour decision process.

To be more precise, after constructing a driving behaviour decision process while traveling the Sangubashi curve according to the AHS, a web questionnaire will be used to gather pseudo data and the effectiveness of the AHS towards the driving behaviour decision process will be analyzed. In addition, by reviewing the improvement results using this data, the feasibility of the suggested evaluation system will be somewhat verified.

### 2.1 Case study

The present study's case study is the Sangubashi curve on upbound metropolitan expressway number 4, Shinjuku line (hereafter Sangubashi curve). The Sangubashi curve is a sudden curve that has been accident prone, and where AHS's information service for prevention of collisions with forward obstacles (hereafter AHS) has been introduced. When the AHS image censor detects things such as tails of congestion and stationary vehicles due to accidents etc., a verbal and written (characters and figures) warning is displayed on the in-vehicle device responding to 3 media VICS and ITS spot [1], and the information is displayed on a variable indication board (information board) on the roadside[2] .

With the introduction of the AHS, the main reasons for the accidents are primarily collision with roadside walls/ overturn and secondary rear end collision, perhaps due to speeding. For rear end collision-related accidents that occurred, the main reason was thought to be the unclearness of the road ahead of the sudden curve.

### 2.2 The construction experiment for the driving behaviour decision process

At Sangubashi curve, the driver's hazard perception, risk perception and driving behaviour is examined. Table 1 shows interview investigation, which leads to the risk awareness structure. An interview was conducted with drivers who actually drive around Sangubashi curve. The subjects talked about their impressions and experiences whilst driving, and the survey is carried regarding the surrounding traffic conditions, road structure, driving conditions, attributes, hazard perception, risk perception and driving behaviour.

Using these results, information from each individual's investigation regarding surrounding traffic conditions, road structure, attributes, hazard perception and risk perception, was used to create a risk awareness structure, and after this these were integrated to create one risk awareness structure. In addition to this, the corresponding relationship between the risk awareness structure and the AHS enforced at Sangubashi curve was arranged, and a logic model regarding AHS for the risk structure awareness was constructed. Lastly, after specifying the risk awareness structure that ITS targets from the logic model, it was developed as the driving behaviour decision process, and the evaluation index for the AHS was sought for each process.

Table 1 - Summary of the interview investigation

| Item | Content |
|---|---|
| Period | $22^{nd}$ – $24^{th}$ October 2012 |
| Method | Individual interview survey |
| Location | Kochi University of Technology, Tokyo Classroom |
| Participants | 11 road monitors on the Metropolitan expressway (Males aged in their 20s to 70s) |

**2.3 The evaluation experiment using the driving behaviour decision process**

Using the travel video from the virtual reality data (VR data) of the Sangubashi curve, a pseudo environment will be constructed, with AHS (in this case, the information board and the audio assist in the car that notifies that there is a stationary vehicle ahead of the curve) being both implemented and not implemented, and whether or not it is possible to evaluate according to web travel video will be verified.

This study was performed as a web questionnaire survey using VR data, as the evaluation process is pseudo-conducted over a short time period. For this, psychological data hazard and risk perception, driving behaviour choice, and part of driving behaviour observable from a web questionnaire was gathered. Physical driving data such as actual incident data and vehicle behaviour and other part of driving behaviour was out of scope of observation.

The subjects watched the travel videos online, and the web questionnaire was used to measure a series of driving behaviour process, including things like hazard perception, risk perception, part of driving behaviour choice from the logic model. Table 2 is the summary of the questionnaire.

The main procedure regarding the questionnaire is as follows. After the notes and purposes of the questionnaire are explained, an online FLV format video will be played. At the time when you wish to slow down, click the brake button, and from that time the start point of deceleration is measured. In addition, whilst watching the travel video, an appropriate scale will be selected in a 6 level scale that will range from “very concerned” to “not concerned at all” regarding risk perception, hazard perception, driving behaviour choice etc., and from “seriously consider” to “not consider at all” for driving behaviour choice etc.

In addition, in order to compare the circumstances of the AHS being implemented and not implemented, the experimental group watched a video of the AHS being implemented and the control group watched a video of the AHS not being implemented. Table 3 shows the VR data conditions, and Table 4 shows the experimental group video image. In the control group, there is no audio assistance or and information board.

Table 2 - Summary of the questionnaire

| Item | Content |
|---|---|
| Period | 25th January 2013 |
| Method | Web questionnaire |
| Subjects | 500 drivers in the metropolitan area with driving experience in the metropolitan expressway within the past year |
| Questionnaire content | Measurement of the deceleration timing using the VR picture<br>Hazard perception<br>Risk perception<br>Driving behaviour choice<br>Normal driving behaviour<br>Operating experience |

Table 3 - conditions for the VR Data

| Item | | Specifications |
|---|---|---|
| Driving lane | | The first driving lane |
| Vehicle speed | | 80km/h |
| Driving mode | | There is a following car or an adjacent car |
| Information board | Display content | "Traffic ahead" "beware of rear-end collisions" |
| | Action | One step of two variables |
| Sound | | Beeping sound, traffic ahead, beware of rear-end collisions |

Table 4 - Picture of the VR data for the experimental group

| Number | 0 seconds | 4 seconds |
|---|---|---|
| Content | Image start | Sound insertion |
| Image |  |  |
| Number | 13 seconds | 16 seconds |
| Content | Information board | Image end |
| Image |  |  |

## 3. Results

### 3.1 Construction experiment of driving behaviour decision process

#### 3.1.1 Creation of the logic model for the AHS risk awareness structure

The black part of Figure 2 shows the risk awareness structure for the Sangubashi curve, as obtained from the interview survey. The risk awareness structure, based on the driving behaviour decision process model as examined previously, includes the following factors: drivers' perceived risks (characters enclosed by a square in the figure), hazards that are felt to be the cause of the risk (underlined characters) and the surrounding traffic conditions, road structure, and one's own state of mind and drivers' attributes perceived as the cause of hazards.

For example, when "there are expressway exits at the left and right side of the expressway", vehicles tend to "change lanes frequently". Since drivers want "to deter other cars from merging into their lane" the "distance between cars is small". When "the distance between cars is small", they feel the risk that "there may be a collision" at Sangubashi curve, because of the "stationary vehicle ahead of the sudden curve" hazard in addition to the hazard "unable to see ahead of the curve".

In this way, from looking at the risk awareness structure, the three risks felt by the driver are "may not be able to fully turn", "may collide with the adjacent car or wall fence" and "may have a rear-end collision". In addition, the risk "may not be able to fully turn" is related to the three hazards "slippery", "did not notice the sudden curve" and "excessive speed". Similarly, the risk "collision with adjacent car or fence" is related to the four hazards, "vehicle becoming closer", "vehicle with disordered behaviour", "fence is close", and "the road is narrow". It can be seen that the risk "may have a rear-end collision" is related to the four hazards, "unable to stop suddenly", "unable to see ahead of curve", "stationary vehicle ahead of the curve", and "the distance between vehicles is small".

Next, the implementation of the AHS and its functions at Sangubashi curve are examined. It can be imagined that drivers will be able to identify when a stationary vehicle exists ahead of a sudden curve, as the AHS will analyze the situation ahead and inform the driver in such a case. In addition, because of this, it can be imagined that the risk of a rear-end collision will be reduced, as drivers will be able to prepare to stop ahead of the curve, and leave a distance between vehicles. From this way of thinking, the AHS was defined to be equipped with four set functions, "stationary vehicle information function", "caution ahead function", "prepare to stop function" and "ensuring vehicular distance function".

In addition, by integrating the risk awareness structure and AHS's functions, an AHS's logic model was constructed in regards to the Sangubashi curve risk awareness structure, as Figure 2 clearly shows. In other words, AHS was defined to affect, in addition to the risk "may have a rear-end collision", the four hazards "unable to stop suddenly", "unable to see ahead of the curve", "stationary vehicle ahead of the sudden curve" and "distance between vehicles is small". Thus in regards to the traffic problems under consideration, by constructing the AHS's logic model, the risk awareness structure was able to be specifically clarified. In addition, from these results it was also shown that the AHS is not effective to solve all risks, but its effectiveness is limited to certain risks.

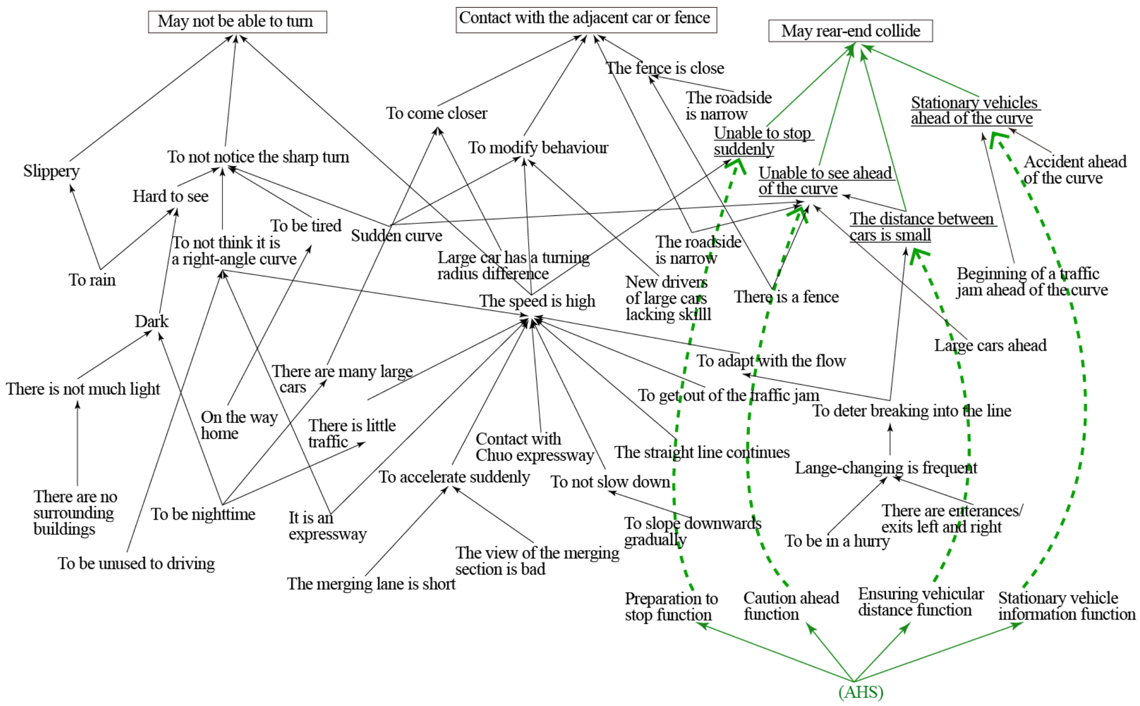


Figure 2 - The AHS logic model for the risk awareness structure of the Sangubashi curve

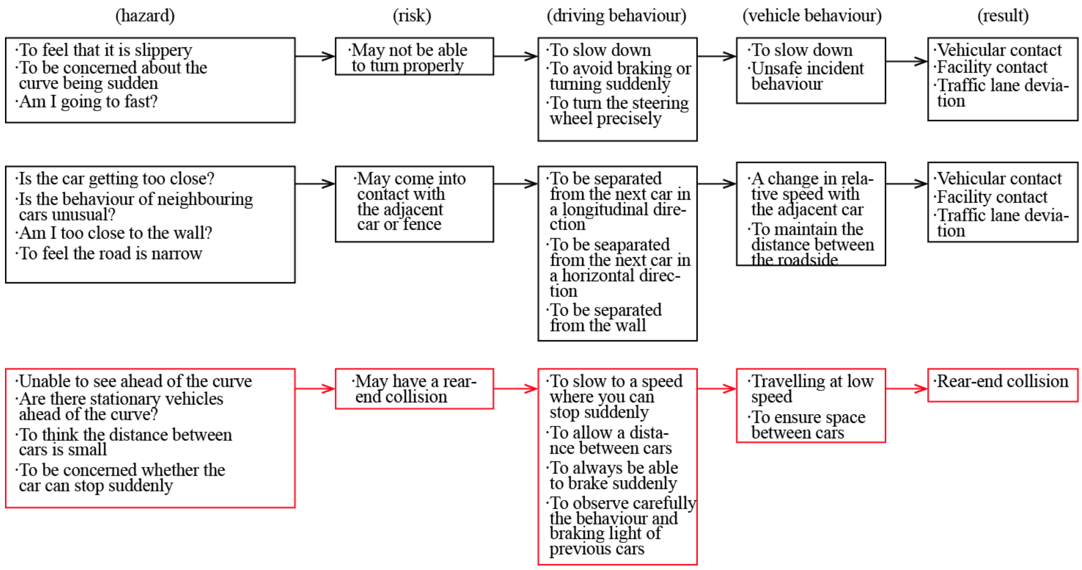


Figure 3 - The driving behaviour decision process for Sangubashi curve

### 3.1.2 The creation of the driving behaviour decision process

The driving behaviour decision process at Sangubashi curve was constructed from the relation between hazard and risk that was found in the logic model (Figure 3). The process from risk perception to result was connected in reference to the results of the interview survey.

The places displayed in red show the expression target of AHS effectiveness in regards to the driving behaviour decision process. Similar to the logic model showing the four functions of the AHS, it can be imagined that the four hazard perceptions “unable to stop suddenly”, “unable to see ahead of the curve”, “stationary vehicle ahead of the curve”, “distance between vehicles is small” are stimulated. These four hazard perceptions stimulate the “may have a rear-end collision” risk perception. Depending on this, drivers select behaviour such as “slowing to a speed where you can stop suddenly”, “increasing the distance between vehicles”, “preparing to brake at all times” “looking ahead carefully at behaviour or brake light of preceding vehicle” and then activate vehicle behaviour, namely, “driving slowly” and “leaving a distance between vehicles”. Depending on what kind of action is taken, whether or not “collision” occurs is determined.

In this way, by constructing a logic model in advance, the driving behaviour decision process that becomes the target for the AHS effectiveness was able to be expressed logically. In addition, the driving behaviour process shows the direct outcome of the AHS, as well as the indirect outcome that further influenced by the direct outcome. In other words, it can be thought that hazard and risk perception are directly affected by the AHS, however rear-end collisions etc. are indirect outcomes resulting from direct effects.

#### 3.1.3 Examining the effect indication based on the driving behaviour decision process

Table 5 shows that the indication and the observed object are examined and arranged from process to process based on the driving behaviour decision process. Furthermore, shaded part indicates the observed target in order to measure the AHS’s effect similarly to how Table 5 was examined. Regarding the observation index for the AHS effectiveness, psychological measures using questionnaire surveys were set as the observed target for the hazard perception process/risk perception process/driving behaviour choice process, which are psychological elements. As the observed target for the driving behaviour process, things related to deceleration behaviours such as deceleration start point, amount of brake used, and brake preparing point e.g. at which the foot is placed on the brake and amount of change in watching point involving cognitive behaviour ahead were set. Aside from this, as the observation index, things such as the variation in speed/acceleration and distance between cars were set for the vehicle behaviour process, as well as number of rear-end collisions for the result process. This way, it was possible to logically set many of the necessary measures necessary for the observation of AHS’s effect, based on the driving behaviour decision process.

### 3.2 Evaluation experiment using the driving behaviour decision process

#### 3.2.1 Comparisons of control groups and experimental groups

The results of web questionnaire are shown in Table 6. Two hundred fifteen control group and 202 experimental group subjects (who did not experience difficulties such as the travel video not streaming, the video stopping or not hearing sound) were examined. Moreover, for questions regarding the deceleration starting point, 115 subjects from the control group and 102 subjects from the experimental group were targeted after excluding the subjects not able to push the button at their desired time, or who did not need to reduce their speed.

In the hazard perception process, an average of 3.57 from the control group and 2.98 of the experimental group were “concerned about whether there was a stationary vehicle ahead of the curve”, a significant difference of 1%. For subjects “concerned whether a sudden brake would be possible at this speed” the average value for the control group was 3.57, while the experimental group value was 3.34, showing a significant difference of 5%. The average value of the experimental group was smaller. In other words, it can be said that hazard perception was stronger when the AHS was provided. On the other hand, in regards to “concerned about what was ahead of the curve” and “concerned about the small space between vehicles”, there was no particular change even when provided with the AHS.

In the risk perception process, the average value of the control group in terms of “concerned whether a rear-end collision would occur ahead of the curve" was 3.37, while the experimental group was 3.08 showing a significant difference of 5%, the experimental group's average once again being smaller. In other words, risk perception was stronger with the use of the AHS. In addition, even when other risk perceptions of the experimental group were compared, "concerned whether it is possible to fully turn ahead of the curve" was 2.95, "concerned about colliding with the adjacent fence or vehicle" was 3.41 and "concerned whether a rear-end collision would occur ahead of the curve" was 3.08 and had comparatively lower values, thus it can be said that risk perception is being prompted.

In the driving behaviour choice process, the average of the control group regarding "slowing to a speed where stopping is possible" was 2.99, and the experimental group was 2.74, a significant difference of 5%, therefore the average of the experimental group was smaller. In other words, in this case drivers provided with the AHS had stronger driving behaviour choice intention. On the other hand, regarding the other choices targeted for the AHS's expression, there was no particular difference even with the AHS. This is possibly because, even when the AHS was not utilized the average score was comparatively lower and subjects were thinking carefully about their driving regarding these choices. Moreover, 2.74 of "slowing to a speed where stopping is possible" is relatively lower compared with the average values of all of the driving behaviour choices in the experimental group, driving behaviour choice is said to be prompted.

In the driving behaviour process, the average time from the beginning of the video until the brake button was clicked was 12.94 seconds for the control group and 12.32 seconds for the experimental group, a difference of approximately 0.6 seconds. Calculating the distance, at a constant speed of 80km/h, the start point of pressing the brake was about 13 meters earlier for the experimental group; however there was no significant difference. Although the AHS was found to have an effect on the driving behaviour choice "to drop the speed to a stoppable speed", it did not affect the change in deceleration starting point. Instead it is thought that it affected how much the brake was pushed. Using things such as driving simulators, there is a need to compare driving behaviour by simultaneously observing the amount the brake is pressed, which could not be measured in this current study.

**3.2.2 Study into understanding and improvement of the ITS's effect**

From the analysis of results up until now, the AHS's effect and improvement study was executed in accordance with the driving behaviour decision process as follows: With the introduction of the AHS the driver's starting point for deceleration was 13m earlier than without, however the statistically significant difference has not yet been confirmed. Looking at the driver behaviour choice, AHS had an effect on the awareness structure regarding "slowing down to a stoppable speed", however, there is no relationship between this and putting forward the starting point for deceleration.

This time, there was a possibility that the resulting heightened awareness in "slowing to a stoppable speed" had an effect on the indexes the amount the brake is pushed and the change in velocity of the vehicle, which were measured in this study. Looking at risk and hazard perception, it can be seen that the introduction of the AHS stimulated the risk perception regarding "concerned whether rear-end collision would occur". In addition, for this reason it can be cited that the hazard perceptions "concerned whether or not there was a stationary vehicle ahead of the curve" and "concerned about whether a sudden stop can be made" were stimulated.

Firstly, compared to other indexes in the driving behaviour choice process, "slowing to a stoppable speed" has a high number. To further heighten the intention behind choices, there is a need to stimulate the risk perception, "concerned whether rear end collision would occur ahead of the curve". Compared to the other risk perceptions, "concerned whether rear end collision would occur ahead of the curve" is shown as almost the same value, however, as this perception is affected by rushing and the need to speed, it is imagined that this perception must be strengthened compared to other risk perceptions to further strengthen "slowing to a stoppable pace". In other words, it is thought that as drivers at Sangubashi are rushing, if there is not a strong risk perception, the intention behind the driving behaviour choice to "slow to a stoppable speed" will not be strengthened.

Hazard perception should also be the same. Hazard perceptions with the AHS are almost the same value as hazard perceptions' that have no relation to AHS, however, in order to further heighten the risk perception "slowing to a stoppable speed", there will be a need to further stimulate the AHS's hazard perception. For example, making information boards and voice content more detailed, intensify stimulation with warning sounds, increase the number of warning sounds, warning about inter-vehicle distance and such, can be considered.

Table 5 - Driving behaviour decision process and index

| **Driving behaviour decision process /** index | Observation target |
|---|---|
| **Hazard perception /** | |
| To feel that it is slippery | Psychological scale |
| To be concerned about the curve being sudden | 〃 |
| Is speed is too fast? | 〃 |
| Is a car getting closer? | 〃 |
| Is the behaviour of neighbouring cars unusual? | 〃 |
| Am I getting too close to the wall? | 〃 |
| To feel the road is narrow | 〃 |
| To not know what is ahead of the curve | 〃 |
| To know there is a stationary car ahead of the curve | 〃 |
| To feel the distance between cars is small | 〃 |
| To be concerned whether the car can stop suddenly | 〃 |
| **Risk perception /** | |
| May not be able to turn properly | 〃 |
| May collide with the adjacent car or fence | 〃 |
| May have a rear-end collision | 〃 |
| **Driving behaviour decision process /** | |
| To decelerate | 〃 |
| To avoid braking or turning suddenly | 〃 |
| To turn the steering wheel precisely | 〃 |
| To be separated from the next car in a longitudinal direction | 〃 |
| To be separated from the next car in a horizontal direction | 〃 |
| To be separated from the wall | 〃 |
| To slow to a speed where you can stop suddenly | 〃 |
| To allow a distance between cars | 〃 |
| To always be able to brake suddenly | 〃 |
| To focus carefully on things such as the behaviour of the cars ahead and the brake | 〃 |
| **Driving behaviour /** | |
| To decelerate | The point at which you begin to decelerate |
| | The amount of braking |
| To avoid braking or turning suddenly | The amount of braking |
| | Steering wheel rudder corner amount |
| To turn the steering wheel precisely | Steering wheel rudder corner amount |
| To be separated from the next car in a longitudinal direction | The point at which you begin to decelerate |
| | The of braking |
| To be separated from the next car in a horizontal direction | Steering wheel rudder corner amount |
| To be separated from the wall | Steering wheel rudder corner amount |
| To slow to a speed where you can stop suddenly | The point at which you begin to decelerate |
| | The amount of braking |
| To allow a distance between cars | The point at which you begin to decelerate |
| | The amount of braking |
| To always be able to brake suddenly | The point at which you prepare to brake |
| To focus carefully on things such as the behaviour of the cars ahead and the brake | Fixation point |
| **Driving behaviour /** | |
| Slowing down | A change in vehicle speed |
| Unsafe incident behaviour | Length and breadth acceleration |
| A change in relative speed with the adjacent car | A change in vehicle speed |
| A change in the lateral distance | Lateral interval |
| Travelling at low speed | Approach speed |
| To ensure space between cars | Distance between the cars |
| **Result /** | |
| Traffic lane deviation | Amount of deviation from the traffic lane |
| Vehicular contact | The number of minor vehicle collisions |
| Contact with a road facility | The number of road facility minor collisions |
| contact in a rear-end collision | Number of contacts in a rear-end collisions |

Table 6 - driving behaviour decision process index

| Driving behaviour decision process | Index | Control group | | Experimental group | | t-Test | |
|---|---|---|---|---|---|---|---|
| | | Average | Criteria Deviation | Average | Criteria Deviation | t | Unilateral P value |
| Hazard perception | Was concerned that the road was slippery | 4.39 | 1.29 | 4.31 | 1.34 | 0.61 | 0.27 |
| | Concerned about whether the curve ahead was sudden | 2.39 | 1.20 | 2.41 | 1.23 | 0.17 | 0.43 |
| | Concerned that I was speeding | 3.54 | 1.36 | 3.35 | 1.32 | 1.47 | 0.07 |
| | Concerned about whether the car alongside would come closer | 3.40 | 1.38 | 3.48 | 1.30 | 0.57 | 0.28 |
| | Concerned whether the car alongside's behaviour was disturbed | 3.53 | 1.30 | 3.56 | 1.27 | 0.23 | 0.41 |
| | Concerned whether the wall and myself | 3.80 | 1.26 | 3.71 | 1.27 | 0.74 | 0.23 |
| | Concerned about the narrowness of the road | 3.56 | 1.34 | 3.53 | 1.25 | 0.22 | 0.41 |
| | Was curious to know what lay ahead of the curve | 2.57 | 1.30 | 2.51 | 1.28 | 0.42 | 0.34 |
| | Concerned whether there was a stationary vehicle ahead of the curve | 3.57 | 1.41 | 2.98 | 1.36 | 4.40 | 0.00 |
| | Concerned about the small distance between vehicles | 3.67 | 1.28 | 3.58 | 1.23 | 0.77 | 0.22 |
| | Concerned about whether it was possible to stop suddenly at this speed | 3.57 | 1.28 | 3.34 | 1.28 | 1.88 | 0.03 |
| Risk perception | Concerned whether the turn could be made ahead of the curve | 2.96 | 1.29 | 2.95 | 1.29 | 0.10 | 0.46 |
| | Concerned whether collision would | 3.47 | 1.28 | 3.41 | 1.25 | 0.44 | 0.33 |
| | Concerned whether rear end collision would occur ahead of the curve | 3.37 | 1.30 | 3.08 | 1.24 | 2.31 | 0.01 |
| Driving behaviour choice | To decelerate | 2.41 | 1.18 | 2.34 | 0.99 | 0.63 | 0.26 |
| | To avoid braking or turning suddenly | 2.29 | 1.25 | 2.26 | 1.04 | 0.27 | 0.39 |
| | To turn the steering wheel precisely | 2.22 | 1.09 | 2.22 | 0.97 | 0.04 | 0.48 |
| | Give the car alongside ample space (longitudinal directions) | 2.78 | 1.19 | 2.80 | 1.03 | 0.23 | 0.41 |
| | Give the car alongside ample space (horizontal direction) | 3.31 | 1.23 | 3.13 | 1.09 | 1.60 | 0.05 |
| | To be separated from the wall | 3.31 | 1.17 | 3.18 | 1.05 | 1.18 | 0.12 |
| | To slow to a speed where you can stop suddenly | 2.99 | 1.29 | 2.74 | 1.07 | 2.17 | 0.02 |
| | To allow a distance between cars | 2.50 | 1.16 | 2.37 | 0.96 | 1.21 | 0.11 |
| | To always be able to brake suddenly | 2.19 | 1.07 | 2.19 | 0.97 | 0.07 | 0.47 |
| | Carefully observing the behaviour and brake light of the previous cars | 2.01 | 1.05 | 2.01 | 0.97 | 0.01 | 0.50 |
| Behaviour | Deceleration start time (seconds) | 12.94 | 3.03 | 12.32 | 3.06 | 1.49 | 0.07 |

## 4. Conclusion

In this present study, how to logically extract the evaluation process was shown by proving the feasibility of the evaluation system using the driving behaviour decision process model. In detail, by using the logic model, it became possible to clarify the effects of the AHS on risk perception. In addition, by examining the driving behaviour decision process based on the logic model, the entire process (hazard perception, risk perception, driving behaviour choice, driving behaviour, and vehicle behaviour and the results) and observation indices were logically shown. By following this, the ITS's direct outcome and indirect outcome were shown. Moreover, based on observation indicators described above, after observing the effect of the AHS, it became possible to grasp the benefits of the AHS for each process. Lastly, from observing the series of processes, it was logically identified that in order to further increase the effect of the AHS, it is necessary to further stimulate hazard perception.

This way, being able to specify how much and what parts of traffic problems are affected by the ITS will become more important in actual road traffic problem areas to judge ITS's necessity and functions specifically. The possibility to easily examine new ITS safety countermeasures by adding on skills and experiences that have been familiar up until now is anticipated, especially for regional and road administers who aren't used to ITS. In addition, this also applies to the operation after introduction of the ITS service. In addition to the skills of the technicians, systematically examining that the ways in which the ITS is effective, what measures should be taken to further obtain specific effects is hoped to constantly provide a safe ITS service.

On the other hand, as this study used a web questionnaire, factors such as driving behaviour, vehicle behaviour and accidents were not observed. Originally the aim was to observe the driving behaviour decision process including these factors, and for the context of each process examine improvements for the AHS and other countermeasures. In addition, this study did not mention which hazard perceptions should be stimulated, however it is hoped these can be examined in the future.

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