INFORMING DRIVERS ON ACCIDENT RISKS: A CASE OF HANSHIN EXPRESSWAY'S WEB-BASED TOOL "SAFETY Drive / Smart Choice"

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ABSTRACT

Hanshin Expressway Company Limited considers accident risk as one of the important concepts for its safe driving assistance and traffic management for the next generation. As part of the initiative, the Company is analyzing its various driving environment data that it possesses as the operator of the network and records of traffic accidents, to be able to predict traffic accidents for given driving conditions. This paper reports the outcomes of the ongoing research effort. Firstly, we propose a framework to utilize "accident risk" information whose use is expected to expand in realizing safe, secure and comfortable road traffic, and present an evaluation framework to develop an effective utilization framework. Secondly, as our first step to implement the accident risk information, we report the development of SAFETY Drive Smart Choice, a web-based tool to provide practical information service to assist route and departure time choice. We will present the findings from our preliminary analysis and future extensions of our effort regarding the accident risk information.

Keywords: accident risk, traffic safety, route choice, driving assistance, traffic management

1. INTRODUCTION

Traffic accident risk is one of the critical components of next generation's traffic management and traffic safety assistance. Understanding environmental factors and mechanisms by which traffic accidents occur is critical for highway operators to improve the existing traffic operation systems to minimize traffic accidents that incur significant social costs. Driving environment particular to urban

highways, including nonlinear driveways, complex junction structures, frequent congestions due to high urban travel demand, have been found to be associated with high occurrences of accidents [1]. Such associations tend to be significantly affected when coincided with certain factors such as particular traffic and/or weather conditions. It is in this context that Hanshin Expressway Company Limited (HECL) initiated a study on the relationship between traffic accidents and driving environment, using data that it has as the operator of the facility, such as road structure, traffic, and weather conditions [2].

The HECL is the operator of Hanshin Expressway, an urban expressway network in the Kansai region of Japan. The expressway consists of a mostly elevated network of some 259.1 kilometers as of January 2015, and the annual average daily traffic through the network reaches 720,000. Accident risk management is one of the operator's important management concepts. Here, the accident risk is defined as the extent of danger that is associated with a particular location at a particular time, and this study refers to accident risk information as insights from predicted values regarding the potential of accident occurrence. The analysis in this study will therefore take into consideration different classes of users in focusing on the risk of accident occurrence (i.e., the likelihood of accidents to occur) and the magnitude of accidents' outcomes (the extent of outcomes given occurrence of an accident). The magnitude of accidents' outcomes refer to societal loss of time as a result of congestion caused by traffic accidents, damages to the people and properties involved in the accidents, the likelihood of secondary accidents (e.g., rear-ending collision to an accident scene).

The objective of the present study is to develop a conceptual framework of "accident risk" information to gain public recognition and promote its use to realize road transportation that is safe, secure, and comfortable. As a first step, this paper will discuss our effort to develop "SAFETY Drive: Smart Choice," a web-based tool to guide drivers to make safer route and travel time choices as well as to provide practical navigation and driving assistance during trips.

The remainder of the papers is organized as follows. The next section will present an overview of user services utilizing the accident risk information. The following section will discuss our evaluation framework to effectively utilize accident risk information. After the discussion of the development of SAFETY Drive Smart Choice, our evaluation results will be presented. The last two sections will point to future extensions and conclude.

2. A USER SERVICE THAT UTILIZES ACCIDENT RISK INFORMATION

This section will present how we perceive the accident risk information can be useful potential users of the service, by their classes:

- Drivers
    - To promote driving with precaution by providing concrete information to assist driving
    - To assist drivers to make safer route and departure time decisions through providing comparative information regarding accident risks and the potential impact on travel time should accidents occur

- Road operator
    - To enable swift accident response operations by providing high accident risk locations, which will be helpful in detecting traffic accidents on the roadway
- Vehicles
    - To support precautious driving by disseminating information regarding expected traffic accident risks via on-vehicle communication devices

These services will utilize expected accident occurrence values. Figure 1 and Figure 2 summarize the structure of accident risk information services to different classes of users. The rich

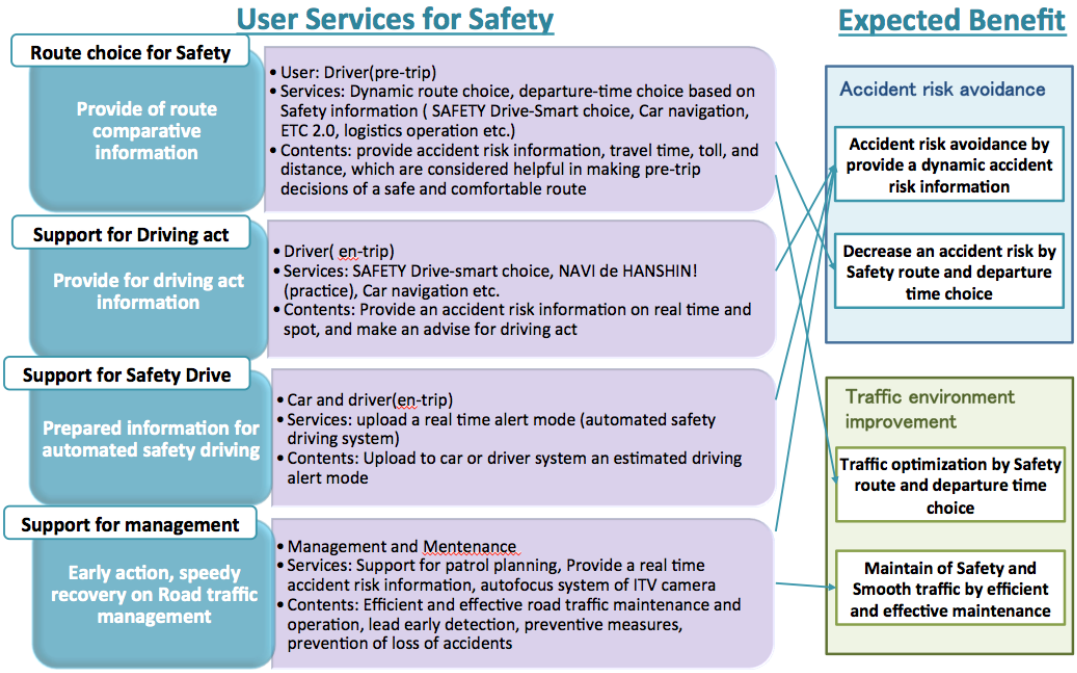

Figure 1 Traffic Safety User Service Using Accident Risk Information

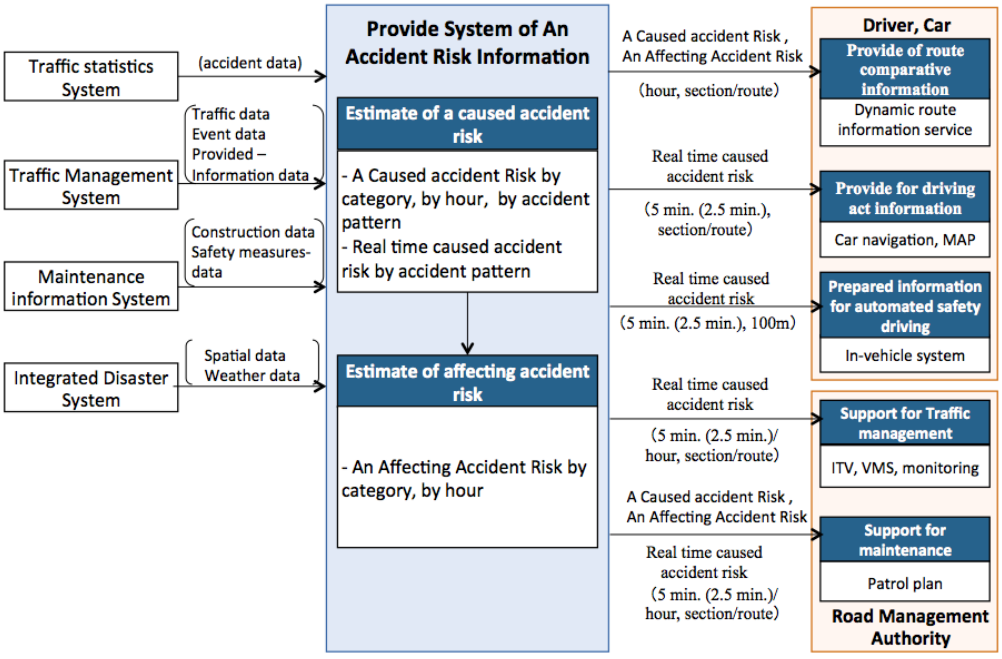

Figure 2 Service Package Utilizing Accident Risk Information

expected accident risk information can effectively contribute to improving the traffic safety on the highway network by providing appropriate information in appropriate contexts. While direct or indirect benefit may differ depending on the contexts and users with respective circumstances, the information can be helpful in managing the accident risk, improving the driving experiences with respect to their safety, security, and comfort.

3. EVALUATION OF ACCIDENT RISK INFORMATION PROVISION

As one may find in instances such as popularity of vehicle collision prevention systems and autonomous cars, interests on technologies to enhance driving safety have grown in recent years, due in part to concerns regarding aging population. However, information that assists safe driving, such as accident risk information, has received little attention. There has been no successful business model that takes advantage of such information, and there has been no guideline to effectively utilize the information for any practical use. This may be due to a few reasons. Firstly, attempts to predict traffic accidents, which are rare and are perceived to be highly random, tend to suffer from skepticism. Only in rare circumstances do members of society receive information regarding traffic accidents or safety of their trips. No meaningful means to evaluate the value of such information have been developed, and no societal consensus has been reached with respect to its benefit.

Therefore, for the accident risk information to be effectively utilized, a strategic procedure needs to be developed to first gain recognition and then explore marketable demand. Specifically, an experimental scheme to feed accident risk information into a safe driving assistance service can be proposed to evaluate the effectiveness of such systems and marketability of concrete services. The overview of a three step strategy to analyze the usefulness of accident risk information and the significance of the present study in the strategy is summarized in the following.

In the step 1, a system to generate accident risk information is facilitated by developing a simulation model with reasonable prediction accuracy is developed. In the step 2, a simplistic yet practical information tool is developed using the generated accident risk information. By promoting the presence of the tool and its usefulness to targeted classes of users who have higher interests on safe driving assistance information, diverse market demands and ways to utilize the information will be explored to improve its usefulness. The step 3 will improve the accuracy of the accident risk information for practical implementation, while evaluating the recognition and response of drivers to improve the effectiveness of the service. Ultimately, it is our hope for this information to be a useful input to the traffic management operation of the Hanshin Expressway.

It should be noted that the present study is the step two of the strategy discussed above, and we will present a simple yet practical web tool, SAFETY Drive / Smart Choice, which has been developed to evaluate the potential use of accident risk information.

Notably, this web tool utilizes expected accident values estimated by the simulation model (i.e. as opposed to the actual statistics). This is due to the fact that accidents are events that are rare, and

section unit time accident rates that are based on the actual statistics suffer from dominance of zeros (Figure 3). Furthermore, randomly occurred accidents due to human errors and so on result in unusually augmented accident rate values. The unstable information may deteriorate the reliability of the information to the users. We therefore employed an empirically parameterized accident prediction model proposed by Daito et al.[2] to generate the accident risk information. The next section will discuss the developed system and expected outcomes, as well as the directions for future work.

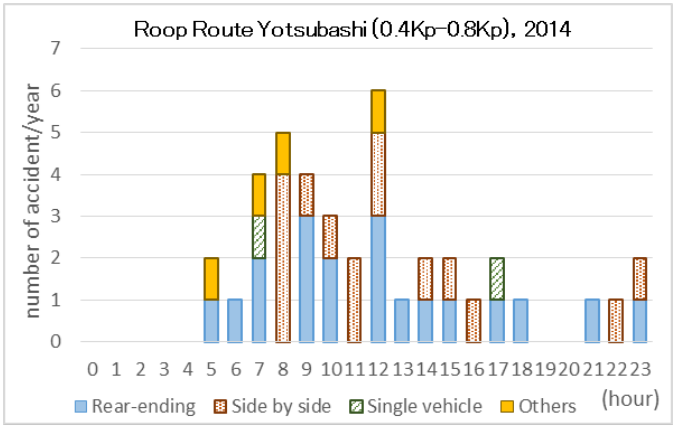

Figure 3 Accident Occurrence by Time of Day

4. DEVELOPMENT OF SAFETY DRIVE / SMART CHOICE

4.1 The Role in the Road Map

As already discussed, the intent of the SAFETY Drive / Smart Choice is not only to assist users to make safer travel decisions but also to promote the use of accident risk information and its effectiveness as well as to analyze market demand for such information. In particular, we consider the following with respect to potential market demand analysis:

- Implementation of safe route / departure time navigation using the accident risk information, and evaluation of the effectiveness as well as desired improvements
- Survey of accident risk information that is particularly effective in determining route / departure time decision
- A conceptual model to spread accident risk information use

This tool is an embodiment of a tool to encourage safer route / departure time decisions through providing accident risk information along with other relevant and useful information, such as estimated toll and travel time. We intend to continue improving the model with a survey administered to users and access log analysis so as to investigate the needs of users and what information they find useful, accounting for the diverse interests of the users.

Also, our proactive campaign to promote SAFETY Drive / Smart Choice will be essential to spread the understanding of the usefulness and benefit of accident risk information. This tool is therefore a conceptual model to propagate the effectiveness of such information services, whereby societal recognition of the value of safety information could increase.

4.2 Targeted Audience and the Direction of Future Development

The classes of users that we target, taking into consideration what the tool can offer, are senior and female drivers with modest safety consciousness, whose shares in the driver population may be relatively small at present but are expected to grow in coming years. We plan to analyze the demand and

needs through a large-scale survey to improve usability of the tool especially to these groups. With respect to other groups and larger population, we will respond to their diverse preferences and needs through the aforementioned survey, and expand the user pool through deepening their understanding of the effectiveness of the tool.

4.3 Structure of the SAFETY Drive / Smart Choice

In pursuit of the aforementioned objective, the tool consists of the following five components (Figure 4):

- Selection of Expressway entrance and exits
- Provision of alternative route information and selection
- Departure time comparison for the selected route, and confirmation
- Provision of information regarding en-route locations that require caution
- Provision of detailed driving advice for each of the cautions

The following subsection will discuss the tool's safe route / departure time selection assistance and post-decision safe driving navigation.

4.4 Appropriate Indices of Accident Risk Information

Because there has been no agreed definition of what constitutes accident risk information, this tool employs multiple interim indices based on our emphases in developing this tool. We intend to improve these indices based on the results of the user feedbacks in the future (Table 1).

- **The likelihood to cause an accident (Accident Occurrence Risk)**: As an index of the probability of causing a traffic accident, we define the accident occurrence risk as the probability of causing an accident during the trip on the expressway from the selected entrance to the exit. We employ the accident occurrence risk as in the number of accidents per unit vehicle-kilometer, which we believe one of the most general macro indexes.

  The likelihood to encounter accidents (Expected Accident Opportunity): one of the drawbacks of the accident rate discussed above is that estimations may be deviant from their perception of the accident occurrence risk. This is prevalent for longer distance travels because generally the longer the travel, the smaller the estimated accident occurrence risk. As such, we employ accident encounter rate proposed by Yoshii et al. [3], a macro-index of the expected number of encounters to traffic accident scenes. This index can be expressed as the percentage of the likelihood to encounter a traffic accident (i.e., witness an accident scene, or to be in a congestion caused by a traffic accident) during a trip between an origin and a destination for a

Figure 3 Smart Phone User Interface of SAFETY DRIVE Smart Choice

Table 1. Accident Risk Information Indices

Index	Note
Risk Level	- Severity index of accident risk - Level 1 (moderately safe) – Level 5 (highest caution) - Ranked based on accident rate and expected number of accidents
Accident Occurrence Risk	- A common index referring to the likelihood of causing an accident through the trip from an origin to a destination
Expected Accident Opportunity	- An index of risk closer to the actual sense of risk felt by users - A driver will be encountered an opportunity to see a traffic accident on away to a destination.
Number of Cautions	- An intuitive index easy to understand - The number of locations en route that exceed cautionary threshold and their locations

- given time of day for the selected routes. It should be noted that traffic congestions prevail the Expressway network during daytime on weekdays, most of which are caused by traffic accidents. This index can be insightful particularly for the classes of drivers sensitive to delays, since the risk of travel time increases for travel route / departure time combinations with low accident encounter rates is obviously smaller. In the survey administered to users, the usefulness of this index will be explicitly asked in terms of the users' needs for the kinds of information that is valued the most.
- **Level of caution to accidents (Risk Rank)**: we have defined a risk rank, a macro index intended to communicate the level of risks, since users are unlikely to be able to make judgment on accident risks merely with the quantitative accident encounter rate discussed above. As shown in Figure 5, risk ranks have been assigned to particular sets of accident rate and the number of accidents, such that the most risky 20% is considered the highest risk zone, and lower risk ranks are assigned similarly. The user interface will display the risk rank values and a caption to describe the level of risks, from "mostly safe" level 1 to "highest caution" level 5 (e.g., "caution necessary (level 3)").
- **Number of locations with cautions, for accident types (Number of Cautions)**: the accident risk information discussed above are all macro indices, and are unable to respond to the demand of users who may need details of each caution in making trip decisions. Taking into consideration the variety of driving environment that require attention for each driver or the needs for information pertaining to the number of high-level cautions and high-risk locations, we include the number of cautions for each

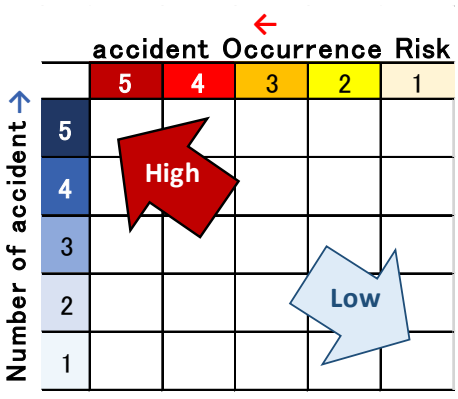

Figure 5 Risk Rank Decision

accident type. We identified 68 locations on the Hanshin Expressway network based

- pervasive accident types (e.g. rear-ending collisions, side collisions, single-vehicle collision). For the planned travel routes and given conditions, the number of locations that exceed predetermined threshold will be reported. Their locations will also be displayed on a map.

Figure 6 Comparative Information Provision Image

4.5 Provision of Comparative Navigation for Safer Route and Departure Time

The effectiveness of various accident risk information may be limited in terms of the extent to which users understand and respond to the accident risk for their planned trips, since many of the indices listed above are not well recognized in society. Therefore, SAFETY Drive / Smart Choice will be equipped with quantitative comparison of index values for route and departure time alternatives and visual comparison of caution plots on a map, so as to provide navigation to users with comparative information (Figure 6).

Figure 8 Interface of Cautions and Existing Map Services

4.6 Provision of Practical Safe Driving Assistance information

Practicality will be critical in providing safe driving assistance information service for given route and departure time that users specify, and this tool is designed so as to effectively respond to this need. First, pre-departure information is provided, as shown on Figure 7, consisting of current location map with photos, with safety information and driving advise. En-route information (catered toward passengers) will also be provided, as shown on Figure 8, which consists of location-specific information on a genetic map. Through the interface with already popular map services, we attempt to improve the practicality of detailed accident risk information so that users can easily digest the information.

4.7 Evaluation of Practicality Through User Survey

In view of the roles expected of this tool presented in subsection 4.1, important contributions of the development of SAFETY Drive / Smart Choice consists of the following components:

- To analyze the effectiveness of its assistance to make safer route and departure time choices using the accident risk information
- To evaluate the contribution of each of the accident risk information and meaningful ways to

use the information

- To identify demand for more effective accident risk information provision services.

We will evaluate responses to the user survey that is attached to the tool and improve the contents and user interfaces in a continuous manner.

5. EFFECTIVENESS OF SAFER ROUTE / DEPARTURE TIME NAVIGATION

Our analysis showed that navigation of users to safer routes and departure time contributes to optimization of road network use by allocating traffic to a more desirable travel paths. As already mentioned, traffic congestions are pervasive on Hanshin Expressway, which is an urban highway network, especially during the business hours on weekdays. The proportion of rear-ending collisions in accident-induced congestions is by far the largest of all accident types. A comparison of accident risk information between competing routes suggests that the accident risks are higher on routes with frequent congestions. Figure 9, for example, shows that the frequently congested Route 3 Kobe Route tends to show higher accident risk relative to the Route 5 Wangan Route. This implies that diverting traffic from a route with higher accident risk with an alternative route with lower accident during business hours could help in avoiding congested routes.

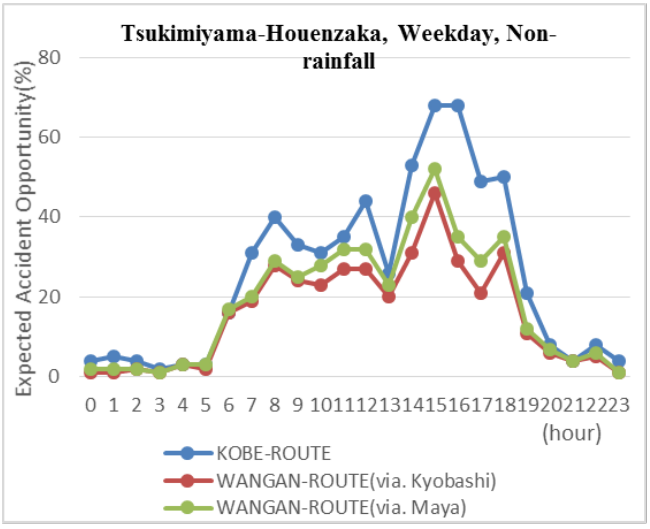

Figure 9 Expected Accident Opportunity Comparison

Furthermore, a comparison of accident risk information for different days of the week and time of the day, as Figure 10 shows, longer travel time tends to be associated with higher accident risk information. In other words, during the daytime on Hanshin Expressway, guiding users to safer departure time would actually contribute to dispersing travel demand to different times of day.

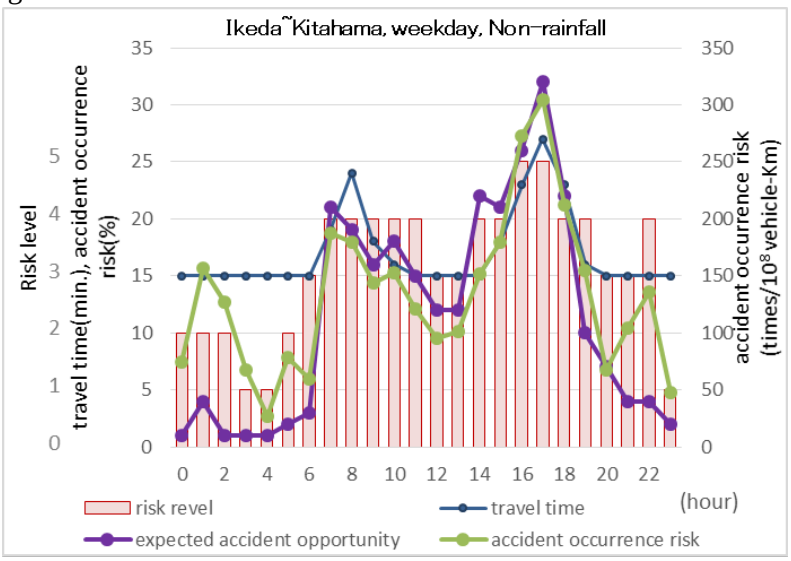

Figure 10 Accident Risk and Travel Time

The findings discussed above indicate that guiding users to safer routes and departure time would not only contribute to reducing traffic accidents but also to

optimizing the use of the limited road capacity. Utilization of accident risk information may be valuable not only in terms of traffic safety but also of traffic management operation.

6. FUTURE EXTENSIONS

As we found that navigation of SAFETY Drive / Smart Choice using accident risk information is effective in pursuing road safety and aiding traffic control operation, we intend to further improve the tool focusing on the following aspects. Firstly, we will analyze the user survey responses to understand how accident occurrence risk and accident impact risk information are recognized by the users to enhance effectiveness of communication to diverse user classes. We intend to improve the usefulness of the tool with respect to the contents of provided accident risk information and the means by which the information is communicated. We will also widely propagate the effectiveness and usefulness of the accident risk information through this tool and through introduction to existing online search engines to expand its use to wider user classes. Furthermore, we would like to increase the accuracy of the accident risk information by refining the parameter estimation model and by introducing real-time information that has been planned for the step 3 and thereafter.

We have conducted a social experiment of how drivers would respond to cautionary information provision between 2012 and 2014. The next step is to reflect the outcomes of the experiment to the evaluation of the SAFETY Drive / Smart Choice tool. The “Project Z NAVI de HANSHIN!” was an experiment project of a partnership of the public and private seven companies aimed at widely spreading safety information for accident-prone locations on the Expressway network[4]. The experiment was extremely successful with positive feedback from users, because the information that had formerly been made available only on the Expressway’s official website was made available through a sophisticated information medium of the private companies.

In particular, the experiment to use a smart phone app provided audio driving navigation service at 86 frequent accident locations on the Expressway for respective days of the week and times of the day, in a manner that would naturally integrate with the existing navigation apps. The concern held prior to the experiment, that information provision through expressway sections with high concentration of frequent accident locations may not be smooth, was confirmed as insignificant in the flow of all the information that were communicated to the users. Integration of the SAFETY Drive /Smart Choice in the step 3 appears viable.

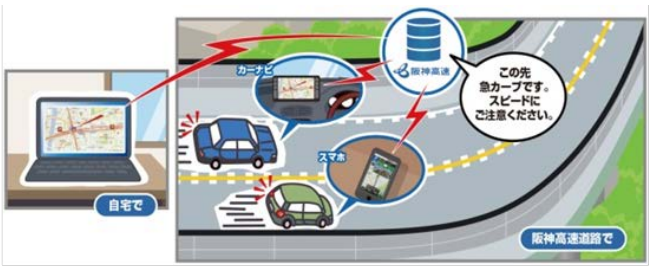

Figure 11 Conceptual Image of Project Z NAVI de HANSHIN!

7. CONCLUSION

In this study, we organized the framework of accident information risk provision service and reported the development of a tool that is easy to use and suitable for wide distribution to utilize accident. We also summarized our findings through this process that there are close relationship between safety and travel time, and that it is possible to provide navigation to cater to the diverse interests of users. Also, providing guidance on safer alternative route and departure time was also found to contribute not only to traffic accident reduction but also to assist traffic management operation to optimize the limited road capacity. We will continue improving the tool through reflecting the feedback from the user survey responses to propagate the concept of accident risk information.

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