3138 THE FUNCTION OF ETC ROADSIDE SYSTEM FOR SMART INTERCHANGE OF SERVICE / PARKING AREA CONNECTION TYPE AS A SOCIAL EXPERIMENT

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ABSTRACT

Smart Interchange, a staff-less and cashless toll collection with dedicated Electronic Toll Collection system (ETC), will reduce the costs of operating tollgates and solve security problem of the gates. Smart Interchange requires only small structures and surface, reducing the construction cost. As well, function of interchange can be added to service / parking areas by connecting such areas with ordinary roads and installing ETC gates at the entrances and exits. It is greatly expected that the Smart Interchange will not only improve the convenience of using expressways and spread ETC further, but also revitalize the economy of regional communities that have currently no interchange, by providing access to expressways.

This paper describes the function of the ETC roadside system for Smart Interchange of service / parking area connection type as a social experiment, and reports evaluation results of the system.

CURRENT SITUATION OF EXPRESSWAY

Today, expressways go through 916 municipalities and have 714 interchanges in Japan. However, there is a great gap with America and European countries in terms of the intervals of interchanges, 363 municipalities, representing approximately 40% of all, do not have access to expressways through interchanges, which have longer intervals, of about 10km, than that of the above countries (free of charge), where intervals are about

4km to 5km on average. Installing interchanges along expressways will mitigate congestion, reduce traffic accidents and environmental degradation through appropriate traffic flow both on expressways and ordinary routes. Moreover, it will increase population, annual income and facilitate the convenience of the location for local companies. Therefore, installation of new interchanges is strongly expected to improve the local economy and road serviceability.

Table 1: Situation of existing interchange in municipalities along expressways

Number of municipalities along expressways	916
Without access through an interchange in the above	363

Table 2: Comparison of average distance between interchanges

Japan	Approx. 10km
U.S. & EU (free of charge)	Approx. 4km – 5km

USE OF THIS SMART INTERCANGE

In Japan, ETC service, offering a cashless toll transaction without requiring a vehicle halt, was started in March 2001 in order to reduce congestion on expressways, control managing costs, and preserve the environment in the vicinity.

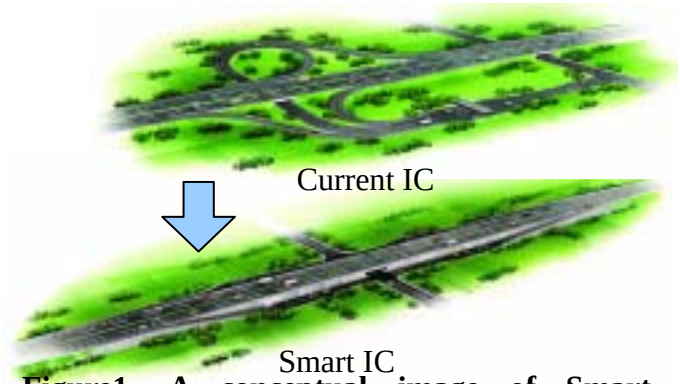


Figure1- A conceptual image of Smart Interchange

Since then, the number of ETC OBEs (on-board equipment) being installed has rapidly increased to about 7.50 million units as of the beginning of July, 2005. Smart Interchange, which is dedicated to the vehicle with ETC OBE, requires about one-third of the surface of existing interchanges.

Introduction of the Smart Interchange is expected since managerial costs are reduced as a result of staff-less operations at gates. (Fig. 1)

IMPLEMENTATION OF A SOCIAL EXPERIMENT ON THE SMART IC

For installing additional interchanges, it is an urgent problem to promote introduction of the Smart Interchange to allow the reduction of construction and maintenance costs. Since Smart Interchange, which is dedicated to the vehicle with ETC OBEs is different from magnetic-card-combined method of the existing ETC, it is necessary to find out its operational issues in Smart Interchange. Therefore, the Ministry of Land, Infrastructure and Transport decided to conduct a social experiment of installing Smart Interchanges at existing service / parking areas that are easy to connect with ordinary roads. In the social experiment, the operation is not based on existing non-stop ETC, Vehicles halt since the reduction of costs of structure for dedicated ETC and the roadside equipment is required.

The social experiment was planned to be implemented jointly with local government agencies. For selecting the sites for the social experiment, invitation was raised to find partners in April, 2004. As the result, 28 sites for the social experiment were adopted. (Fig. 2) Ingress and egress to be placed are dedicated to ETC, and type of interchange configuration, restriction of vehicle types and the ETC system operation hours vary by the experiment site. Therefore, the system of that operations at experiment sites ranges from a half interchange type of single direction, to an interchange type with either ingress or egress, to a daytime-limited operation type, and to an exclusive use type for large vehicles.

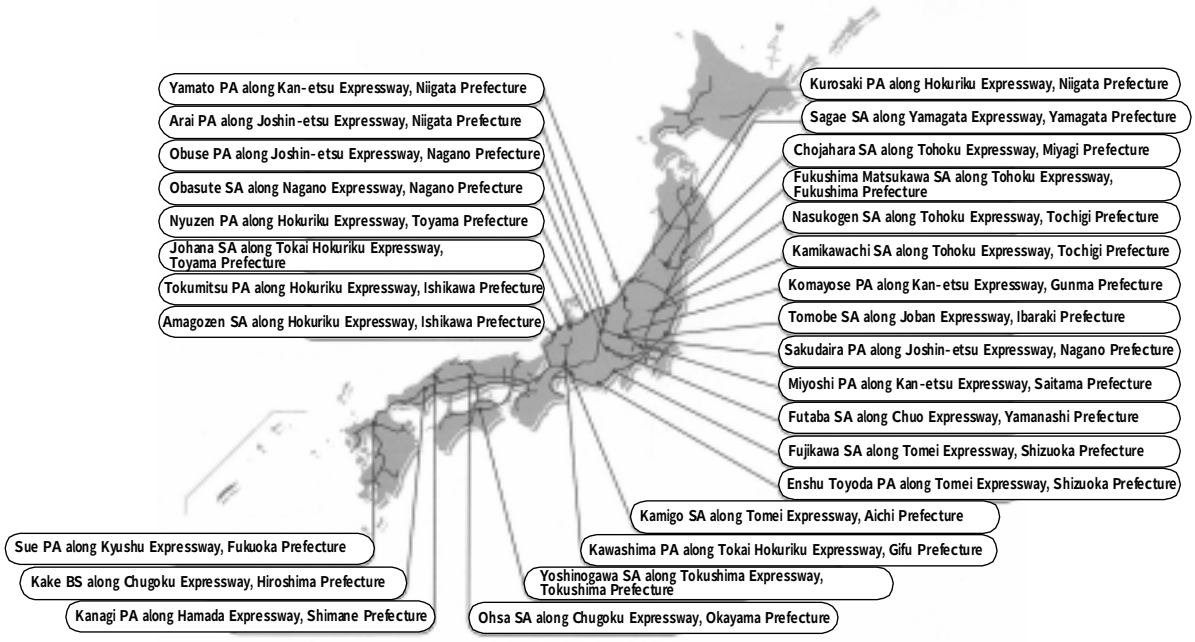


Figure 2- Location of Social Experiment for Smart Interchange of Service/Parking Area Connection Type in FY 2004

FUNCTION OF ETC ROADSIDE SYSTEM FOR A SOCIAL EXPERIMENT

Toward the social experiment, the National Institute for Land and Infrastructure Management, in consideration of the operational requirements such as ensuring safety and toll collections, has revised function of existing ETC roadside system, as shown below in Table 3, to achieve lower-cost system development. For the ETC roadside system for Smart Interchange of service / parking area connection type as a social experiment, the function was designed to be the most basic level to achieve further cost reduction.

Figure- 3 Smart Interchange of service / parking area connection type

Table 4: Comparison between ETC roadside system for the social experiment and existing ETC roadside system

Operation	Device	ETC roadside system for the social experiment	Current ETC roadside system
Restricted to particular vehicle	Wireless roadside device	When restricting a tractor, single antenna at entrance method	Double-antenna method is employed
Dedicated for the vehicle with ETC OBE	ETC lane sign board	Fixed sign board	Movable sign board
For a vehicle halt	Vehicle start control	General purpose products are allowed (lift control in 3s)	Dedicated devices （lift control in 500ms）
	Vehicle detector	A single device is used without sensing axle load or reverse operations	4 sensors
A short term operation during community experiment	Tollgate server	Security processing section is composed of the current devices	Duplicated security procession

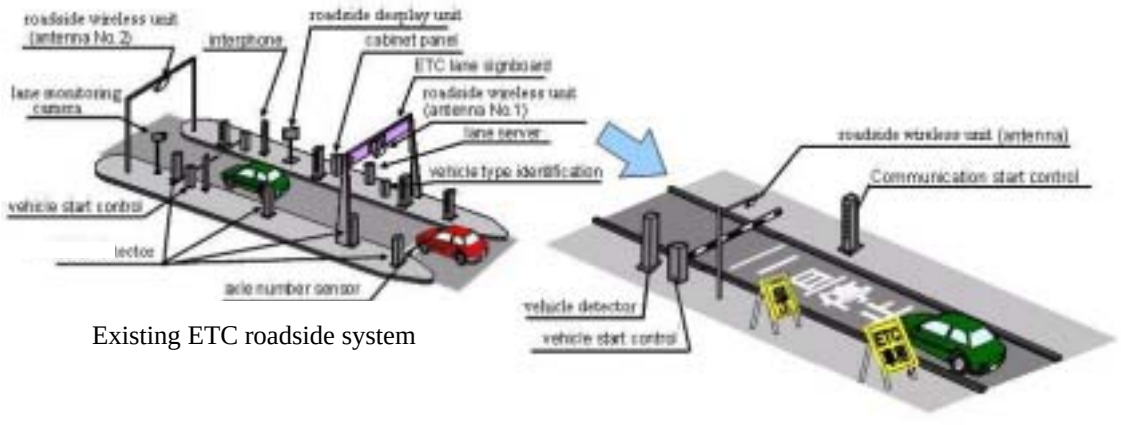
The Smart Interchange requires a vehicle halt at gate and the system does not identify the vehicle positioning at gate. Therefore the number of roadside wireless units and vehicle detectors reduce, and general-purpose units are used for vehicle start control to reduce costs.

One of the objectives of the social experiment is to identify specifications of ETC units and systems suitable for the Smart Interchange. Various combinations of devices different from existing ETC system are subject to the social experiment operations. (Fig. 4)

Table 5: ETC tollgate device component

	Device
①	Roadside wireless unit (lane server)
②	Roadside wireless unit (antenna)
③	Communication start control
④	Vehicle start control
⑤	Axle number counter　　* Note 1
⑥	Roadside display unit
⑦	Vehicle detector
⑧	Lane monitoring camera

*Note1:　Installed only at gates without restriction of tractor.



Existing ETC roadside system

ETC roadside system for Smart Interchange of Service / Parking area connection type as a social experiment

Figure 4- Image of ETC roadside system configuration for Smart Interchange of service / parking connection type as a social experiment

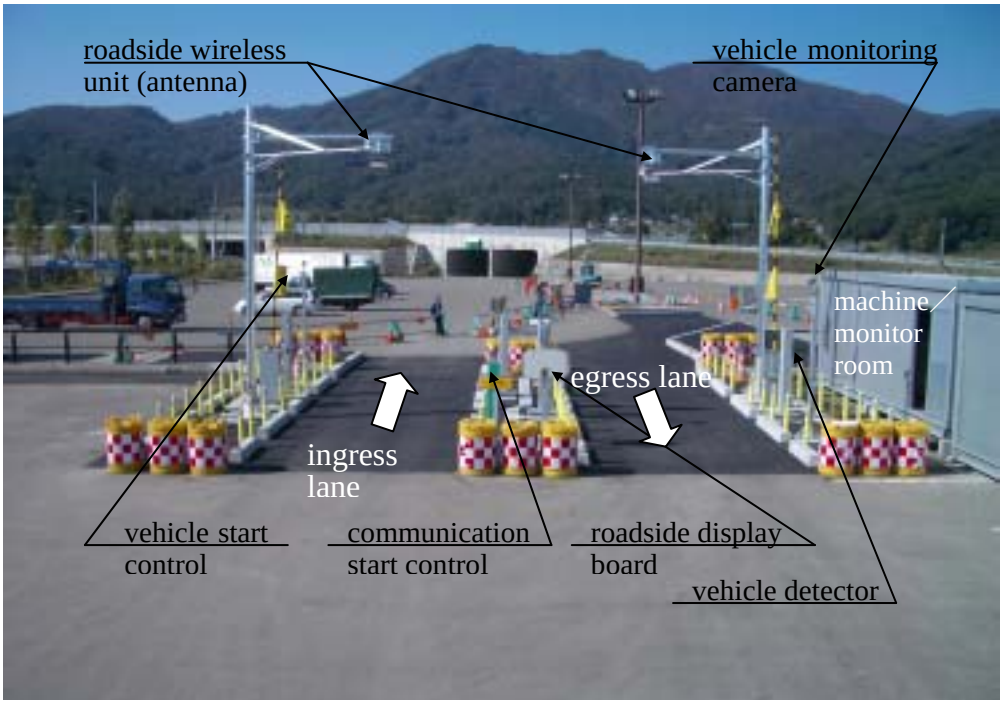


Figure 5- The Social Experiment for Smart Interchange of Service / Parking Area Connection type (Arai PA)

Regarding the specifications for the social experiment, the specifications of ETC Equipment (draft) Applicable to Smart Interchange of Service / Parking Area Connection Type as a Social Experiment was prepared. The communication with OBEs and security capability are same as existing ETC system, but other mechanisms are applicable to make a vehicle halt operation. The fundamental functions of the ETC roadside system are as follows.

1 Roadside wireless unit (lane server)

A roadside wireless unit (lane server) identifies a vehicle as either ETC, non-ETC, or a default ETC. It also manages toll charge, communication with upper devices and provides other data processing. A roadside wireless device for the social experiment use is, as a rule, installed in a machinery section of a monitor room because of easy maintenance and simple placement.

2 Roadside wireless unit (antenna)

A roadside wireless (antenna) unit communicates with ETC OBE to carry on ETC transactions. In the social experiment, vehicle types are not identified by the roadside system in case of limiting the inflow of tractor, where a single antenna method was employed as a standard because vehicle types were preliminary limited there. However, in the case that the inflow of traction vehicles is not limited, double-antenna method will be adopted to collate vehicle classification based on the counted axels with vehicle collected by the antenna.

3 Communication start control

The communication start control is a trigger system to start communications when detecting vehicle approaching the antenna. The trigger system is composed of a communication-start sensor and a communication-start button. Usually the above sensor automatically detects approaching vehicles.

In existing ETC, when normal communication failed because the ETC card is not inserted into the OBU, the vehicle must go back to the position of the first detector and start communication again with the card being inserted. However, in the ETC roadside system in the social experiment, pressing the button for communication start enables to restart the communication.

In addition to the above, inter-phones are installed in the body of the same unit to secure communication with the driver in trouble when the vehicle enters the gate. 2 sets of button and inter-phones (for large vehicles and small vehicles) are installed on the right side of forward direction, or one set of them (for small vehicles). For left side, one set of them are installed depending on the local situation.

4 Vehicle start control

A bar lifts to control vehicle entering the gate to start. In non-stop lane operation, it takes a short time of 0.5 second for completing open / close movement since a high-speed movement is required. And For protecting vehicles to hit the bar, the system provides movable capacity for forward. However, in the ETC roadside system where a vehicle halt operation was adopted, the system accepts the use of general-purpose bar unit such as a bar with a right side lifting with a fixed point on left side. Such a bar system is adopted in staff-less parking control systems. In the social experiment, the system requires the bar to complete open / close operations in less than three seconds.

5 Axle number counter

An axle number counter detects the number of axles, which allows the system to detect tractor. The axle counter consists of a detector which laterally detects a vehicle, and an axle sensor which is embedded in the road. The vehicle classification based on the counted axels is collated with vehicle collected by the antenna.

6 Roadside display unit

The LED board at egress gate displays classification of vehicle type for toll rates and its toll charge. When a communication error occurs, its causes are also displayed. (same with the existing ETC)

7 Vehicle detector

A vehicle detector placed adjacent to vehicle start control is to control a close movement of the vehicle start control. In the Smart Interchange of service / parking area connection type, communication-start system with reduced capacity and functions replaces Vehicle detector, and termination of communication and command for lighting off illumination sign was controlled by a timer. Therefore this system allowed reduction of the number of vehicle detectors to 1 unit for controlling close movement of the vehicle start control, while existing ETC roadside systems require 4 vehicle detectors.

8 Lane monitoring camera

A vehicle monitoring camera allows remote staff to monitor ETC lane operations. Operations are constantly monitored by staffs at local monitoring office.

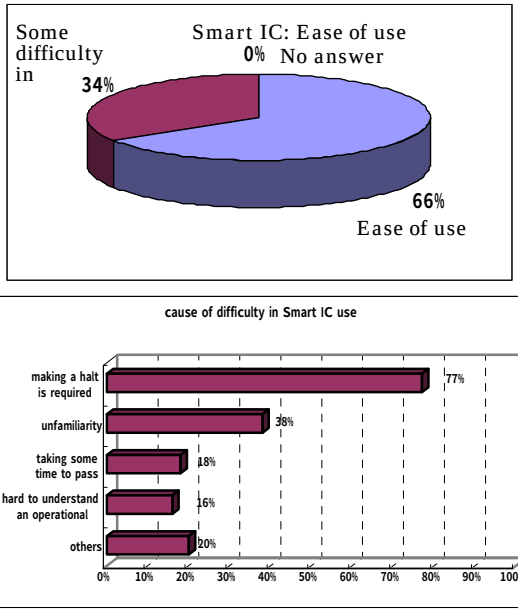
RESULTS OF THE SYSTEM EVALUATION ATTAINED FROM THE SOCIAL EXPERIMENT

Major results of the evaluation attained through the social experiment for Smart Interchanges which offered various data by the end of March 2005 are described below.

(1) Results of evaluation on system operations

1) Complaint for a required vehicle halt (Figure 7)

A questionnaire result shows user's complaint (25% of all) of a vehicle halt in terms of user's convenience at Smart Interchanges. Therefore, it is necessary to get user's understanding regarding safety through a vehicle halt.



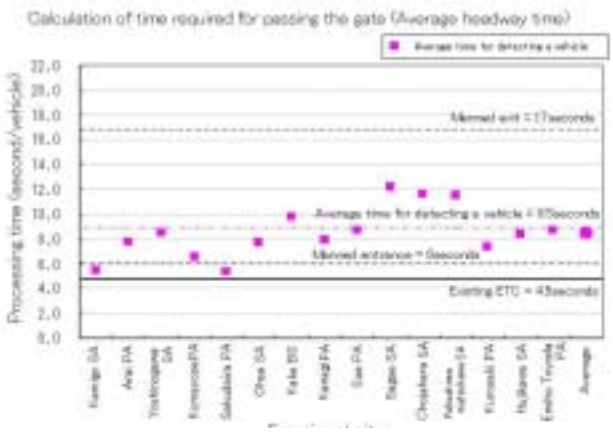
Figur 7- Smart IC; degree of ease of use

2) Timing of open movement of open/ close bar for vehicle start control

The time from the start of communication between the vehicles and roadside units to the lift of the open / close bar of vehicle start control is important in order to satisfy both encouraging vehicle halt and traffic transaction capacity. To this end, the time setting from the start of communication to the lift of the open / close bar should be tried in arrange of time (0 - 2 seconds). It is necessary to preset the optimal timing for lifting the open/ close bar. For the social experiment, it was preset at 1.5 seconds.

3) Time required for passing the gate

The times required for vehicle passing the gate in the Smart Interchange of service/parking area connection type were measured at each social experiment site (Fig. 8). Under the operation with a vehicle halt, the average headway time for entrance and exit gates was 8.5 seconds, and the transaction of traffic was approximately 400 vehicle/ hour (average number of waiting vehicles was set at 1). It will be necessary in the future to examine this time together with the timing for lifting the open/ close bar.



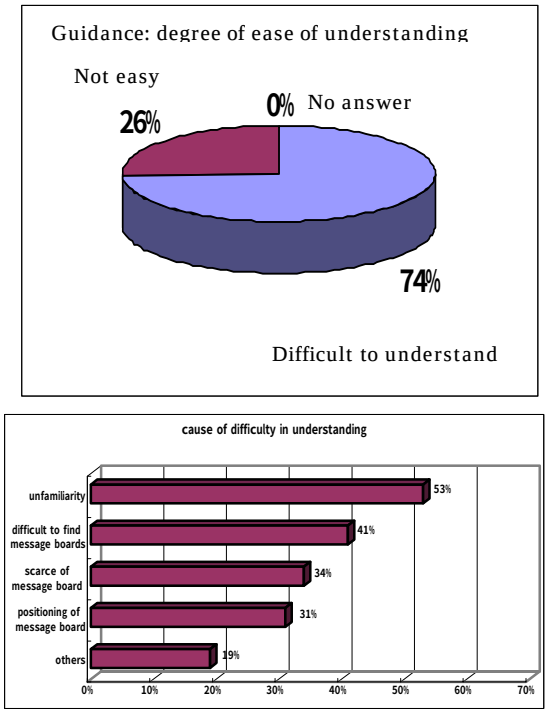
Figur 8- Average time required for passing the gate

4) Measures for Erroneous vehicle access

Erroneous vehicle (non ETC vehicle) access is observed at ETC gate even an ETC access guidance is provided prior to the gate. Therefore, it is necessary to give such a vehicle the information on unavailability of passage and appropriate guidance.

(2) System layout for user benefits

The questionnaire outcome reveals that visual identification of the vehicle start control bar and visibility of roadside display unit is highly evaluated by users (Figure 9). This outcome proved that the layout of the Smart Interchange of service / parking area connection type system is effective and does not cause objection with users.



Figur 9- Guidance: degree of ease of understand

SMART INTERCHANGE IN THE FUTURE

The released proposal on the ITS Second Stage by the Smartway Project Advisory Committee in July 2004 proclaimed that the number of interchanges across the nation should be doubled. The structurally simple Smart Interchange system is expected to penetrate in the future. The social experiment conducted proves the serviceable operation of the system, even though some issues are identified to be improved. Based on the result of the social experiment, improvement of safety, smoothing of traffic guidance, revise of conditions for operation in consideration of reducing the total cost, and revise of specifications of equipment will be realized to promote the challenge toward full-scale system deployment in the future.