Intelligent Transport Systems - Overview and Japanese Systems

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1. Overview of ITS Activities in the World

1.1. Expectation to ITS

Japan, North America and Europe strongly expected ITS to alleviate traffic congestion and to reduce traffic accident. VERTIS (Japan) estimated that ITS could improve traffic congestion by 80 % (100 billion $ /year benefit) and reduce accident loss by 30 % (20 billion $ /year benefit) by the year of 2010.

ITS America estimated the ITS benefit on traffic safety such that more than 11,000 annual deaths and 440,000 injuries could be saved by the year of 2010. European countries also expected ITS to improve traffic congestion which accounts about 800 billion $ /year loss, and to reduce traffic accidents which accounts about 80 billion $ /year loss in 1986.

1.2. ITS Activities in Asia-Pacific, North America, and Europe

ITS R&D activities have been intensively carried out since 1980s in three worldwide regions: Asia-Pacific, North America and Europe. In Japan, although CACS, a navigation system, started already in early 1970s, it seems too early to be accepted in public. Then, from the middle of 1980s, several ITS projects such as RACS, AMTICS and SSVS were initiated separately by the corresponding ministries. However, since 1994 when VERTIS, an industry –academia organisation to promote Japanese ITS activities with the help of five related ministries, was formed, ITS R&D as well as deployment have been more cooperative among the ministries. VICS (Vehicle Information and Communication System) is one of the cooperative outcomes.

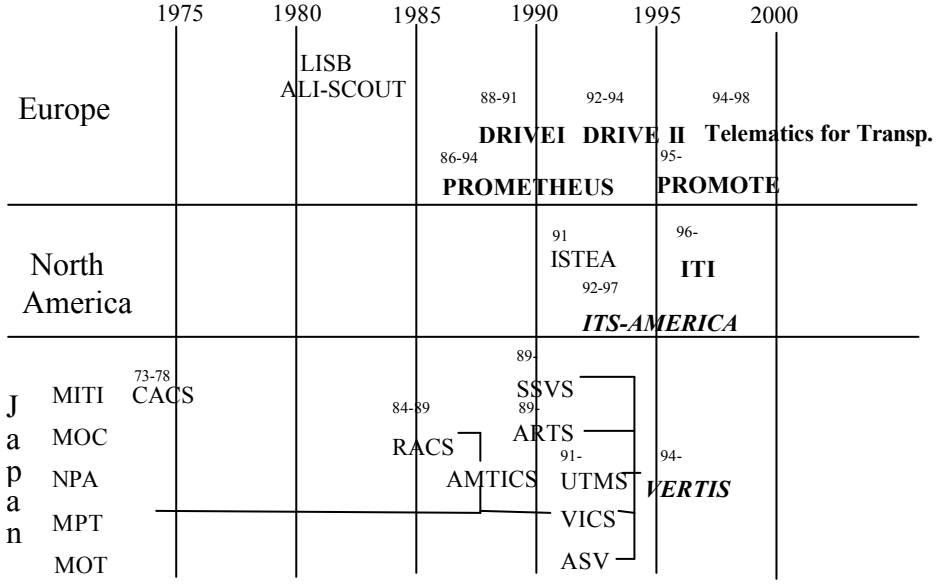


Fig. 1.1. ITS Projects in Three Regions (see Appendix for Abbreviations)

1.3. ITS Component in Japan

Table 1.1 shows areas and services covered by ITS in Japan. We define nine ITS areas associated with 20 user services. On the other hand, five ITS areas are defined in North America: ATIS, ATMS, AVCS, CVO, and APTS. Japanese and European classifications are slightly different from one in North America, but their areas and services can be possibly categorised into the above five areas.

Table 1.1. ITS Areas and User Services in Japan

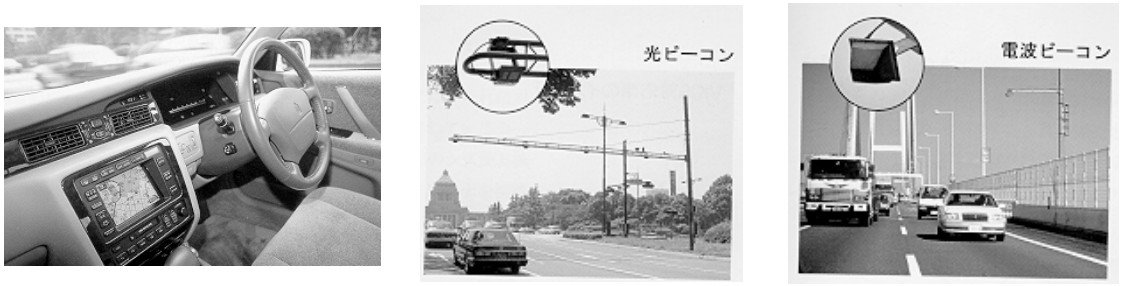
9 Development Areas	Main Users	20 User Services
1. Advances in navigation systems	Drivers	1) Provision of route guidance traffic information 2) Provision of destination-related information
2. Electronic toll collection system	Drivers Carriers Management agencies	3) Electric toll collection
3. Assistance for safe driving	Drivers	4) Provision of driving and road conditions information 5) Danger warning 6) Assistance for driving 7) Automated highway systems
4. Optimization of traffic management	Management agencies Drivers	8) Optimization of traffic flow 9) Provision of traffic restriction information on incident management
5. Increasing efficiency in road management	Management agencies	10) Improvement of maintenance operations
	Management agencies Drivers Carriers	11) Management of special permitted commercial vehicles
	Management agencies Drivers	12) Provision of roadway hazard information
6. Support for public transport	Public transport passengers	13) Provision of public transport information
	Carriers Public transport passengers	14) Assistance for public transport operations
7. Increasing efficiency in commercial vehicle operation	Carriers	15) Assistance for commercial vehicle operations 16) Automated platooning of commercial vehicles
8. Support for pedestrians	Pedestrians, etc.	17) Pedestrian route guidance 18) Vehicle-pedestrian accident avoidance
9. Support for emergency vehicle	Drivers	19) Automatic emergency notification

operations	20) Route guidance for emergency vehicles and support for relief activities

2. Advanced Transport Information Systems (ATIS)

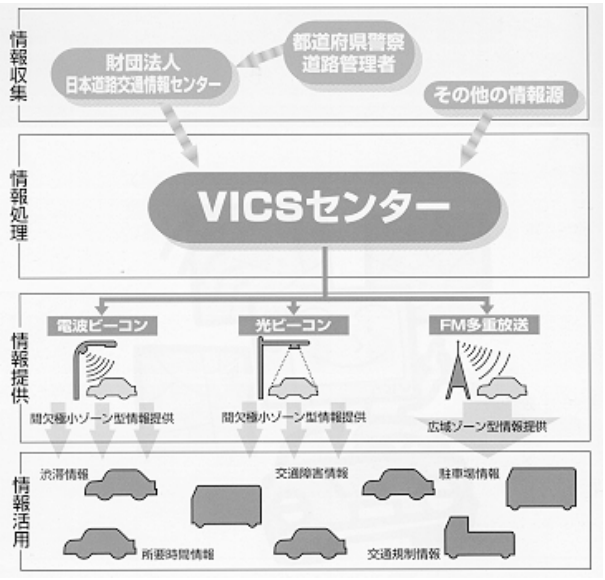
2.1. VICS and ATIS in Japan

VICS (Vehicle Information and Communication System) and ATIS (Advanced Traffic Information System) have been recently in operation in Japan. VICS started from April 1996 in Tokyo and Osaka by VICS Center supported by Ministry of Construction, Ministry of Telecommunications and National Police Agency and expanding the service area. VICS Center receives real time traffic information from Highway Traffic Information Center which gathers the information from each of the highway authorities. And VICS Center provides the information through roadside beacons as well as FM broadcasting. Two types of beacons are currently used: the microwave beacon on motorways and the infrared beacon on surface streets. Revenue of VICS is derived from technical charge from private companies.



On-board Unit　　Infrared Beacon　　Microwave Beacon

Fig. 2.1. An On-Board Unit and Roadside Beacons



Traffic surveillance by road authorities.

VICS center receives the collected data.

Fig.2.2. Information Flow in VICS

Level 1 (Character) Level 2 (Simple M

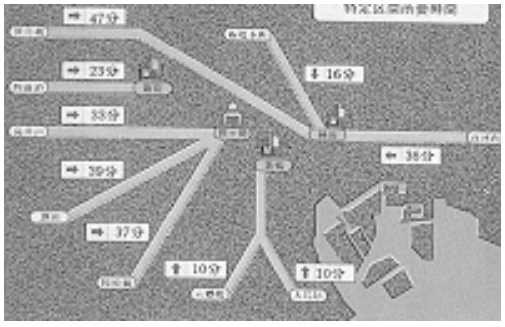
Information on travel time, parking

Fig. 2.3. Display Types of VICS On-Board Unit

On the other hand, ATIS (Advanced Traffic Information System) was started in April 1995 by ATIS Center supported by Metropolitan Police Agency and private companies. ATIS Center gets the same information as VICS and provides to users through telephone lines. Main differences from VICS are that ATIS take care of users' inquiries on traffic conditions through telephone lines and that the ATIS service area is limited in the metropolitan area.

Fig. 2.4. ATIS Display on PC

Fig.2.5. ATIS On-Board Unit



(travel time on major routes)

(parking availability)

Fig.2.6. Display Types of ATIS

2.2. Information Systems in Overseas

In United States, HAR (Highway Advisory Radio) started first on access roads to the Los Angels airport in 1972. The roadside broadcasting stations of HAR provided traffic condition to vehicle drivers through 530 kHz microwave. After the evaluation project of HAR in Minneapolis, Federal Highway Administration (FHWA) actively promoted HAR especially on highways around major transportation terminals. Two kinds of broadcasting frequencies of 530 and 1610 kHz are used and the covered area by one station seems narrower compared to the Japanese Highway Radio system.

In Germany, ARI (Auto-fahrer Rundfunk Information), a highway radio system using FM (Frequency Modulation), was introduced in 1974 to alleviate traffic congestion on north-bound autobahns during summer holidays. Similar systems were developed in various countries in Europe and they employ RDS (Radio Data System) which can inserts several additional data to available vacant spaces in the FM wave as the multi-layered data. At the beginning, the RDS specification was not standardized in Europe. However, in 1980, EBU (European Broadcasting Union) examined various RDS systems in Switzerland and the standardized RDS was eventually settled in 1984. Nowadays, the RDS is commonly used to provide traffic information and hence the system is called RDS-TMC (Traffic Message Channel). The RDS, although the specification is different from one in Europe, is also used in VICS as well as in Character Broadcasting in Japan.

2.3. Future Extension

(1) New Media

For information provision using telecommunication, the Tele-Tel (a videotex) system has been introduced in France. In Japan, the Captain system was deployed but was not well promoted. The system utilising the Internet would be one of the most promising tools for the information service at home and at offices. The mobile telephone is also powerful media, since it can provide service basically at any time (not only during driving). The new media is expected to provide not only traffic information but also other transportation related information such as parking availability, travel planning information, sight seeing spots, public transportation services, gas stations, and so on.

In Europe, the GSM (Groupe Speciale Mobile) system is considered to be introduced. In GSM, a specific channel of the mobile telephone is exclusively assigned for traffic information provision so that we can access the information always through telephone.

(2) Integration of Multi-modal Information

A comprehensive transport society covering not only highway traffic but also public transport should be established. This intermodal transport is internationally accepted and the ITS

technology could be utilized. Romance system is one of the pioneer systems in Europe as a unified information collection and provision system.

(3) Provision of Information so that a Traveller can Choose Trip Time

At present, we can receive current traffic condition but cannot know how the condition has been and will be over time. Although the current traffic information is useful to select a route to a driver's destination, it is not sufficient to choose trip time; that is, when to depart. Based upon our research, the peak-cut demand adjustment is quite effective to mitigate traffic congestion. Traffic congestion of about 7 km long on the Metropolitan expressway could be eliminated by adjusting trip departure times by only 15 minutes in average.

Information provision on traffic situation over time would be immediate acceptable tool to shift trip times. For this purpose, we need to develop a system which efficiently accumulates past traffic conditions as well as accurately predicts near future traffic condition.

3. Electronic Toll Collection (ETC) System in Japan

3.1. What is ETC ?

The ETC system automatically collects toll charge through a bi-directional communication between a vehicle on-board unit and an infrastructure station. Since 1995, 10 consortiums on ETC development have been formed and R&D as well as deployment tests have been intensively implemented. The first ETC system will be in operation from April 1999 on an intercity motorway in Japan.

1994.4 25 companies applied to the ETC R&D project
1995.6 10 consortiums + Ministry of Construction + 4 public corporations started R&D
1995.7 Field test was started
1999.4 to be in operation

Fig. 3.1. An ETC Field Test Site at Odawara Toll Gate.

In overseas, approximately 30 ETC systems have been in operation starting from the Trondheim toll road, the Orlesand tunnel in Norway and the Lincoln tunnel in United States since late 1980s. Although most ETC systems employ the flat toll pre-paid system, we can find the flat toll as well as distance based post-paid system at Austrade in Italy. In Asia, ETC was introduced in Malaysia in 1994, which handles the flat and distance based pre-paid system.

Interesting features on ETC are that a one-piece on-board unit which fixes an IC card into the main unit is more popular and that rental on-board units are available to promote ETC in most countries.

The instant bi-directional communication between a vehicle and the infrastructure may not be difficult using the well-established ETC technology. However, the issue is the efficient trouble management mainly due to human errors; for example, a vehicle without an on-board unit may enter a ETC lane or a ETC vehicle may enter without sufficient money account.

Fig. 3.2. ETC in Australia (M2, T-PASS)

Fig. 3.3. ETC in Malaysia (PLUSTAG, flat + distance base, pre-paid, 1994-)

Fig. 3.4. ETC in France
(Paris-Lyon, flat, pre-paid, 1991-)

Fig. 3.5. ETC in Italy
(Austrade, flat + distance base, post-paid, 1990-)

3.2. Expectation to ETC

The immediate purpose of ETC is to alleviate traffic congestion at tollgates, which shares about 35 % of total congestion on intercity motorway in 1996. In average, about 12 seconds is required to pay a flat toll by cash and 5 seconds by highway tickets, but for a distance based charge on the intercity motorway, more time would be needed. On the Metropolitan expressway (flat toll), the maximum discharge rate per tollgate is 500 to 600 vehicles per hour. However, it is expected to increase to 1200 vehicles/ hour if all vehicles carry the ETC equipment.

Additional effects of ETC would appear in the interchange design. Since the tollgates are not necessarily constructed at one place, the interchange needs less land space. Consequently, we can facilitate on- and off-ramps more frequent interval so as to reduce traffic volume on the mainline. ETC also provides benefit to road authorities, since a person collecting toll is not needed and management of collected toll is also automated. The ETC system could possibly deal with spatially as well as temporally dynamic charge. Hence, ETC has many application rooms, for example, utilization to the peak road pricing and to on-street parking charge, etc.

3.3. System Components

There are mainly two types of on-board units: a one-piece unit combine the transaction function with the communication system, whereas in a two-piece unit, transaction function is stored in a separable IC card. For the two-piece unit, the main unit can be used by several different IC cards and also if you carry the IC card with you, more security would be warranted. The IC card could be used for various purposes other than ETC such as shopping.

Other than the on-board unit, ETC requires various equipment such as one to identify vehicle types, a camera taking pictures for enforcement, a bar controlling vehicle passing, a display telling if a coming vehicle carries the on-board unit, and so on.

3.4. Transaction

The ETC system in Japan must deal with both flat toll and distance based charge and various vehicle classifications, since different toll schemes are employed depending upon road authorities. And also ETC has to monitor vehicle routes because the toll could be different by routes even if the origin and destination are the same.

For the pre-paid system, since the remaining amount is recorded in the on-board unit, the record should be securely write protected. Because users may traverse tool roads of different authorities, they must establish a scheme to cooperatively settle the accounts.

3.5. Future Problems

(1) Mixed Traffic of ETC and non-ETC vehicles

Since all vehicles cannot carry the on-board unit at once, we should consider the mixed traffic of ETC as well as non-ETC vehicles at tollgates. At least, both ETC and non-ETC booths should be hence facilitated. However, if the number of booths is not very many at a tollgate, we may not facilitate two kinds of booths in proportion to the traffic demand. Therefore, a booth handling both types of vehicles has been planned to be installed.

(2) Promotion of ETC On-board Units

If not very many vehicles have the on-board units, the benefit of ETC cannot be fully achieved even if the infrastructure is well established. Since the on-board unit does not seem very expensive (about 150 $), users will buy the units if they find convenience and merit from the equipment. For the further promotion, as mentioned before, the rental system has been introduced in several countries. Also, the charge to ETC vehicles could be less expensive than to non-ETC vehicles. Since non-ETC vehicles can receive benefit (= less congestion at the gates) because of ETC vehicles, this kind of charge discrimination would be justified.

(3) Efficient Infrastructure Improvement

Existing infrastructure at tollgates should be reformed so as to deal with ETC vehicles. The efficient way in the reformation is to utilize the existing structure.

(4) ETC Equipment for Other Purposes

We may add values on ETC IC cards for several other purposes. It may be used for payment of other public transportation so as to establish the intermodal society. Also, it could be used just like a credit card for usual shopping.

For traffic management, the IC card would be useful. For instance, the card would pay parking charge as well as record the violation of traffic law or even pay violation fee automatically. Eventually, it could be the driving license. Furthermore, if the uplink function is more supported so as to send more information to the infrastructure, we may use it for transportation survey. Without expensive survey, we could know travel demand pattern based upon the uplink information.

APPENDIX Abbreviations

LISB (Leit-und Information-System Berlin)
ALI-SCOUT (Autofarer Leitung und Information Siemens)
CEC (Commission of European Communities)
EURIKA (EUropean REsearch Coordination Agency)
DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe)
PROMETHEUS (Program for European Traffic with Highest Efficiency and Unprecedented Safety)
PROMOTE (PROgram for MObility in Transportation in Europe)
ISTEA (Intermodal Surface Transportation Efficiency Act)
ITS-AMERICA (Intelligent Transportation Systems/ Society of America)

CACS (Comprehensive Automobile Traffic Control System)
RACS (Road/ Automobile Communication System)
AMTICS (Advanced Mobile Traffic Information and Communication System)
SSVS (Super Smart Vehicle System)
ASV (Advanced Safety Vehicles)
ARTS (Advance Road Traffic Systems)
VICS (Vehicle Information and Communication System)
UTMS (Universal Traffic Management Systems)
VERTIS (Vehicle Road and Traffic Intelligence System/ Society)
ITI (Intelligent Transportation Infrastructure)