# Hitachi Group's Initiatives Regarding Trends in Vehicle Information Systems

Takeiki Aizono, Dr. Eng.
Yoshinori Endo
Shinya Otsuji
Kenichiro Yamane
Akitoshi Shimura

*With the launch of "telematics" services — namely, information services provided for vehicles utilizing wireless-transmission devices such as mobile phones — by major vehicle manufacturers, the number of shipped car-navigation systems equipped with transmission functions is increasing year by year. Moreover, in recent years, IT acquired over the years from the field of intelligence has been installed in cars, and new on-board information platforms, such as wireless communication, HDDs (hard disc drives), and local area networks (LANs), are being developed. In keeping with this business trend for on-board information systems, Hitachi is providing three solutions regarding safety, convenience, and entertainment. As for safety, we are developing VRM (vehicle relationship management) technology that ensures improved driver safety and security by means of "vehicle diagnosis" (which utilizes vehicle data stored on the on-board HDD) and "full-time diagnosis" (which utilizes wireless communication). As for convenience, we are promoting "traffic-information-application navigation" — for forecasting traffic jams according to statistical traffic information stored in on-board navigation systems and the latest traffic information broadcast from traffic-control centers — that helps drivers get to their destination more quickly and more comfortably. As for entertainment, by combining copyright protection and billing systems utilizing the latest super distribution technologies in a wireless-communication manner, we are developing "rich content distribution" that can reduce both communication costs and transmission times. Drawing upon our strengths acquired over the years in the areas of vehicle-terminal technology, information-transmission technology, and parts-diagnosis technology, from now onwards, Hitachi Group will continue to promote solutions related to vehicle safety, convenience, and in-vehicle entertainment.*

## INTRODUCTION

TELEMATICS is an information-providing service for vehicles achieved through wireless communications such as cellular networks, and some leading companies have started these services. A telematics market is expected to emerge in the near future because the sales of car navigation systems with communication functions that can receive telematics services have also been increasing each year.

Vehicle manufacturers have already invested in telematics aimed at CRM (customer relationship management) to increase the added value of vehicles through offering B2C (business to consumer) services, such as news and weather, to improve sales. However, in future, B2B (business to business) services or VRM (vehicle relationship management) will make good use of vehicle information and become an important business field. For example, they are developing new after-market services in cooperation with leasing and insurance companies and improving vehicle quality by using real-time vehicle information gathered through communication.

IT derived from the information-business field has been introduced into vehicles in recent years, incorporating new on-board information infrastructures such as wireless communications, on-board HDDs (hard disc drives), and in-vehicle LANs (local area networks).

Wireless communications have been introduced into vehicles as telematics has become more popular. The number of vehicles with functions to connect with centers through cellular networks continues to increase at a fixed ratio. Most vehicles will be able to connect to centers in the near future.

On-board HDDs began to become popular as the sales of car navigation with music-server functions to accumulate musical content increased. On-board HDDs are expected to become increasingly popular

in the future because HDD technologies such as better shock-resistance, environmental-resistance, and enlarged capacity continue to be improved. Consequently, detailed vehicle information will be accumulated in on-board HDDs in addition to maps and musical content.

The number of vehicles equipped with in-vehicle LANs is also increasing. In-vehicle systems tend to be decentralized and networked depending on whether the vehicle is electric or has an electric powertrain and in-vehicle LANs will become increasingly popular in the future. Both control and the diagnostic information will also be able to be gathered more easily through in-vehicle LANs.

Hitachi Group proposes three system solutions, namely, safety, convenience, and entertainment in the telematics business field according to these trends and the popularity of on-board information infrastructures.

The safety solution is VRM. Most conventional safety services in the telematics business field have been cooperative road services where drivers have called operators to arrange rescues in emergencies. Future safety services will shift to improving driver safety and providing greater relief based on detailed vehicle diagnostics obtained through vehicle information accumulated in on-board HDDs or regular diagnostics through wireless communications. Moreover, our aim is to achieve an sustainable vehicle society by integrating vehicle information gathered from cruising vehicles into the total lifecycle management of vehicle parts.

Navigation systems using wireless communications, which offer a convenient solution, are referred to as "off-board navigation," processing route searches at the center. Off-board navigation provides more services, on the basis of the latest map information downloaded from the center through wireless communications, to the driver and terminal costs can be kept low. Moreover, it achieves highly efficient navigation that can estimate congestion based on the latest traffic information and statistical information accumulated in the navigation system.

In terms of the entertainment solution, we propose a super-distributed method that delivers rich content to vehicles. Content such as music, movies, and user licenses are managed separately. For example, users can listen to encrypted music from on-board HDDs pre-installed before shipment by only downloading the license of the music they would like to listen to from the center. The latest music and movies are accumulated in on-board HDDs through CDs or wireless communications such as digital broadcasting or wireless LANs.

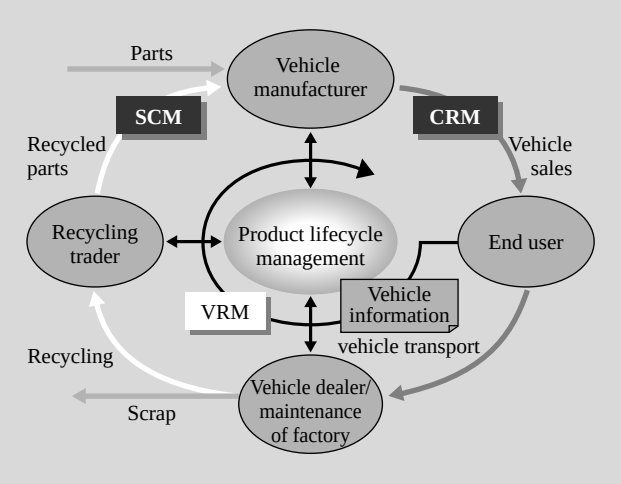



*Fig. 1—Lifecycle Management Concept.*
*The parts lifecycle, which involves the manufacture and sales of parts, the user's operation status, and the recycling of parts that would otherwise be scrapped, is managed centrally.*

VRM and a navigation system, which is being applied to Hitachi Group's traffic information, to improve safety and convenience are explained in detail in the rest of the paper.

## VEHICLE RELATIONSHIP MANAGEMENT

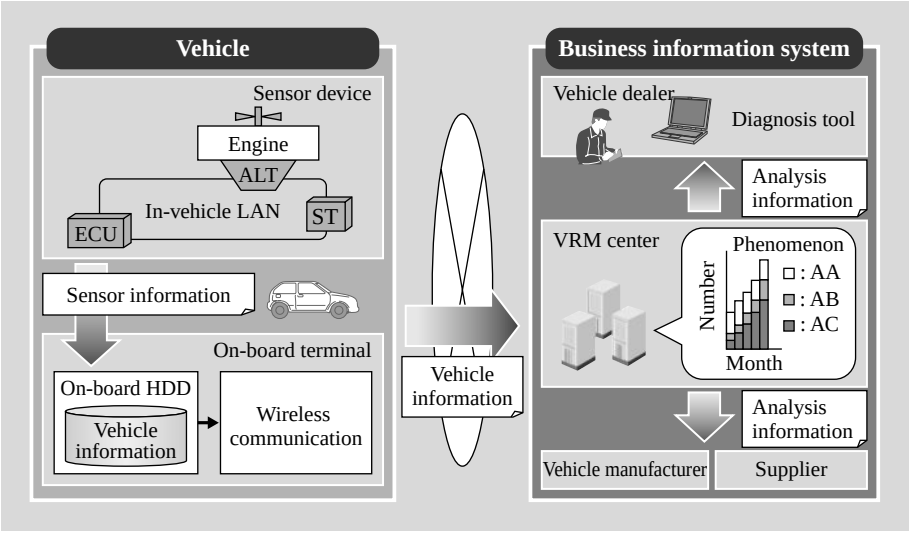
### Lifecycle Management of Vehicle Parts

Vehicle manufacturers are trying to increase production efficiency, reduce manufacturing costs, and increase sales. They are continually improving SCM (supply chain management) systems to reduce the cost of vehicle parts. In addition, CRM targets sales activities more efficiently by managing each customer's information individually.

A vehicle recycling law was passed in Japan in 2002 and a vehicle scrapping management system increasing the distribution of recycled parts was established. If VRM is used to collect detailed information about individual vehicles after they are sold, it will be possible to centrally manage the parts lifecycle. That is, it will be possible to coordinate the manufacture and sales of parts, the user's operation status, and the recycling of parts that would otherwise be scrapped (see Fig. 1). Furthermore, VRM would contribute to driver safety by monitoring the condition of parts while vehicles were cruising.

### VRM System Solutions

Many processors have recently been introduced into motor vehicles, and the number of diagnostics programs developed for electrical parts is increasing




ALT: alternator
ECU: electronic control unit
ST: starter

*Fig. 2—VRM-system Components. Vehicle information can be gathered and easily sent through in-vehicle LAN, on-board HDD, and wireless communications.*

because newer vehicles have more electrical parts. These are more likely to cause trouble than mechanical components. As in-vehicle systems will be large-scale distributed control systems, there will be an increased likelihood of trouble due to problems with software, hardware, and in-vehicle networks. We therefore need to maintain vehicle safety by using VRM to diagnose potential problems. Hitachi Group is trying to do this by using control-system technology we developed while producing large-scale and extremely reliable systems such as those providing electrical power to railways, and by using the diagnostics know-how we accumulated through developing electric parts such as motors and inverters.

The on-board terminal in a VRM system gathers information about the status of the ECU (electrical control unit) and individual parts through an in-vehicle LAN, then stores this information in the on-board HDD (see Fig. 2). The accumulated information is edited or converted and sent by wireless communications to the VRM center, where it is used to support the maintenance provided by vehicle dealers. It is also available to the designers at the vehicle manufacturer. The accumulated information in the on-board terminal is continuously used for in-vehicle diagnostics, which informs the driver of the causes of trouble and the need for periodic maintenance.

Cellular networks or W (wireless) LANs are used for wireless communications. When a problem is

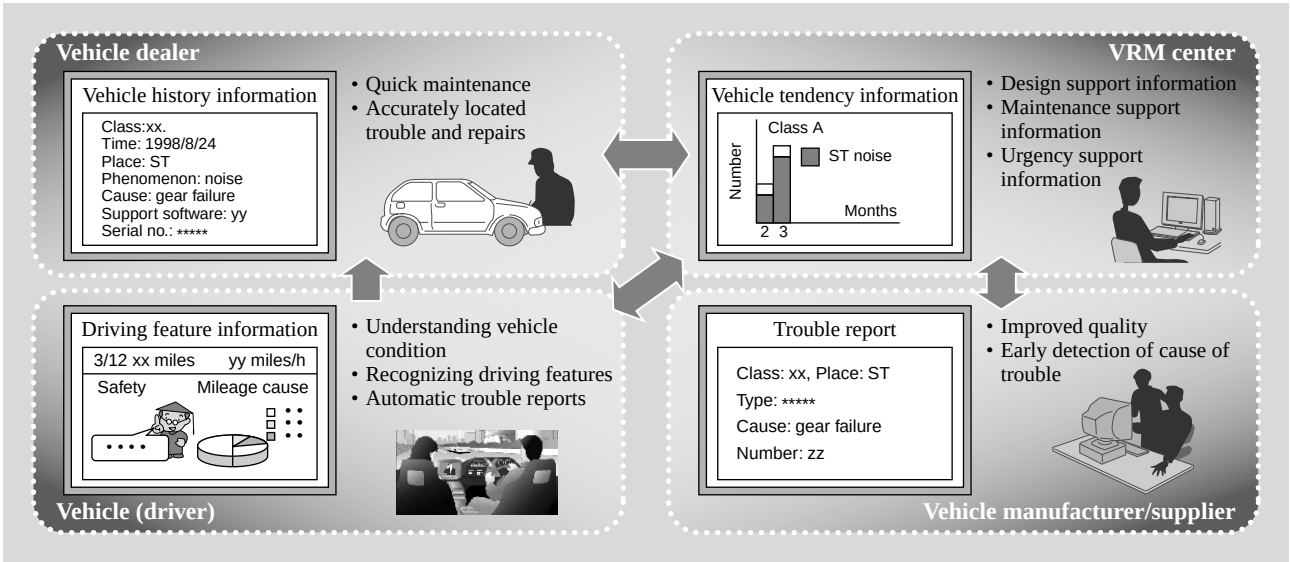
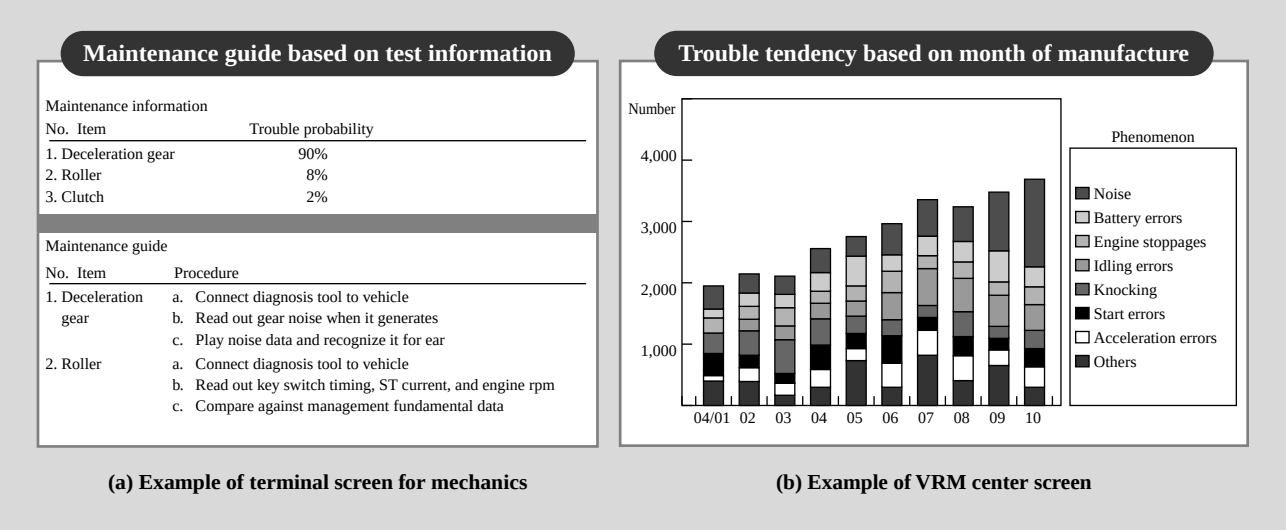



*Fig. 3—Example of VRM Usage.*
*Vehicle information helps to inform driver about maintenance schedule, maintenance at vehicle dealer, and parts quality at vehicle manufacturer.*




**(a) Example of terminal screen for mechanics** **(b) Example of VRM center screen**

*Fig. 4—Application Screen.*
*Maintenance manual used by dealer's mechanics is renewed based on trouble-generating situation in accordance with kinds of vehicle and time of manufacture.*

detected that may disrupt vehicle operation, information that specifies the cause are immediately sent to the VRM center through a cellular network. When a vehicle is taken to a vehicle dealer, the vehicle information accumulated in the on-board HDD is directly read out to the dealer's system through a WLAN and the dealer's mechanic analyzes the problem in detail by using that information.

In this way, the VRM system can help to keep a vehicle in the best condition at all times through the in-vehicle LAN, on-board HDD, and wireless communications by collecting, storing, and sending vehicle information.

## Application

The VRM system involves the driver, dealer, vehicle manufacturer, and supplier, and the vehicle information gathered from several vehicles is analyzed at the VRM center (see Fig. 3).

The accumulated information in the vehicle is analyzed in the on-board terminal and the condition of the vehicle or driving features are displayed. A driver can determine the maintenance period or recognize the source of trouble by looking at the display. When serious trouble is detected, the relevant information is automatically reported to the VRM center, which then relays it to the dealer, road-service facility, insurance company, or whoever else might need this. The driving features are also useful in helping to improve mileage and the driver's consciousness of safety.

At a dealership, the information accumulated in the vehicle is used as a diagnostics tool and can help determine what parts need maintenance or have caused trouble. This can reduce the amount of time a driver spends waiting at the dealer and specifies the causes of problems more accurately. Moreover, the VRM center analyzes the trouble-generating situation and its tendencies in accordance with the kind of vehicle involved and the time it was manufactured. The analysis results are then reflected in the maintenance manuals used by the dealer's mechanics. For example, if a particular problem often occurs in a certain kind of vehicle, this will be looked for before other possible problems are checked (see Fig. 4).

When problems occur or trouble tendencies are found, the vehicle manufacturer and the supplier evaluate the cause extensively by using detailed vehicle information gathered from each vehicle. The analysis results prove helpful in improving the quality of the next product. In this way, VRM helps to develop better and safer vehicles and parts.

## Example of Vehicle Diagnostic Technology

The particular analysis technology used to diagnose symptoms or faults depends on the parts and in-vehicle subsystem. There are also several possible analysis algorithms in the same subsystem. This section describes an example of the technology used in diagnosing problems with the ST and ALT.

When there is trouble with the deceleration gear in an ST, the most noticeable phenomenon is the change in gear noise. Low-frequency gear noise is clearly

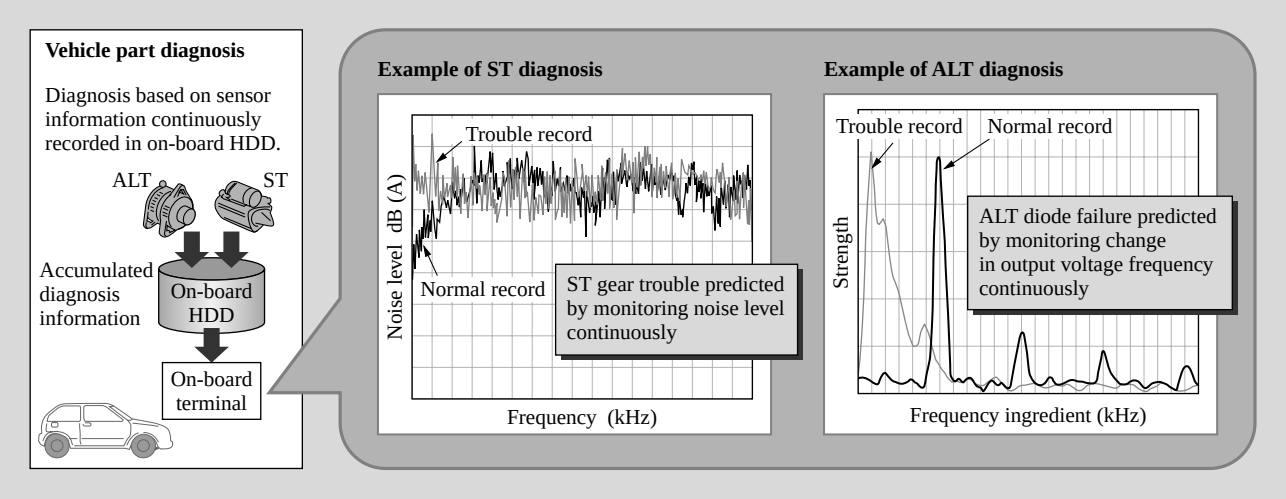



*Fig. 5—Overview of Vehicle Diagnostics Technology.*
*It is possible to diagnose symptoms by measuring gear noise in ST and by measuring frequency of output voltage in ALT.*

abnormal. The gear noise produced by the ST can be diagnosed by measuring the difference between this abnormal low-frequency noise and normal low-frequency noise. That is, if there is a lot of low-frequency noise, the ST must be examined — and perhaps repaired or replaced — because the gearing is not normal.

Diode failure can be caused by heat generating in the ALT, and this failure can be detected by measuring the change in ALT output voltage. That is, diode failure can be diagnosed if there is a lot of low-frequency noise in the output voltage (see Fig. 5).

### VRM for Electric Vehicles

The number of electrical parts in vehicles is increasing each year and electrical parts are being used more often in the powertrain. There will thus be an increased need for programs diagnosing in-vehicle networks and electrical parts. This will make the introduction of a VRM system even more important because we expect that hardware or software problems will be generated more frequently in the future.

## NAVIGATION SYSTEM TO WHICH TRAFFIC INFORMATION IS APPLIED

### Trends in Traffic-information Business throughout Japan

Most navigation systems, which have currently penetrated the market, are equipped with VICSs (vehicle information and communication systems) and are used to display traffic on a map and to search for routes that avoid congestion. The VICS traffic information is provided through three mediums (FM multiplex broadcasting, infrared rays, and radio-wave), but since June 2002 it has been possible for private enterprises to process and edit traffic information and provide users with information through a fourth medium such as mobile phones. Applying useful traffic information to a navigation system is expected to find the fastest route to a destination and provides users with accurate arrival times. We developed a technology for estimating statistical traffic data, which is incorporated in navigation systems, based on large amounts of stored VICS data and technology that combines statistical and real-time traffic data (see Fig. 6).

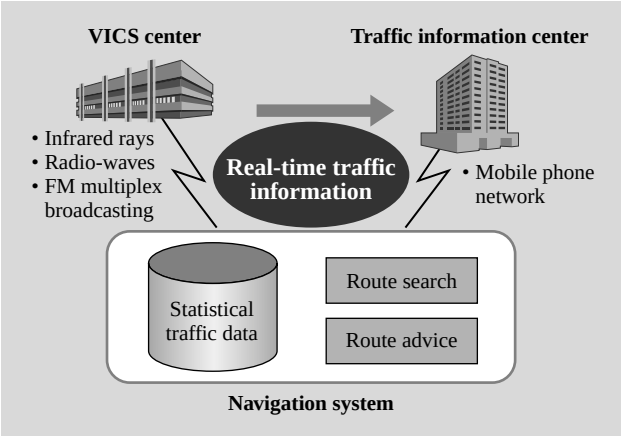



*Fig. 6—Navigation System to which Is Applied Traffic Information.*
*It makes use of real-time traffic data from VICS center and statistical traffic data installed in itself.*

## Technology for Processing and Editing Traffic Data

(1) Statistical traffic data

Common sense tells us that traffic conditions differ on weekdays and holidays and throughout the day. Similarly, when VICS data is appropriately classified, there are similarities that are correlative. Under conditions where statistical traffic data were installed in a navigation system, we studied data classification that retained accuracy while reducing the amount of data.

We will describe how statistical traffic data was estimated in the following. First, data related to incidents such as traffic accidents were detected and excluded from the stored traffic data in each classification. The accuracy of the data was improved by averaging the remaining data. Next, information coverage was also improved by estimating the traffic conditions for sections of road on which traffic information had not been provided from neighboring traffic data.

The statistical traffic data we developed covered most roads throughout Japan and the data was about 200 Mbyte. We plan to improve the accuracy of data using that from probe cars, which is described below.

(2) Effect of statistical traffic data

To evaluate the appropriateness of statistical traffic data, we ran driving tests in several areas for two months. The average error in estimation of the statistical traffic data was approximately equal to that of VICS information.

There is a sample of the route that was searched with the statistical traffic data in Fig. 7. The route search places a weight on each link reading the travel time for the vehicle to reach its destination from the statistical traffic data. Therefore, the navigation system guides the user to a route that will avoid frequently congested roads, improving the accuracy of the arrival time at the destination. Moreover, when real-time traffic data is available, it uses this within the neighborhood and statistical data in the others, under changing traffic conditions as the vehicle moves and time passes. Therefore, even if incidents such as traffic accidents arise, it can guide the user to routes that avoid these.

## Traffic Congestion Predictions and Deployment of Telematics Services

(1) Prospects for telematics services

There is an integrated traffic information system of the future outlined in Fig. 8. It will achieve not only

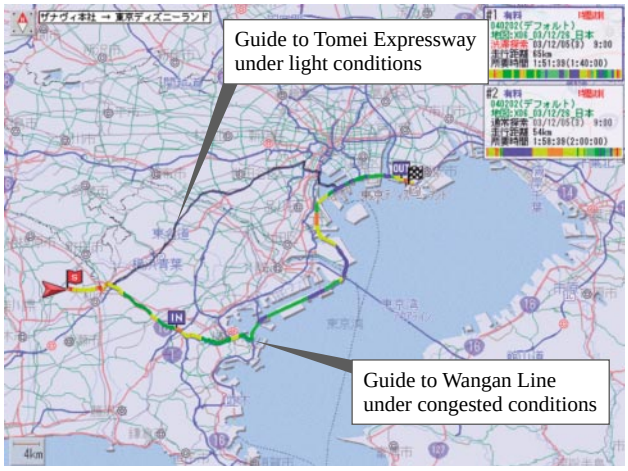



*Fig. 7—Sample Route Search Using Statistical Traffic Data. Navigation systems use real-time data in neighborhoods and statistical data in other wider areas and guide users on appropriate routes at all departure times.*

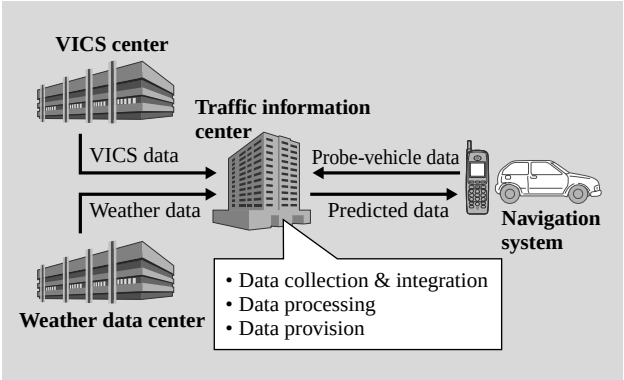



*Fig. 8—Composition of Integrated Traffic Information System. Various kinds of information is collected at traffic information center to improve accuracy of provided traffic information.*

local predictions based on statistical traffic data but center predictions based on other information such as probe-vehicle and weather data to improve information accuracy.

(2) Application of probe-vehicle data

The travel times on links that are calculated by map matching functions in navigation systems are sent to the traffic information center as probe-vehicle data. We can thus provide drivers with traffic information on roads that is not provided by VICS. We expect that the accuracy of information will be better improved by applying probe-vehicle data to estimating statistical traffic data and predicting congested traffic.

(3) Congested traffic predictions

Conventional navigation systems assume that current traffic conditions will continue until the destination is reached. However, the new system that

has statistical traffic data installed improves the accuracy of information, because it can predict changes in traffic conditions each time. Center predictions will greatly improve not only the accuracy of information but how appropriate the found route is. This is because it can predict future conditions with other real-time data such as probe-vehicle data and weather information as well.

## CONCLUSIONS

We discussed VRM and a navigation system that applied traffic information by Hitachi Group to improve safety and convenience.

Vehicles will continue to evolve because of new electrical parts and IT. Future work is how attractive services by improving driver safety using these new technologies can be provided. Hitachi Group will propose various system solutions to improve safety, convenience, and entertainment in addition to VRM and a navigation system to which traffic information is applied.

## REFERENCES

(1) Y. Nakatsugawa et al., "A State and a Trend of In-vehicle Network Technology," *Journal of Society of Automotive Engineers of Japan*, Vol. **55**, No. 2, pp. 36-42 (Feb. 2001) in Japanese.
(2) "Which In-vehicle LAN will Be Used in the Future?," *Nikkei Mechanical*, No. 577, pp. 67-72 (Oct. 2002) in Japanese.
(3) M. Morioka et al., "Telematics Services and their Prospects for the Future," *Hitachi Hyoron* **84**, pp. 513-516 (Aug. 2002) in Japanese.
(4) T. Tsunehiro et al., "Open Superdistribution Infrastructure Realizing the Tenacity of the Content Protection," Information Processing Society of Japan, EIP14-5, pp. 31-42 (Nov. 2001) in Japanese.

## ABOUT THE AUTHORS

Takeiki Aizono
*Joined Hitachi, Ltd. in 1992, and now works at the Telematics Business Development Center, the Automotive Systems. He is currently engaged in starting a new business of telematics and arranging the development of VRM architecture. Dr. Aizono is a member of the Institute of Electrical and Electronics Engineers, Inc.(IEEE) and the Institute of Electronics, Information and Communication Engineers(IEICE), and can be reached by e-mail at aizono@sdl.hitachi.co.jp.*

Yoshinori Endo
*Joined Hitachi, Ltd. in 1988, and now works at the Product Research & Development Division, Xanavi Informatics Corporation. He is currently engaged in the design and development of car navigation systems. Mr. Endo is a member of IEICE, and can be reached by e-mail at endouy@mail.xanavi.co.jp.*

Shinya Otsuji
*Joined Hitachi, Ltd. in 1992, and now works at the Advanced Technical Center, the Automotive Systems. He is currently engaged in the R&D of VRM Systems. Mr. Otsusji is a member of IEICE, and can be reached by e-mail at shinya.otsuji.tx@hitachi.com.*

Kenichiro Yamane
*Joined Hitachi, Ltd. in 1993, and now works at the 2nd Department of System Research, Hitachi Research Laboratory. He is currently engaged in the R&D of traffic information systems. Mr.Yamane is a member of the Institute of Electrical Engineers of Japan (IEEJ) and Japan Society of Civil Engineers (JSCE), and can be reached by e-mail at yamane@hrl.hitachi.co.jp.*

Akitoshi Shimura
*Joined Hitachi, Ltd. in 2000, and now works at the 4th Research Department, Systems Development Laboratory. He is currently engaged in the R&D of VRM Systems. Mr. Shimura is a member of the Institute of Electrical and Electronics Engineers, Inc. (IEEE), and the Society of Instrument and Control Engineers(SICE) and can be reached by e-mail at shimura@sdl.hitachi.co.jp.*