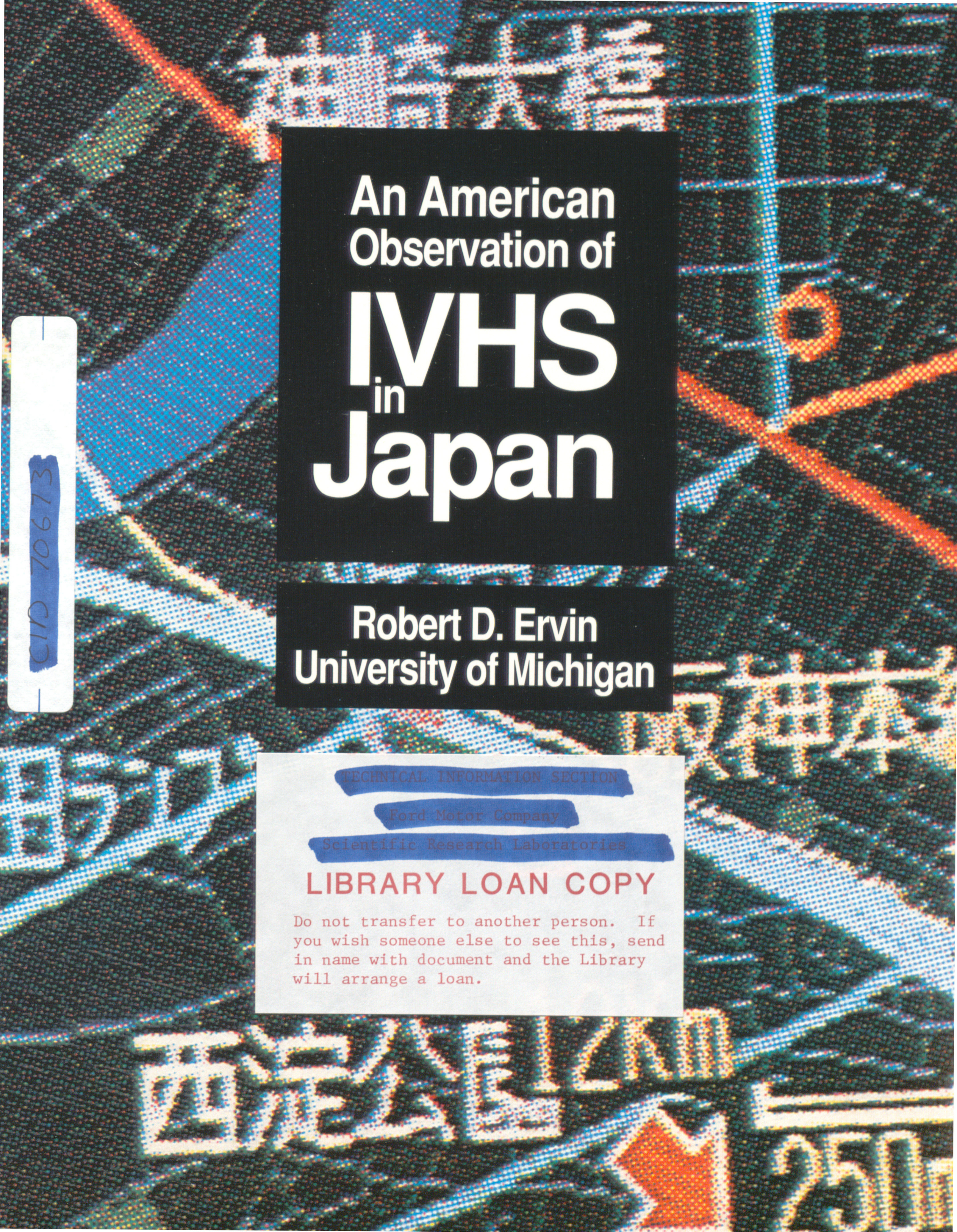

An American Observation of IVHS in Japan

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Contents

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Foreword

This report has been prepared outside of the normal course of sponsored research at the University of Michigan. Namely, a private enterprise organized a study visit to Japan which was financed entirely by fees paid by the seven industrial participants. This trip served to expose the Team Director and author of this report, Mr. Robert D. Ervin, to individuals, organizations, and example IVHS packages that in some way portray the state of IVHS in Japan. Mr. Ervin has also been engaged in the IVHS movement in the U.S. since 1987 and serves with Professor Kan Chen as Co-Director of the IVHS Program at the University of Michigan. Mr. Ervin had not, however, studied Japan's IVHS activity in depth prior to the study visit, although the Michigan Program has enjoyed participation by five large manufacturing companies based in Japan.

Following this visit, the Team Director became convinced that "the story of IVHS in Japan" would be instructive at least to the U.S. community interested in IVHS and should be presented as an American perspective on the subject. Through supplemental interviews with Japanese leaders in IVHS and a detailed review of the Japanese IVHS literature, this report has been prepared. A draft copy was sent to certain individuals in Japan for comments and corrections which have since been incorporated into the text.

1.0
Executive Summary

An infrastructure for advanced driver information systems is undergoing a final stage of definition and appears to be near deployment in Japan. It is expected that by 1995, the larger cities in Japan will provide a continuous data radio broadcast of travel time and other traffic characterizations covering tens of thousands of road links. The data will be receivable through in-vehicle packages which range in cost and functionality from that of modest receiver/computers costing a few hundred dollars to interactive navigators and step-by-step route guides costing a few thousand. By the year 2000, some basic level of travel data broadcast, and perhaps two-way localized communication as well, will be available throughout much of Japan. Both OEM and after-market packages will be available for sale as extensions to the current market for stand-alone navigators. Collision warning and other active safety innovations are expected to be marketed widely by 1995. Development is proceeding on headway control and automatic collision avoidance products to be marketed by the turn of the century.

Especially in the imminent deployment of a system for communicating traffic data in real time, Japan appears to be well ahead of other regions of the world. In its near implementation of active safety technology within the vehicle, Japan is at least in line with the European timetable and far ahead of any expected market in the U.S. Thus, one is prompted to ask, "how has this occurred?" The answer can be summarized in terms of the "Seven-C's" of IVHS in Japan, as follows:

Congestion

The state of traffic congestion in Japan provides the most obvious reason for the accelerated pace of IVHS development. Over vast portions of the metropolitan areas of Japan, average speeds below 10 mph prevail through much of the daytime, even on expressways. Accordingly, IVHS in Japan springs very much from a "demand-pull" phenomenon following upon an enormous commitment to traffic management since 1970. Indeed, a Japanese infrastructure for automated driver information systems can be readily deployed precisely because so much of the traffic surveillance and control system has already been built to deal with congestion.

Conditioning

The travelling public has been conditioned to expect continual improvement in motorist information services. These expectations have been established over some twenty years of growth in the use of active signs showing changeable text and graphics, highway advisory radio, detailed traffic broadcasting, travel-time displays, and trip-planning aids. Movement to advanced driver information systems appears to be, in this context, a reasonable rather than a radical extension—especially in light of the tremendous popularity of consumer electronics in Japan.

Centralization

The authority to create a public infrastructure for IVHS rests essentially in three centralized agencies. These agencies have, respectively, the responsibilities for highway construction, traffic control, and radio frequency allocation. Although local jurisdictions operate local roads, the central government's role in local traffic management is distinctly supervisory. Moreover, a pattern of innovation has been established with new technology flowing out of government research and finding ready deployment throughout the Japanese road system. While radio spectrum for IVHS appears to be available, it should be noted that its allocation to this usage is not without conflict, and certain key issues are yet to be resolved. Nevertheless, the track record in this area, plus recent special efforts in this regard, suggest that resolution will happen.

Collaboration

Joint development of an IVHS technology by industry and government has proceeded with characteristic speed and effectiveness in Japan. On the order of fifty large Japanese corporations have collaborated in these developments, many of whom have designed and built their own in-vehicle packages for communication with prototype infrastructures. These experiences have advanced the product-readiness of corporations and revealed the need for certain standards, two of which have already been accomplished—namely, that for the map database and the format for coding data and application programs on CD-ROM's.

Customers

Japanese auto manufacturers enjoy a customer base that includes many executive buyers who simply take the "full-option" package without rigorous criticism of each of the features. In this climate, even the less functional dead-reckoning devices, which were available when the market was launched in 1988, were sold in substantial numbers. The result is that the automakers have had the great benefit of early experience in the fabrication, assembly, maintenance, and servicing of complex information systems in the field. In the 1991 products, many improvements and extensions are already evident. Nevertheless, much future improvement is expected in the area of human factors design.

Continuity

IVHS development has been carried forward as an unbroken process in Japan since 1972. The method of study at each stage of this process can be summarized as "learning by doing." That is, although considered choices were made of the technologies to be examined in each collaborative project, the premium seems to have been placed on gaining early experience. The assessment of each field experiment has come not so much through formal evaluation protocols as through a highly participative "conferencing" which then allows the whole community to move forward readily to the next stage. The continuity sustained over twenty years reveals one widely-held conviction; namely, that the IVHS paradigm is both basically sound and highly significant to the future of automotive transportation.

Cash

At each stage of development, money has been available—first for traffic management, then for collaborative research, and soon for IVHS implementation. While public money has been the catalyst from the beginning, private expenditures started early and accelerated as markets approached. The high priority placed upon public funds for traffic management is explained partly by the fact that the right-of-way itself has come at a very dear cost, due largely to the incredible value of Japanese real estate. Accordingly, new funds to stretch the serviceability of highways through advanced technology are seen as both sensible and proportionate with the sunk capital.

This pattern of activity, as characterized by the "Seven-C's," essentially assures that Japan will be the first nation in the world to undertake wide-scale deployment of advanced driver information systems. One should also expect a rapid application of active safety technologies in Japan such as collision warning and headway control. In this case, the virtual freedom from tort liability is a key enabler. Japanese manufacturers are already in a near-market stage with various systems which may be held back in the U.S. for many years to come due to fear of the litigation exposure. Thus, one can expect that Japan will certainly be among the first nations to deploy and refine accident avoidance systems within the favorable climate of their domestic market. Since both government and industrial funds are also supporting very long range research in this general area (ten to twenty years before application), we should presume that Japanese industry will press into the broader arena of advanced vehicle control systems well into the future.

Moreover, the application of IVHS in Japan can best be described as "emerging." The period of formulating the vocabulary and sorting out the respective interests among private and public players is largely past. The movement is no longer nascent. Rather, it appears on the verge of undertaking the first nationwide deployment of an IVHS infrastructure and is aspiring to goals that go well beyond.

The value of these observations for the American reader may be primarily in the context of a "*case study*." That is, the overall story of IVHS in Japan, while peculiar in many respects relative to the American scene, is nonetheless a fascinating study in "the elements of IVHS"—from public need to collaboration by field experiment; from the early product deployment which quickens the industrial juices to the struggle over standards, jurisdictional domains, and the financing of infrastructure. Thus, the author suggests that this report is not so much a documentation of the "facts about IVHS in Japan" as it is an example case for considering more deeply what IVHS is all about, anyway. Hopefully, the reader also finds that Japan has done a marvelous job in exploring certain regions of the IVHS territory, and thus, has enabled the rest of us to better see the landscape.

2.0
Introduction

This document provides a broad overview of the development and application of Intelligent Vehicle Highway Systems (IVHS) in Japan. As indicated in the Foreword to this report, this presentation derives largely from a Study Mission to Japan conducted in March of 1991; and reflects one American's perspective on what was shown in Japan, presented in Japanese publications, and learned through various personal interviews. Wherever it has appeared useful, this discussion compares the Japanese setting for IVHS application with that of the U.S. These comparisons apply primarily in the areas of the road systems, their usage, the governmental responsibility for roads, and in social and legal distinctions which enable or constrain IVHS applications within countries. Thus, the "environment" for IVHS is addressed as well as the technology from which it's built.

This report has been written assuming that the reader has already been introduced to the IVHS concept . If this is not the case, the author suggests study of the "Proceedings of the National Workshop on IVHS" sponsored by Mobility 2000[1] as an American portrayal of the general subject. (It should also be noted that Japan has not used the term IVHS per se in characterizing its programs—although research and development in Japan has certainly dealt with most of the elements outlined in Reference [1].) Since this report is intended for persons with diverse professional backgrounds, the discussion provides a technical or situational context for each subject, assuming that each individual reader will be more attuned to certain topics and less to others.

The report is organized to go from the physical and organizational setting for IVHS in Japan to the specific activities and technologies comprising the state of IVHS itself. In Sections 3 and 4, the Japanese road system and its usage are presented. The heart of this discussion is that Japan is experiencing a high level of congestion throughout its road system. Before considering the steps being taken to deal with congestion and other issues addressable by way of IVHS, it is necessary to consider the distribution of governmental authority impacting upon roads and the possible application of intelligent systems technology. Thus, in Section 5, the major government agencies having jurisdictional authority in areas that may be impacted by IVHS are discussed.

In Section 6, the rather advanced state of traffic management in Japan is presented. This matter is highly significant to IVHS implementation since the traffic management system constitutes a basic building block for IVHS infrastructure.

Section 7 begins the immediate discussion of IVHS developments in Japan. This section outlines certain additional organizations which have been created to foster collaborative projects and discusses each of the projects in terms of its content and its impact on the trajectory of the overall Japanese program. In Section 8, observations are presented on the state of technology taking each of ten functional areas under consideration. In Section 9, a set of miscellaneous "application issues" are addressed including, for example, tort liability, aging drivers, and financing the infrastructure. This discussion addresses both socioeconomic and market-based subjects which will bear upon the particular form of IVHS that will be deployed in Japan. Section 10 provides a summary view of the type of Advanced Traveler Information System (ATIS, using Mobility 2000's acronym) that is likely to be implemented on a wide scale in Japan beginning in about 1993. Finally, in Section 11, observations are made on simple indicators of Japanese industry preparing to do business in IVHS products and services.

3.0
The Road Network in Japan

Japan has a modern road system comprised of national expressways (corresponding to the U.S. Interstate System); general national highways (corresponding to the non-Interstate portion of the primary highway system in the U.S.); prefectural roads (corresponding to non-primary state routes); and city, town, and village roads (corresponding to county and municipal roads in the U.S.). Using these crude correspondences, one can gain a rough sense of the scale of the road system in Japan through comparison with the respective values of road length in the U.S., as shown in Table 3.1.

Table 3.1. Comparison of the Japanese and U.S. Road Systems [2,3]

Road Type	Length of Road System in Japan Total Miles	Length of Road System in the U.S. Total Miles	Length Ratios, Japan/U.S.
Expressways	2,700	45,000	6%
Primary Highways	29,000	259,000	11%
Prefecture (State)	80,000	49,000	16%
Local (County & City)	575,000	3,073,000	19%
Total Road System	686,700	3,876,000	18%

(figures as of 1988)

The road system in Japan is distributed over a total land area equal to 4% of that of the U.S. and serves a population roughly equal to half of the U.S. population. Since approximately 70% of Japan is heavily mountainous, however, the road system is especially concentrated in some 30% of the total land area. Comparing the 18% of U.S. roadways with the approximate 1% (i.e., 30% of 4%) of U.S. land area, one observes right away that the trafficable portion of Japan's topography is densely packed with roadways, and indeed, is largely urban in nature.

Looking at the distribution of road length by type of road classification above, one notes that Japan is considerably more equipped with local roads than it is with expressways and other higher-capacity facilities. Thus, the traffic load borne on the Japanese road system is carried predominantly by a network of surface streets whose throughput is determined heavily by the methods of intersection control. The extent of the traffic management system deployed over this road network is outlined in Section 6.0.

As in the U.S., the roads with the highest level of design standard (i.e., the Expressway/Interstate networks) were built entirely since 1960. Virtually 100% of the National Expressway system in Japan, however, is constituted of **toll facilities.** As will be apparent later in this report, the robust financial health of the Expressway system, deriving from its toll revenues vastly raises the potential for IVHS deployment on this set of highways.

In considering any of the physical facilities in Japan, one quickly encounters the remarkable issue of real estate value. A release through the Associated Press in January 1991, for example, stated that the land value of Japan is equal to four times the total real estate value of the United States.[4] Since its land area is only 1/25th of the area of the U.S., this corresponds to a per-acre value in Japan which is 100 times that of the U.S!

The incredible tilt toward the valuation of real estate, brought on by a superheated supply-and-demand conflict, also seems to explain the apparently high investments that have been made in managing and maintaining the road system. That is, attention to highway resources seems to go beyond the level of simply keeping up the plant so as to efficiently move people and goods. Indeed, the right-of-way claimed for road-building was obtained at such a dear cost to the community that the highway itself becomes something of a national treasure.

In addition, the construction costs are often exceedingly high, especially in the common case of urban ex-

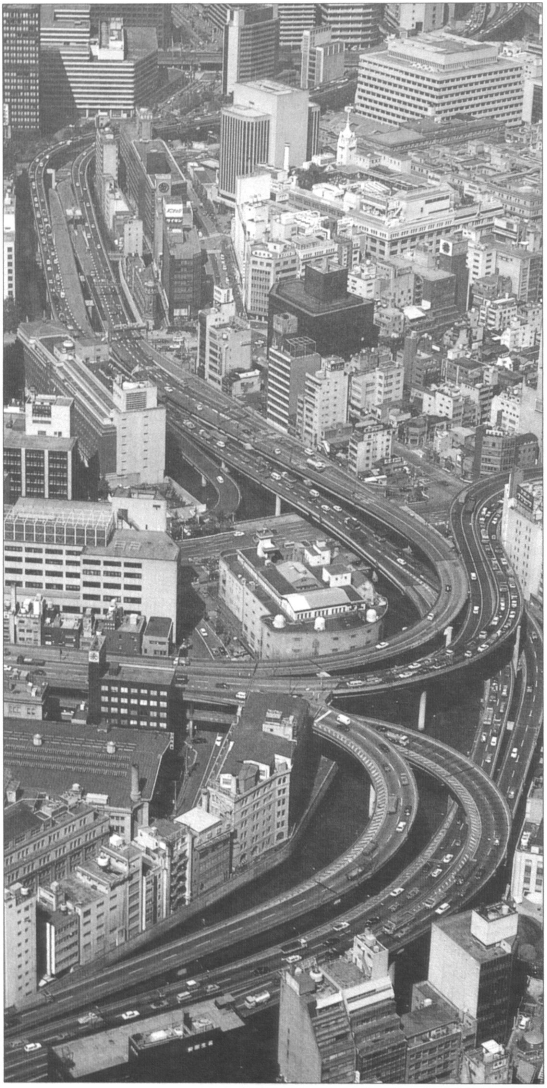

Figure 3.1 A portion of the Metropolitan Expressway illustrating routing over rivers and canals to minimize the disruption of property and to avoid the incredible costs of Japanese real estate.

pressway facilities which are built as elevated roadways such as shown in Figure 3.1. The photo indicates that, where possible, expressways are built to run along the public property of rivers and canals; although construction over water introduces its own special costs. In an even more exaggerated cost example, the "Second Tomei" Expressway, whose construction between Tokyo and Osaka is currently in the planning stage, will have more than half of its approximate 250 mile length tunneled through mountains (with the one advantage, of course, that the real estate is dirt-cheap).

The significance of fantastically costly highways is that Japan is likely to view further investments which improve the serviceability of the road system—say, for an IVHS infrastructure—as marginal costs relative to the high capital value of the facilities to begin with. Indeed, IVHS infrastructure investments would seem quite in line with the tradition of vigorous support for highway development and operation.

4.0
The State of Road Usage and Traffic Safety

In 1988, 46% of the Japanese population held a driver's license, compared with 69% in the U.S.[5,6] The total number of motor vehicles in Japan was 55 million—approximately 30% of the fleet in the U.S. Highway travel in Japan amounted to 360 billion miles annually, corresponding to approximately 17% of the U.S. traffic volume.[2,3] Thus, at first glance, the ratio of traffic volumes (17%) and total road lengths (18%) suggests that vehicular density on Japanese and U.S. roads is roughly comparable. Such a comparison is seen to be overly simplistic, however, when one considers that road length per se does not reflect total lane length and that limited access highways have far greater productivity than surface roads. In the U.S., for example, we note that 21% of the total traffic is carried on the 1% of the road system comprising interstate highways.[6]

Other factors related to on-street parking and local delivery of goods, to be discussed later in this section, also pose special impediments to traffic on urban streets in Japan. Further, a greater majority of Japanese road usage is urban than in the U.S., such that traffic becomes densely concentrated onto the great urban street networks.

While Japan may be noted for its extensive public transit system (where approximately equal numbers of passengers were moved by transit as by private vehicles in 1988), the demand for motor vehicle transportation has grown sharply, approximately tripling in volume since 1970.[2,7] The corresponding growth in motor vehicle traffic in the U.S. during the same period was a factor of 1.9.[8] Thus, Japan has seen a profound transient in traffic demand in recent years, creating perhaps a greater sense of urgency for traffic management than has existed elsewhere.

As has been experienced in all the industrialized nations, of course, the expansion of highway capacity in Japan has been followed by inexorable growth in usage as illustrated graphically in the example of Figure 4.1. The figure shows correspondence between the total length of the Metropolitan network of expressways in Tokyo and the daily vehicular traffic on the system over the twenty-seven years of expressway construction.[33]

Total highway travel resulted in 13,447 traffic fatali-

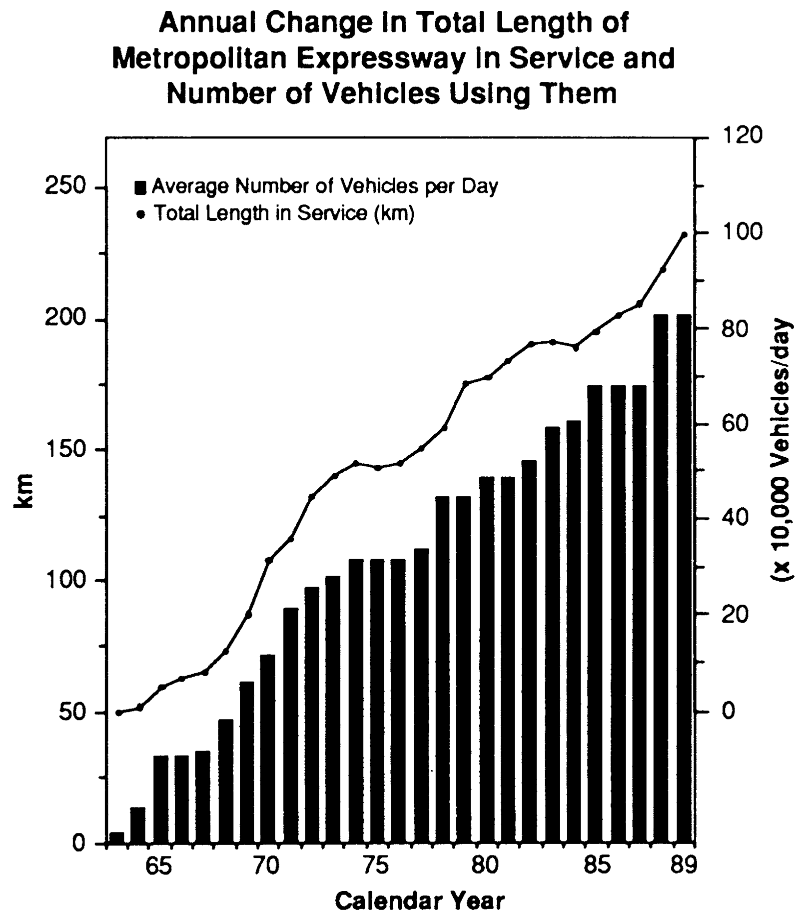

Figure 4.1 The correspondence between capacity (segmented line) and demand (dark bars) over the 27 years of development of the Metropolitan Expressway.

ties in Japan in 1988, for a fatality rate of 3.7 per 100 million vehicle-miles (i.e., a rate which is approximately 50% greater than that of the U.S.).[7,9] Nevertheless, tremendous progress in traffic safety was made in Japan since 1970, when a fatality rate of 12 per 100 million vehicle-miles was recorded. As will be seen later, a primary response to the great accident burden prevailing around 1970 was the highly ambitious deployment of traffic control systems throughout the country.[7] Perhaps more than any other single development, the concerted program for building a traffic management infrastructure, prompted heavily by safety concerns as well as congestion relief, has accelerated Japan's preparation for IVHS.

While the statistical accident record can be the subject of elaborate study all its own, it may be useful to cite the view of one Japanese automaker, noting that collision modes are distributed differently in the U.S. and Japan. In particular, auto collisions in Japan are seen to occur in an overwhelmingly front-rear manner with far fewer incidence of off-frontal impacts than in the U.S. The expectation is that a technology reducing the risk of rear-end collisions will have special benefit for the congested road system of Japan. A related view is that Japan's automakers are more interested in intelligent systems for longitudinal control of the motor vehicle than for lateral control.

Taking the subject more broadly, it is rather apparent that traffic safety is a matter of strong interest within the IVHS community in Japan. For one thing, the auto manufacturers see a near-term market for accident avoidance systems and appear to be in vigorous pursuit of the related technology. Also, as will be discussed later, it is striking that the National Police Agency, which has responsibility for the control of road traffic in Japan (and has fostered the AMTICS program, outlined in section 7.2), is organized under the National Public Safety Commission. Accordingly, the lead agency with responsibility for traffic management derives its basic mandate from the concern over public safety (rather than from a "highway performance" mission per se).

On the basis of direct observation in the major urban centers of Osaka, Nagoya, and Tokyo, any visitor quickly notes that the problem of traffic congestion is major.

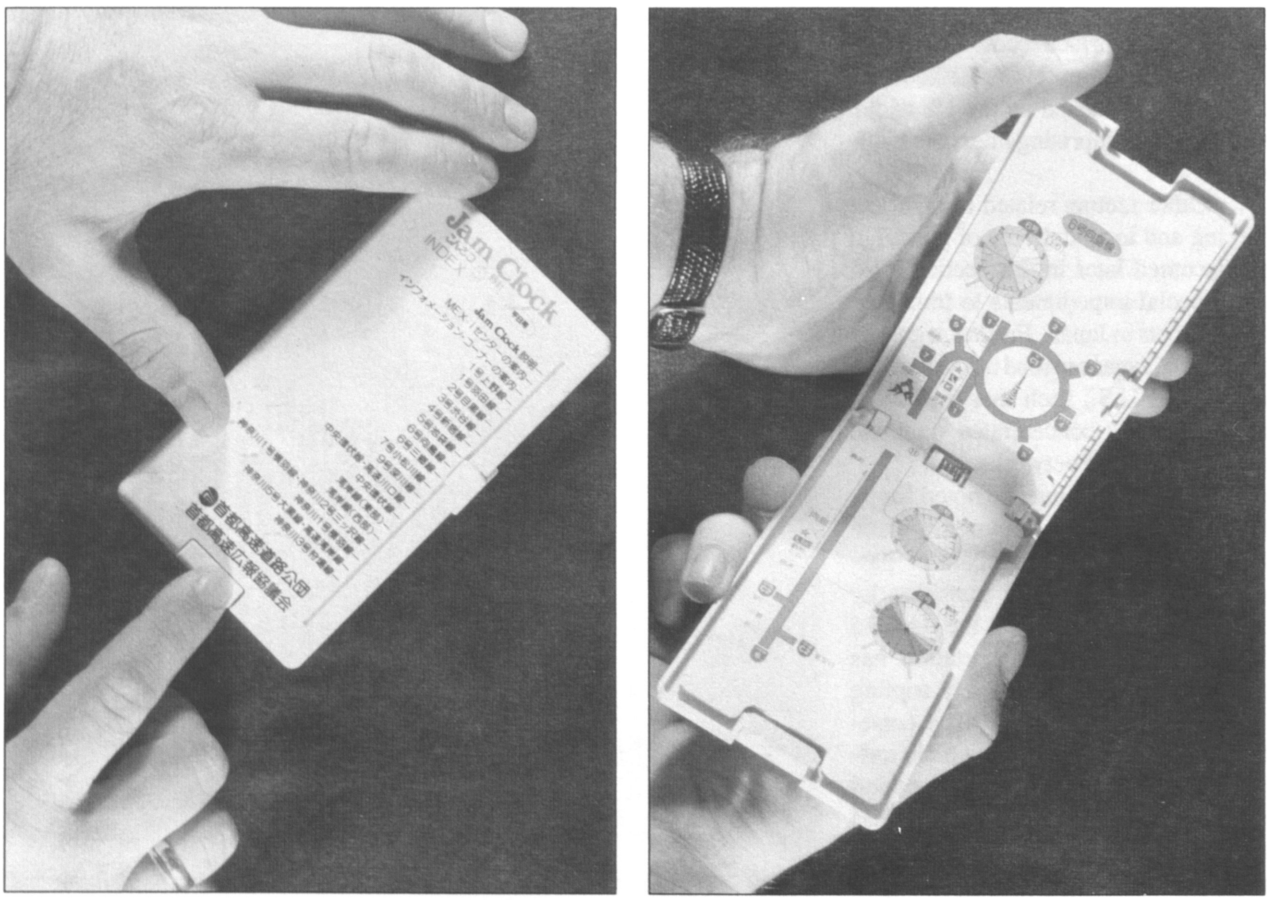

Figure 4.2 Jam Clock provided to users to the Metropolitan (Tokyo) Expressway system as a trip-planning aid.

Lacking access to hard statistical data on the matter, the following observations tend to portray the magnitude of the problem:

- In the Kansai experiment of the AMTICS system, a video map uses color-coding to show the state of congestion in downtown Osaka. The congestion level on each road link is displayed by a color indicating one of the following ranges of average travel speed: 0-3 mph, 3-6 mph, 6-9 mph, and above 9 mph.
- The Metropolitan Expressway (MEX) network, serving greater Tokyo, provides graphical display panels over the roadway which are color coded to indicate "normal flow," when the speed is above 25 mph; "slight congestion," when the speed is between 12 and 25 mph; and "congested," when the speed is below 12 mph.
- A commuter's information device distributed by the MEX comprises a handy set of index cards organized to display a round-the-clock indication of the typical state of congestion on the network as a function of clock time. The cards are arranged in a pop-open selector called the "Jam Clock" shown in Figure 4.2. Illustrations in the Jam Clock show that average speeds on much of the MEX in the hub area of Tokyo are below 12 mph from 7:00 AM through 8:00 PM.
- The Study Team visiting Japan took a bus from the Shinjuku area of Tokyo to the suburb of Kawasaki from 8:00 to 9:20 on a Friday morning. The average speed of the bus was 8 mph.
- The 91-mile Hanshin Expressway network serving the greater Osaka area reported in 1989 a total of 14,600 "traffic jams," defined as a condition which continues for at least 30 minutes wherein a lane of vehicles at least one kilometer long is either "slowing, stopping, or starting." It is highly significant to note that 76% of these conditions were attributed to "natural congestion" and only 7% to accidents, 4% to vehicle breakdowns, and 6% to construction. (It would be an interesting exercise to compare such experience in Japan with the causes of congestion in the U.S.-reported study by Lindley,[10] where at least 50% of the total vehicle-hours of delay were caused by "accidents and other incidents." Care would be required, however, to account for the different terms used in characterizing congestion.)

One of the primary reasons for severe congestion on surface streets in the urban areas is the illegal parking of cars and the parking of delivery trucks. An official at the National Police Agency indicated that for the 3.5 million cars registered in the Prefecture of Tokyo, only 2 million garages actually exist. The reason for the discrepancy, of course, is that the extremely precious real estate in Tokyo has been built upon, leaving a gross deficiency in parking areas. To deal with the crisis, a major crackdown on illegal parking began on July 1, 1991 with strong enforcement of the so-called "Garage Law." Some anticipate that with enforcement of this law, many citizens must forego car ownership altogether, thereby greatly reducing highway demand in the Tokyo area. Habitual offenders of the Garage Law will be brought in line by the payment of a $700 fine each time they illegally park overnight.

Interestingly, the average annual mileage accumulated on relatively new automobiles in Japan is approximately 6,000 miles (compared to 13,000 in the U.S.). Japanese professionals accompanying the IVHS Study Team estimated that, among car owners in Tokyo, annual travel with their vehicles is probably closer to 3,000 miles with most of the accumulation occurring on the two or three times a month when the car is used for leisure travel. When the question is asked, "Then why does a person buy a car at all?", the answer is that (a) salaries provide for very substantial incomes, but (b) real estate is so forbiddingly expensive that most city residents cannot purchase their own permanent residence, so (c) the purchase of an automobile provides the only reasonable opportunity for the ownership of capital goods—and, of course, it also gives freedom for occasional individual travel. But now, such cars cannot be left parked on the streets of Tokyo.

Moreover, the most compelling reason for the rapid development of IVHS in Japan is simply the state of traffic congestion. While later discussion will show that other commercial and institutional factors have combined to expedite the IVHS process, the rapidly-worsening state of traffic congestion over the last twenty years has provided a consistent stimulus for action by the responsible public agencies and those who steer industrial policy in Japan. At least inferentially, some of the government initiative reveals apprehension over the long-term future of the automobile given the problems created by highly congested road systems.

In addition, the concern for traffic safety seems genuine and, if anything, is the object of greater IVHS expectations in Japan than in the current U.S. conversation on IVHS. Nevertheless, as in other nations, traffic safety in Japan has the same political dimension which accounts for the safety flag being waved a bit more than the program for action seems likely to support.

5.0
Governmental Jurisdictions Impacting upon IVHS

The Government of Japan incorporates an Executive Branch comprised of some thirteen Ministries, five of which have a direct impact upon the process of IVHS development and deployment. Shown in Table 5.1 are the units of these Ministries which play significant roles.

By way of commentary, it is in the context of governmental roles that the IVHS process in Japan differs most markedly from that in the U.S. Firstly, the Ministry of Construction is a major unit of the Executive Branch of government whose Minister is a member of the Prime Minister's Cabinet, having the U.S.-equivalent position of a Secretary within the President's Cabinet. In matters pertaining to road administration, the MC has responsibility rather like that of the U.S. Federal Highway Administration (FHWA), at least in the latter's relationship to the States. That is, the MC develops highway specifications and plans and supervises their implementation while contributing funds to the construction of the road system. The analogy to the FHWA is somewhat tenuous; however, insofar as the MC also administers many of the roads from

Table 5.1 Units of Japanese Government Involved in IVHS [11]

Ministry	Pertinent Unit	Function vis-a-vis IVHS
Ministry of Construction (MC)	Road Bureau	Planning, supervision of construction, and administration of roads; survey and mapping of toll road system; construction of traffic safety facilities
Ministry of Home Affairs (Nat'l Public Safety Commisssion)	**National Police Agency (NPS)** Traffic Bureau	Development, staffing, and administration of traffic control systems on all but National Expressways
Ministry of Posts and Telecommunications (MPT)	Radio Regulatory Bureau	Radio administrative policy, frequency allocation, monitoring of radio waves
Ministry of International Trade and Industry (MITI)	Agency of Industrial Science and Technology	Planning, organization, and funding of national programs for incubating industrial technology
Ministry of Transport (MOT)	Road Transport Bureau	Approval of vehicle equipment for safety and pollution acceptability

(Bold type indicates the governmental units most frequently referenced as having responsibility for IVHS-related programs.)

a maintenance perspective. The MC conducts the planning and land expropriation for the National Expressway (toll) facilities; but, the operation and administration of the regional expressway networks such as the Hanshin (Osaka-Kobe) and Metropolitan (Tokyo) facilities is conducted by individual public corporations which operate rather autonomously, being only indirectly accountable to the MC. Also, the MC itself supervises the largest of all expressway corporations, the Japan Highway Public Corporation, which provides expressway linkage throughout rural Japan.

(Since, as mentioned earlier, real estate is so expensive in Japan, the MC's role in acquiring highway right-of-way has been handled very discreetly. The concern over potential economic disruptions resulting from highway expansion is said to have conditioned the MC so that it conducts *all* of its business in a rather private manner. This simplistic, but perhaps insightful, profile of the MC was proposed to the IVHS Study Team as partial explanation to the apparently greater prominence of the AMTICS experiment, fostered by the NPA over the RACS experiment, fostered by the MC (see Section 7.2). That is, the MC and its promotion of RACS may seem to a visitor as less flashy, and perhaps more tentative because of the natural reticence of the MC in public matters (at least that's the way the author perceived it). The implication is that, notwithstanding the difference in corporate cultures, the determination of the MC in the area of IVHS development is easily as great as that of the NPA).

The National Police Agency is a unit organized under the National Public Safety Commission whose Chairman also has the rank of a Minister of State (the U.S. equivalent of a Member of the President's Cabinet again, but with responsibilities also covering criminal and domestic security areas as well as the central national role in traffic safety and operations). The most remarkable aspect of the NPA, in terms of this agency's impact upon IVHS development, is that it has responsibility for developing, specifying, and supervising a *nationwide* network of Traffic Control Systems. By contrast, in the U.S., highly individualized (and, in general, poorly developed) traffic control systems have been installed by state, city, and county agencies, albeit with modest federal influence where federal cost sharing has been involved. In Japan, the constellation of 161 traffic control centers throughout the country all follow the NPA-developed specifications and all incorporate an NPA administrator who reports ultimately to the Director of the NPA Traffic Bureau in Tokyo. Clearly, a significant explanation for the strength of the NPA in controlling the configuration of local traffic control systems is that the Agency covers 50% of the cost for such systems.

Six corporations (namely, koito Kougyou, kyousan Seisakusho, Matsushita, Nihon Shingou, Omron, and Sumitomo Electric) command all of the business in the installation and refurbishment of the NPA's traffic control centers. Many of the primary components and subsystems installed by these companies are standardized as is Japan's own signal optimization package called ATCS (Area Traffic Control & Surveillance System). Thus, there is uniformity in (1) the traffic control infrastructure (suggesting ease of nationwide deployment of any new system that must link with traffic surveillance and control facilities), and (2) the administrative channel to all 161 control centers (which must eventually deploy additional hardware and software as the NPA may specify for implementing IVHS). One quickly jumps to the observation that these two characteristics, which would appear to be of profound significance in making IVHS happen, are unparalleled anywhere else in the world.

The Ministry of Posts and Telecommunications (MPT) is likewise a unit of the Japanese Cabinet. It has responsibilities including the regulation of wire and radio communications throughout Japan. Thus, it covers tasks equivalent to those of the U.S. Federal Communications Commission (FCC), although the MPT is situated with the status of a full cabinet department. In the twenty-year history of Japan's movement to develop an IVHS technology, the formal appearance of the MPT as a *collaborating partner* has come about only recently (although related communications technology has been under development by the agency's Research Center for Radio Systems for some time). Since the crucial issue of radio frequency allocation falls under MPT's jurisdiction, their current involvement in the VICS Program (to be discussed in Section 7.0) is one of the signs indicating a serious turn toward deployment of an IVHS infrastructure.

The Ministry of International Trade and Industry (MITI) is a unit of the Japanese Cabinet which has no formalized equivalent in the U.S. government. It constitutes an expression of Japan's industrial policy whereby public monies are spent to nurture and develop science and technology having manifest value for commercial development. At the fundamental end of the spectrum of scientific research, MITI's program has some parallel to that of the U.S. National Science Foundation (NSF), which in the last few years has begun to subject major portions of its program to the "test for industrial relevance." MITI's work on IVHS, in particular, has been of a rather applied nature but tends toward a fifteen- to twenty-year time horizon.

While the nationally-distributed traffic control system can be attributed primarily to the National Police Agency, the roots of Japan's direct examination of cooperative vehicle-highway systems is traced to MITI. Further, MITI has sustained a continuous, unbroken program to develop such concepts since it began the CACS Program in 1973 (see Section 7.2.1). Accordingly, while MITI has no mission responsibility relative to highway traffic or the performance of the road system itself, it boosts IVHS development so as to improve the utility and social acceptability of the motor vehicle—a product of Japanese industry.

The Ministry of Transport (MT) has an apparently minor role in IVHS activities. Its responsibilities include regulation of motor carriers and matters concerning automobile liability insurance, and both the safety and pollution performance of road vehicles. When new vehicle features pose any possible issue for traffic safety, the MT must grant approval before their usage on public roads is permitted.

The only other quasi-governmental bodies having a role to play in IVHS development, and most certainly deployment, are the expressway public corporations which, as mentioned earlier, operate the regional and interurban expressway networks using toll revenues. The rather flush financial condition of these organizations renders them (1) already advanced relative to providing traffic control services to their customers, and (2) quite capable of bearing a substantial financial burden for IVHS deployment, assuming they choose to do so. They are all administratively linked to the Ministry of Construction and, thus, are situated for an effective transfer of an IVHS infrastructure technology for expressways. Since the expressways do not come under the jurisdiction of the National Police Agency, however, they have not been required to develop traffic control systems complying with the NPA standard (which is basically designed for signalized street systems, anyway). Nevertheless, very impressive traffic control centers have been constructed by the major expressway public corporations following MC-prescribed standards and constitute major resources upon which to deploy IVHS infrastructure.

6.0 Traffic Management

As indicated earlier, Japan has worked since around 1970 to deploy an extensive traffic management system nationwide. The state of development of this system is discussed here in terms of traffic surveillance, control centers, signal optimization, and motorist information systems.

Table 6.1 Characteristic Error Rates with Differing Vehicle Detectors.

Detector Type	% Errors in Detecting Passing Vehicle
Inductive Loops in Pavement	1
Ultrasonic Detector Installed Overhead	3
Computer-processed TV Image	10

6.1 Traffic Surveillance System

To the degree that a road network is instrumented for real-time surveillance of traffic flow, traffic can be managed through such means as central control of signal timing, control of expressway ingress, advising drivers via signage and radio communications, and eventually facilitating route choice through a cooperative IVHS linkage with on-board computing. The core of conventional traffic surveillance systems is the vehicle detection device. The comparative accuracy of three such detection devices used in Japan is shown in Table 6.1 (although some believe that the capability of image-based systems is becoming considerably better than that shown).[12]

Notwithstanding the somewhat poorer accuracy of the ultrasonic detector relative to induction loops which have been the common choice in the U.S., vehicle detection in Japan is overwhelming by means of ultrasonic devices. Japan favors the ultrasonic detector because of its ease of installation and maintenance. This preference is easily understood, of course, when one considers the difficulty of maintaining in-pavement devices where the road system suffers extreme levels of recurrent congestion. The modest inaccuracy of the ultrasonic detector has been found to be of little consequence to controlling overall traffic flow since calibration of the system over time can serve to adjust for patterns of under- or over-counting of vehicles.

Shown in Figure 6.1, the ultrasonic detector employs an emitter within a 6- or 7-inch diameter reflecting horn. The time elapsed between emission of a tone and its reflection back to the sensor is detected to determine the presence or absence of a vehicle. On the Hanshin Expressway network, the IVHS Study Team was also shown usage of the variation in reflection time as a means of distinguishing cars from trucks (since the greater elevation of truck cabs and cargo bodies provides a considerably shorter reflection path back to the sensor). There has also been substantial success in estimating vehicle travel speed by

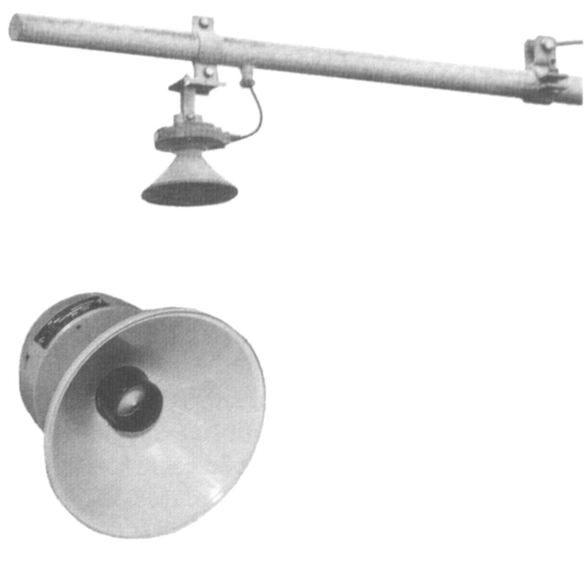

Figure 6.1 Ultrasonic Traffic Detectors used in Japan.

processing the detector signal for both duration of vehicle presence and the height difference indicating the car/truck distinction. The speed estimation is made feasible by the fact that the overall length of both cars and trucks in most popular use in Japan vary rather little within their respective populations. (The author estimates that perhaps 80% of the cars vary less than +/- 10% in overall length and that 80% of the trucks which are high enough in elevation to be detected as the heavy-duty variety vary less than +/- 15% in length. It should be noted that tractor semitrailers are relatively rare in Japan, and that the great majority of all heavy truck traffic in urban areas involves single-unit trucks averaging about 30 feet in overall length.)

Accordingly, the primary means of traffic surveillance in Japan is by means of ultrasonic detectors mounted on overhead poles in the vicinity of surface street intersections. The detectors have been deployed primarily to enable traffic-responsive control of signal timing. A total of 132,000 intersections across Japan are signalized. Approximately 41,000 of these are controlled by computer from the traffic control centers in 161 large and medium-sized cities based upon data collected from a total network of approximately 60,000 detectors. An additional 20,000 intersections are grouped into locally-coordinated sets having both responsive and fixed timing elements. Finally, some 72,000 intersections are controlled individually through detection of vehicles present at the intersection and/or by pedestrian activation. In the centrally-controlled systems, detectors are often distributed to roughly estimate queue length behind a traffic signal as well as vehicle presence right adjacent to the intersection.[13]

Relative to video imaging of traffic, examples were seen of operating systems on both the Hanshin Expressway and at the Tokyo Metropolitan Police Department. On the Hanshin network, a set of infrared cameras are employed to read the four large digits on the Japanese license plate (see Figure 6.2) at separated points along the roadway as a means of tracking travel time through certain branches of the system. Passive IR is used in daylight conditions and active IR at night. It was noted by expressway administrators that the capture of only four digits, while entirely suitable for the evaluation of travel-speeds, was also attractive since it retained the privacy of the motorist. The reading device was said to be correctly determining all four digits at both the upstream and downstream stations on approximately six vehicles out of ten in daytime, and four out of ten at night.

In central Tokyo, some twenty locations employ CCD cameras whose images are being continuously transmitted by coaxial and fiber-optic cable to the Control Center where real-time processing of the image is providing traffic detection. These data, as well as that from other conventional ultrasonic detectors, are processed to determine travel time across major links in the network. Shortly, travel time updates will be presented to motorists on a limited basis using changeable message signs (called "variable sign boards" or "variable information boards" in Japan) along the surface street system. By 1995, Control Center officials in Tokyo plan to have a broad "link-time" characterization of their system through the deployment of additional computing capability and a denser network of detectors. An official of the NPA estimated to the IVHS Study Team that his agency intends to expand the number of detectors deployed in Japan to support centralized traffic control from 60,000 to 100,000 by 1996. Even absent IVHS functionality in vehicles, the link-time characterization made possible by these plans will be of value to motorists as information delivered via changeable message signs and highway advisory radio.

Also on the Metropolitan Expressway network in the greater Tokyo area, paired sets of ultrasonic detectors are

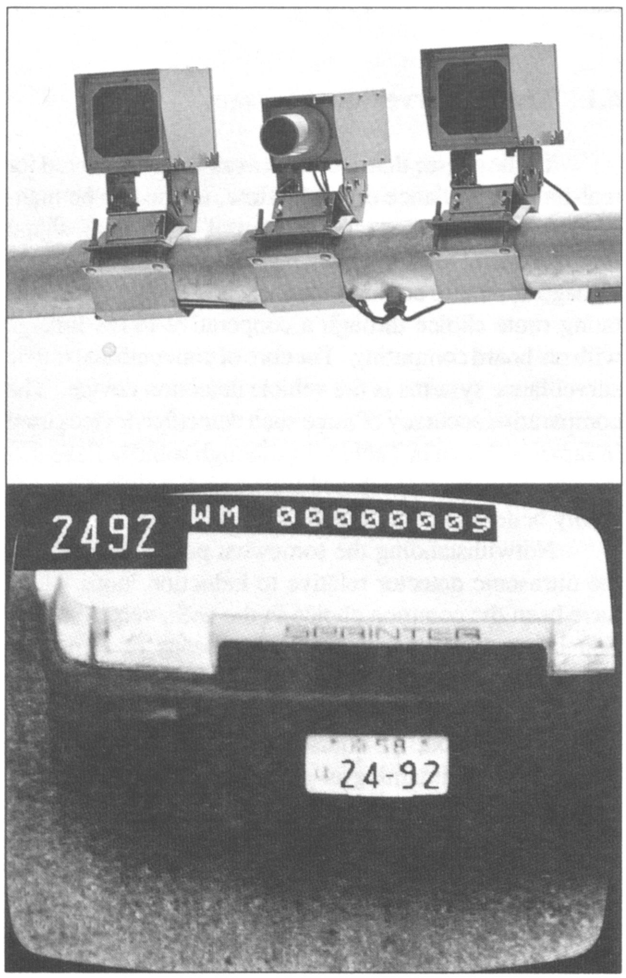

Figure 6.2 Infrared imaging equipment (above) used to produce the license plate image (below) from which the four large digits are recorded and later matched as a means of measuring travel time over major branches of expressway.

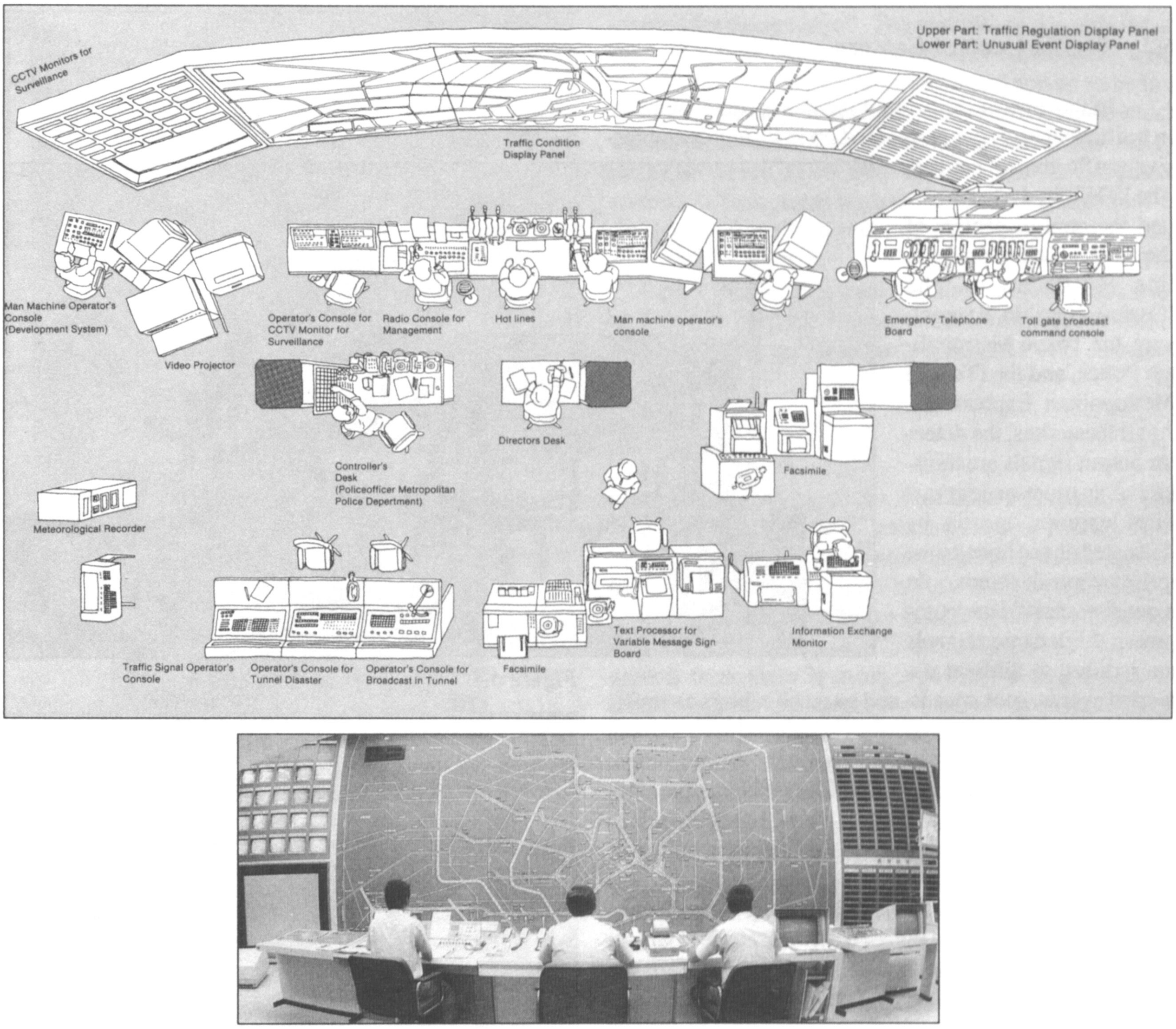

Figure 6.3 Traffic Control Center Layout and Display Board at the Metropolitan Expressway.

being employed to determine "spot speeds" which suitably characterize current "link-times" along relatively short sections of non-branching expressway. The ability to predict travel times over longer and more complex branches of the system is still "rather poor," however, and is the object of concerted development.

Notwithstanding the ambitious pursuit of link-time estimation capability using a network of conventional detectors, a number within the Japanese IVHS community hold the view that conventional technology will not suitably support link-time estimation as needed for cooperative (IVHS) route-guidance applications in Japan. Whether a much better traffic characterization can be extracted from conventional detection data using fuzzy and neural systems computation methods or other forms of artificial intelligence is undetermined.

The matter of network surveillance and link-time estimation is obviously a crucial question. If Japan's deployment of detector-based surveillance over the surface street system and the expressway networks does not fully serve the needs of IVHS, the achievement of the needed surveillance will burden the selection of Japan's new IVHS system architecture. At the same time, few in Japan expect to use vehicles as traffic probes. In any case, the resolution of the surveillance needs is a significant issue (and one that is to be addressed in the newly-formed VICS program, discussed in Section 7.3).

6.2 Traffic Control Centers

In some ways, the pride of Japan's accomplishments in traffic management is summed up in its highly impressive traffic control centers. The IVHS Study Team visited the control centers of the Osaka Prefectural Police Headquarters, the (Osaka) Hanshin Expressway, the Tokyo Metropolitan Police, and the (Tokyo) Metropolitan Expressway. At all these sites, the detector output signals are transmitted as more-or-less raw time histories, mostly by dedicated phone lines, to the traffic control center. In extensive mainframe computers, the detection signals are reduced to discreet detection events, spot-speeds, and so on. Findings on traffic flow across the network are then employed in two basic ways, namely:

1). as real-time input to the ATCS signal control algorithms, and thus, to control signal lights at surface street intersections and at the entrance ramps of expressways;
2). in illuminating a large display board in the control center (as shown in Figure 6.3), in response to which:
    (a) control room operators attempt to confirm the nature of incidents via remotely-controlled television cameras, where available, and other means;
    (b) emergency services are alerted as appropriate;
    (c) motorist advisory information is formulated; and,
    (d) traffic broadcasters, employed by commercial radio stations, also permanently ensconced in booths overlooking the control display; alert their listeners to the state of traffic.

The various traffic control centers distribute information directly to motorists using installed facilities, such as:
    (a) variable-message sign boards (see Figure 6.4),
    (b) variable-graphics sign boards (see Figure 6.5),
    (c) highway advisory radio (for which a driver-alert sign is indicated in Figure 6.6),
    (d) trip-planning aids provided in parking areas and certain rest stops along expressways (see Figure 6.7).

The traffic control centers which have been established across Japan vary in extent of detection network and the variety of services provided according to the size of the

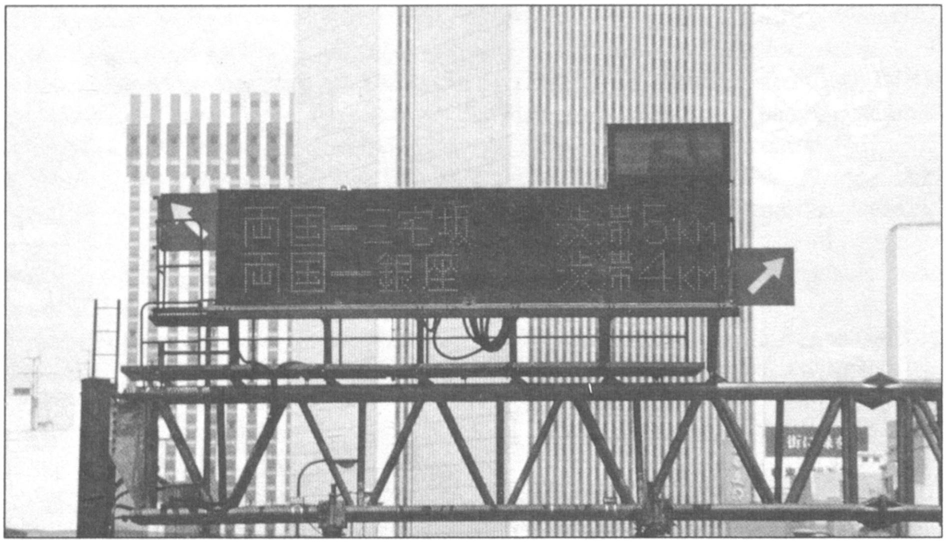

Figure 6.4 Variable-Message Board.

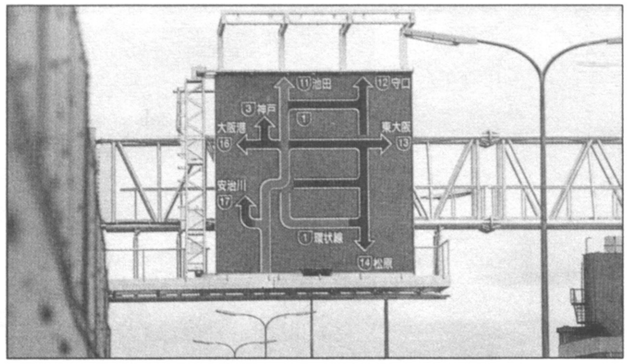

Figure 6.5 Variable-Graphics Board.

Figure 6.6 Sign alerting motorists to tune in for Highway Advisory Radio.

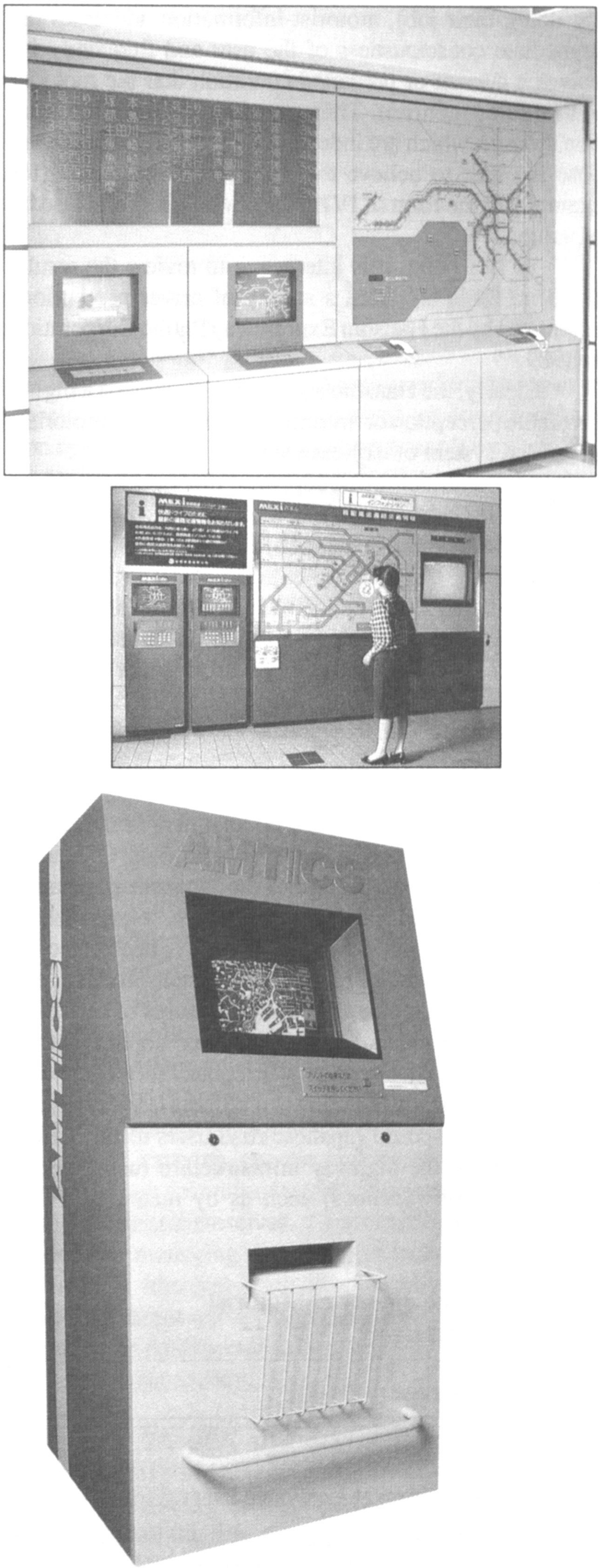

Figure 6.7 Traveler information stations—covering the Hanshin Expressway, Metropolitan Expressway, and the AMTICS Kansai experiment Area in Osaka.

community being served. The impression one gets is that the larger facilities are certainly well-funded and well-maintained. The available services also appear to be in a state of vigorous upgrading. Expensive workstations which were apparent in the two expressway control rooms seen by the IVHS Study Team were described as "development systems." These units were being used by Center staff to develop software in support of signal processing, traffic analysis and prediction, and motorist information. The example functions that were displayed showed that a wide array of advanced services are under consideration—some of which would appear to mesh well with IVHS concepts.

6.3 Signal Control

Since 1980, Japan has developed and implemented its own traffic signal optimization software. This package, known as Area Traffic Control and Surveillance System (ATCS), addresses the same basic wide-area optimization problem as is intended by the British SCOOT and Australian SCATS systems. ATCS differs in certain structural aspects from these systems, however, in that it was intended to deal with larger numbers of intersections in a single CPU while drawing from a somewhat sparser network of traffic detectors.[13] Nevertheless, Japanese presentation of the system shows that it addresses not only the real-time control of signal networks, but also a hierarchy of additional functions to support the broad activities of the control center, the development of the historical traffic database, and the long-term management of traffic control plans.

Interestingly, Reference [13] notes that the SCOOT system focuses its basic control strategy on optimizing lightly-to-heavily congested networks, adding special procedures when traffic becomes fully saturated. Japan's ATCS package, on the other hand, focuses its entire strategy upon the saturated end of the congestion spectrum as if it were the norm to be dealt with. Thus, we note that the ATCS system is another tool configured peculiarly to handle the unusually congested state of the Japanese road system. Although it is not known to have been applied anywhere outside of Japan, one could speculate that ATCS may find more application in the years ahead as other areas in the industrialized world develop the kind of saturated traffic conditions which are seen everyday in Japan.

6.4 Motorist Information Systems

As mentioned above, the traffic data collected and processed within each control center is typically employed in an extensive system of motorist information. The means of presentation include sign-boards shown in the earlier figures, highway advisory radio, and trip-planning aids. Such informational services are not restricted simply to urban areas. For example, some 3,000 variable-message signs are installed along and adjacent to the more than 3,000 miles of inter-city expressway. Nevertheless, the highest concentrations of motorist information devices are in the largest cities (with an average of four variable message signs deployed on the mainline or on approaching cross-streets per mile of expressway in Tokyo and Osaka).

One distinctive example of motorist information was seen by the Study Team in Toyota City. A group of some eleven parking structures in the central portion of the city are instrumented and centrally monitored for the generation of motorist information showing parking availability. Lot-status signs and even graphical signs highlighting advisory routes to available parking are provided along approach roads coming into the city as is an HAR service.

Another unusual aid is provided at twenty-two service centers adjacent to the Metropolitan Expressway system in Tokyo. The so-called "Mex-I-Robot," an automated inquiry terminal located in parking areas and shopping centers, allows the motorist to request the travel time between any origin and destination along the system. The terminal is driven by the link-time data which is made available from the paired spot-speed detectors throughout the MEX.

The unusual localized services, as well as the wide-area information systems, reveal that Japan has put a rather high emphasis upon the motorist-information aspects of its program. Accordingly, it seems useful to reflect upon the strategic significance that the motorist information experience may have in preparing the Japanese road user for IVHS. That is, a positive experience with conventional means of motorist information would seem to condition the road user to expect credible, useful services from those who are responsible for traffic management. Perhaps of even greater impact upon driver perceptions than the control of traffic signals, for example (where the individual motorist may have only a vague sense that traffic managers are doing their job), motorist information addresses the immediate consciousness of the user and frequently involves a current or predicted condition that the motorist will be able to confirm. Thus, over time, motorist information systems which are indeed of high quality will predispose the user to believe that further enhancements (for example, in the form of IVHS functionalities) will also be of value.

To this point, it is interesting to review the results listed in Table 6.2 from a survey of driver perceptions conducted by the Hanshin Expressway Public Corporation in 1989.[14]

Clearly, the Hanshin survey results suggest a highly favorable perception of information services by motorists using that system of expressways.

Moreover, it may be supposed that (a) a majority of motorists in Japan have had experience with motorist information services, and that (b) their experience is good. Further, along the intercity expressways and especially within the larger cities, motorists have been accustomed to seeing a steadily expanding variety of motorist information services over the last twenty years (such that road users probably expect continuing innovation in the future).

Associated with this general view is the observation that traffic control systems (and their information services to motorists) have been installed throughout Japan such that any concerns about equitable treatment of urban versus rural road users may be more-or-less moot. Of course, there is a rather small portion of the Japanese population that could be called truly "rural" anyway. Nevertheless, traffic control centers and sub-centers have been placed in every prefecture on the islands of Kyushu, Shikoku, and Honshu, and in about half of the prefectures of relatively undeveloped Hokkaido. Thus, it can be argued that the attention given to delivering traffic control services and, in particular, quality information to motorists is likely to have favorably predisposed Japanese road users to further enhancements of the highway infrastructure (using public monies and toll revenues) such as by means of IVHS implementation.

Table 6.2 Results of Survey revealing perceptions of the quality of Motorist Information System on the Hanshin Expressway

Question	Response
Do you use the (changeable message signs?)	95% said "very much"
Do you listen to roadside radio?	50% listen at least once every 2 trips
Do you use the travel time information signs?	84% said "always"
Are the travel time forecasts correct?	86% said "almost always"
Do you detour after obtaining (incident-advisory) information?	34% said "often" 53% said "sometimes"

7.0
A Capsule History of Organized IVHS Developments

In this section, the collaborative efforts in Japan to develop and increasingly deploy advanced driver information systems and other IVHS concepts are reviewed. The reader is also referred to the extensive literature documenting the individual programs [e.g., 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 39]. Instead of dwelling upon the technical details which are presented in the literature, the emphasis here is upon noting the nature of the work which has been done, its basic thrust, organizational arrangement, continuity, and expected future trajectory. The collaborative organizations themselves will be discussed in Section 7.1, albeit with topical reference to the technology projects in which they have been engaged. Subsequently, in Section 7.2, the individual projects will be briefly discussed with emphasis upon the apparent role each has played in the development of an IVHS consensus in Japan.

7.1 The Nature of Collaborative IVHS Organizations in Japan

The public agencies with managing authority over the collaborative projects undertaken in Japan were listed and discussed in Section 5.0. Three of these agencies have created separate not-for-profit *associations* for the explicit purpose of carrying out the collaborative activity in a manner which accommodates the bureaucratic constraints of the agencies themselves. Characteristically, each association has managing direction and technical staffing by individuals who had originally served within the corresponding parent agency. These associations are funded through fees paid by industrial members with subsidy from the sponsoring agency.

7.1.1 The JSK organization created by the Ministry of International Trade and Industry

The Ministry of International Trade and Industry (MITI) started the first major IVHS-type project in Japan called the Comprehensive Automobile Traffic Control System (CACS) (see Section 7.2.1). The system design in CACS involved two-way digital communications between vehicles and the roadside for obtaining cooperative route guidance.[16] Begun in 1973, the CACS program was funded by MITI and supervised by its Agency of Industrial Science and Technology.

At the close of this project in 1979, MITI created the Association of Electronic Technology for Automobile Traffic and Driving (known by the initials of its Japanese translation, Jidosha Soko denshi gijutsu Kyokai, or JSK) as a continuous facilitator of IVHS technology including interests in autonomous vehicle control (which are not within the range of current interests of the police, construction, and telecommunication agencies). The mission of JSK is premised upon the concern that electronics technology must help to address "the needs and pressures imposed on (society) by the ever-increasing use of the automobile." Thus the improved safety, congestion-relief, and overall transportation efficiency promised by the broad range of IVHS concepts fall squarely into JSK's interests, as do consumer issues associated with the ease and pleasure of driving.

This association counts fifty-seven companies among its members (including Bosch, General Motors, Mercedes-Benz, Philips, and Volvo from outside of Japan). A timeline of JSK activities through 1988 is shown in Figure 7.1. Perhaps a good summary of the MITI/JSK dynamic is that various IVHS technologies are "incubated" with a nearly seamless interface between MITI's own projects which are typically rather advanced, and the near-application programs (like AMTICS and RACS) headed by other agencies. Many of the industrial leaders taking roles in the NPA and MC projects also participate in forming and guiding the JSK program.

Clearly, a highly effective transfer of the learning from CACS through to the current VICS program has been facilitated even though the system architectures of interest in Japan have changed greatly. One can assume that the companies participating in these activities gained an increasing grasp of the associated technologies and of the institutional issues involved in working with the road and communications agencies. Nevertheless, CACS was an expensive exercise, costing some twenty-five million dollars in the mid-seventies using 1976 exchange rates (for a present value, if invested at 8%, around $86 million).[16]

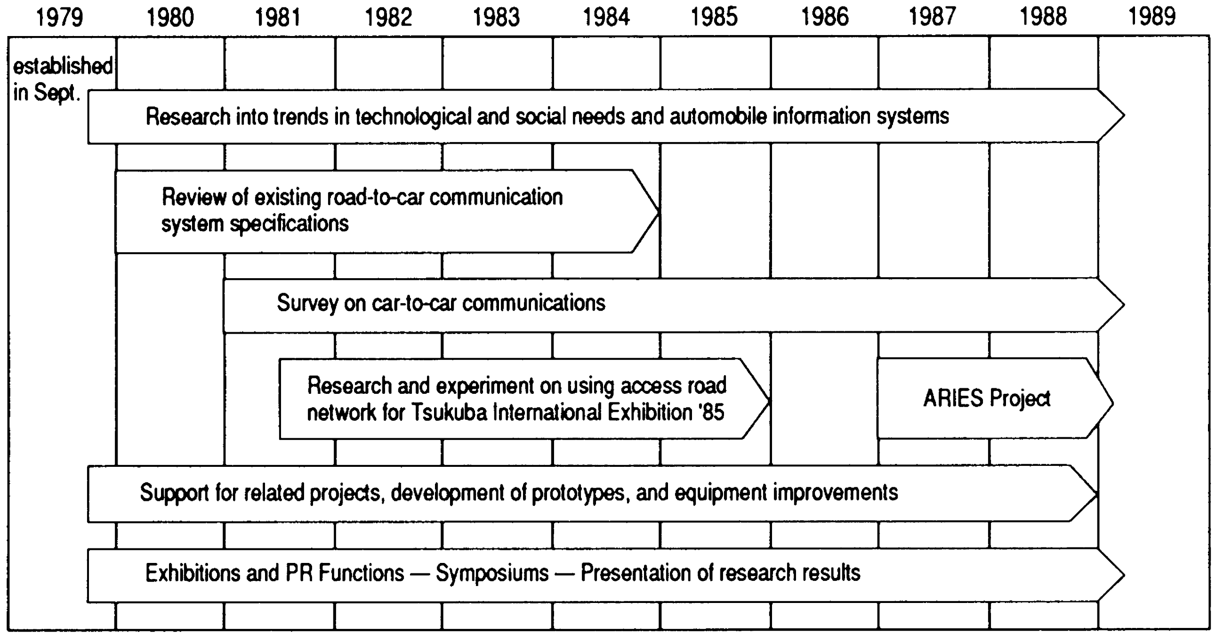

Figure 7.1 Timeline of JSK activities through 1988.

Obviously, this type of long-horizon research forces the partners to "stretch" their vision as well as their capabilities while getting a more realistic understanding of how to work with the other parties.

7.1.2 The HIDO organization created by the Ministry of Construction

While supervising IVHS-related projects through its Public Works Research Institute, the Ministry of Construction (MC) manages such activities through the Highway Industry Development Organization (HIDO). HIDO provides, again, the external association needed for collaborative involvement with industry and for combining industry funds with the Ministry's monies. HIDO became directly involved in IVHS in 1984 when the RACS project was begun. A total of twenty-five private companies participated in the project (by means of cash as well as the in-kind contribution of technology development, prototype construction, equipped vehicles, and so on).

Reflecting the fact that the MC supervises the expressway public corporations, the test site for the 1989 RACS experiment was placed along portions of the (Tokyo) Metropolitan and the Tokyo-Nagoya expressways. Further, both the architecture of RACS and the functionality it is intended to deliver reflect the MC's operational emphasis upon major highways and expressways (although RACS applies to the urban street system as well). Thus, for example, RACS was conceived with a localized two-way communication interface by which (a) vehicles can serve as traffic probes over the relatively long stretches of "rural" highway which are less well instrumented with detectors, (b) tolls can be collected automatically at expressway toll stations, and (c) FAX transmissions can be made to and from vehicles engaged in relatively long-duration trips. At present, all three of these particular functions are in jeopardy because of a denial by the Ministry of Posts & Telecommunications for use of the up-link microwave transmission from the vehicle to the roadside. Apparently, the MPT feels that insufficient justification exists, at least at present, for authorizing the microwave up-link. However this obstacle becomes resolved, it should be expected that the inclination of the MC (and, thus, HIDO) in matters of IVHS functionality will be toward motorist services and traffic management tools that are especially suited to the major highway/expressway system.

7.1.3 The DRMA organization created by the Ministry of Construction

In 1987, the association of companies working on RACS made the proposal that a digital road map database be developed covering all of Japan. A map standard was specified, and in 1988, the MC established the Digital Road Map Association (DRMA) as the mechanism for creation and future maintenance of the desired databases. Again, the association engages many industrial members together with the parent agency. In this case, the rational attachment of the association to this particular supervising agency was determined by the fact that the MC's Geographical Survey

Institute has long maintained general responsibility for the topographical mapping of Japan.

The digital road map now commissioned for automotive (and many other) uses represents a tremendous effort beyond the level of the large-scale topography which is available from MC maps. (The DRMA estimated a ten-year project to produce the national database needed to fully support route guidance functions[24]). The simple explanation for the DRMA's existence is that (a) the government and industrial users of the map database all insisted that the map format be standardized immediately, and (b) none of the influential parties wished to make a proprietary business out of the background database which is now charged to the DRMA. Thus, a long-term participative association for sharing the costs and the decisions on configuration was attractive. Members of the association are receiving copies of the current version of the DRMA database on magnetic tape for use in the development of application systems. As will be discussed in Section 8.1, individual manufacturers are producing enhancements which go well beyond the DRMA database to make proprietary navigation packages and other products more useful to the customer.

7.1.4 The TMT organization created by the National Police Agency

The National Police Agency supervises the Japan Traffic Management Technology Association (TMT) as its "extramural association" for developing IVHS technology and practices. In 1987, the TMT proposed the project entitled, "Advanced Mobile Traffic Information and Communication System" (AMTICS). In collaboration with the Research Center for Radio Systems which is an operating unit of the Ministry of Posts and Telecommunications, TMT undertook first a three-month pilot experiment in Tokyo in 1988, followed by a major demonstration of AMTICS in the Kansai district around Osaka in 1990.

Significantly, the makeup of the AMTICS architecture reflects, as with RACS above, the range of jurisdiction of the parent agency. In this case, the domain of the NPA covers traffic information and control on the surface street system—a network characterized by (a) relatively extensive installation of traffic detectors such that vehicles-as-probes are less important, (b) virtually no toll facilities such that spot-communication for the sake of vehicle identification and tolling is not sought, and (c) typically short trips (at least in distance, if not time) such that a high-bandwidth uplink for FAX transmission and other personal communications is less attractive. Accordingly, the current AMTICS system design involves only one-way transmission of digital information by means of a broadcast medium. Also, test sites for both the 1988 pilot test in Tokyo and the 1990 Kansai experiment gave coverage over dense networks of surface street systems as well as the urban expressways.

In carrying out its development of the AMTICS program, it is interesting to note that the TMT established three so-called "Conferences" to facilitate dialogue during critical phases of decision-making on AMTICS. The first, in 1987, was called the "Conference on the Practicability of AMTICS" and involved a consultation of 59 companies over a two month period, following which the Conference consigned study of the AMTICS concept back to the TMT. After completion of the three-month pilot study of the teleterminal communications system and ancillary elements, a "Conference on the Experiment of AMTICS" was established with the participation of forty-five companies. This latter Conference was convened for the duration of "The Kansai Experiment" of AMTICS whose field operations ran officially for the six months of a Garden and Greenery Exposition in Osaka beginning April 1990. The AMTICS Practicability Conference, now with fifty-eight member companies, appears to have addressed the evaluation of the Kansai experiment and discussed operational forms of the system that are suited to the commercialization constraints. It is at this stage that the RACS and AMTICS architectures are being reconciled by means of the new collaborative construct called "Vehicle Information and Communications System" (VICS), as discussed in Section 7.3.

It is difficult for an outsider to appraise the effectiveness of the "Conference" activities outlined here. Candid comments by persons involved in the process suggest that the Conferences have served not so much for effective evaluation of the experiments, but rather for maximizing the demonstration value of the work and for distributing information. In fact, there seems to be some concern that methodical evaluation of IVHS experiments is lacking, generally, in Japan.

7.2 Collaborative Programs

Using the organizational mechanisms which provide for collaborations, a number of joint projects have been undertaken to advance IVHS. Each of these will be discussed briefly below with emphasis upon the significance of the project to steering the overall movement toward IVHS in Japan.

7.2.1 The CACS Project

The first major IVHS project in Japan was the "Comprehensive Automobile Traffic Control System" (CACS) begun in 1973 and sponsored by MITI.[16] The project was remarkably ambitious and covered a six-year period of research and pilot testing. Twelve industrial companies participated in the study and produced the vehicle packages that were employed. The National Research Institute of Police Science of the NPA shared in the project as well.

CACS was an effective means of introducing a broad group of industrial and public organizations in Japan to the elements of driver information systems and real-time traffic analysis. Shown in Figure 7.2, for example, is an illustration prepared by Sumitomo Electric Co. tracing the parallel branches of development for navigation systems and traffic information projects back to this initial project.

The CACS system represented a highly centralized form of IVHS architecture with minimal intelligence on-board the vehicle. A two-way communication link was provided using in-pavement loop antennas situated upstream of intersections in the street network. The vehicle transmitted its ID and destination via digital coding over this inductive radio link. The roadside unit then communicated instructions for turning at the upcoming intersection based upon a stored "guide table" of routes from that point to any destination. The road links in the guide table were weighted to reflect the assessment of traffic flow that had been made possible by the use of vehicles as probes. In the CACS experiment, some 1,000 vehicles were equipped with a simple communication instrument to provide travel-time data as probes. Another 330 vehicles were equipped to receive route guidance and other information services.[16]

CACS was valuable for providing at least the following:

1) an early exercise in mobile digital communications;
2) the configuring of a traffic control center to interface with real-time digital communications (with associated involvement of public agencies who have since become leaders of IVHS in Japan);
3) early development of traffic-prediction algorithms based upon probing of travel time from the cooperative vehicle sample;
4) an experience in planning the structure of a mapping

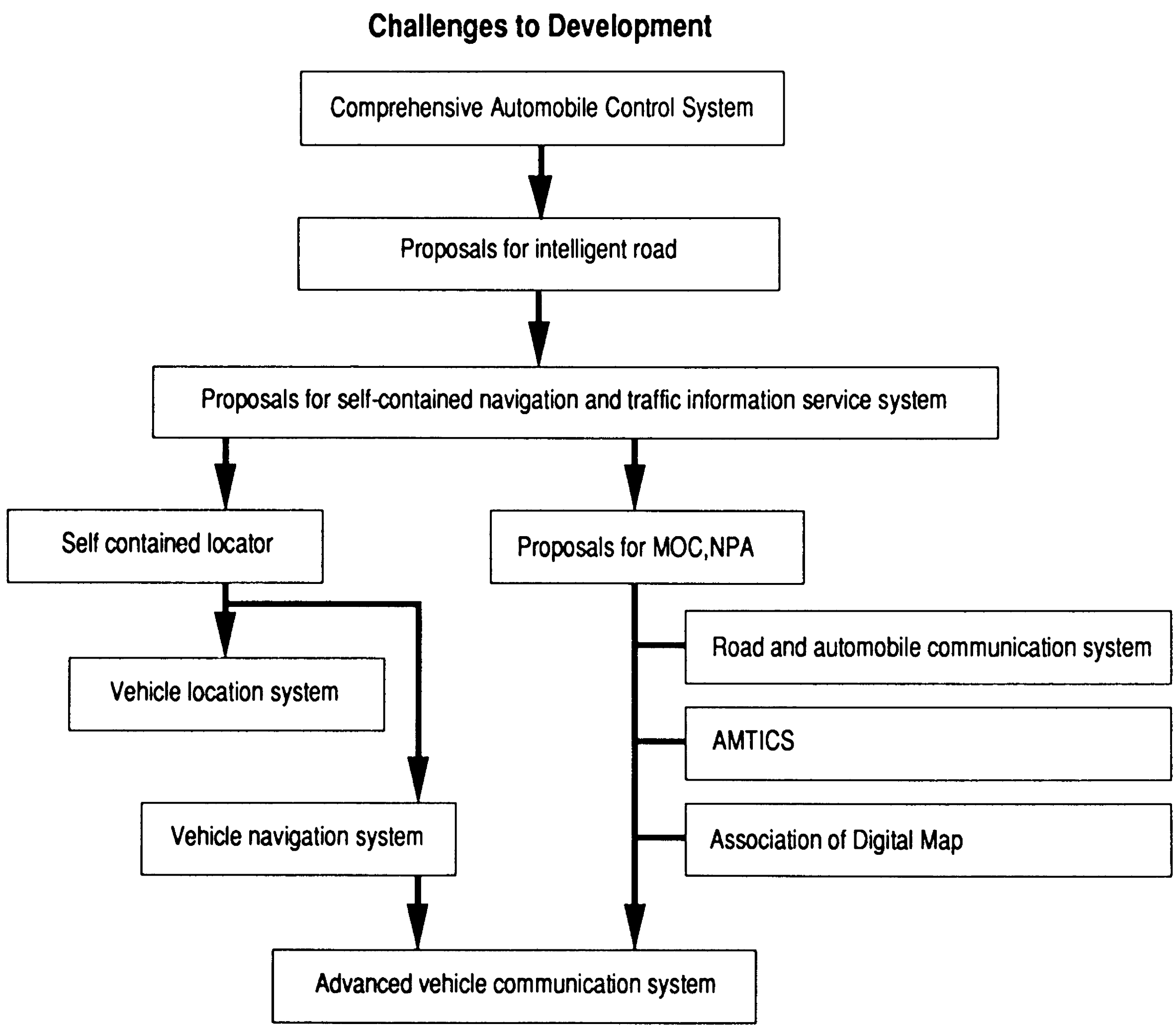

Figure 7.2 Flow of activity from CACS to the present (as interpreted by Sumitomo Electric).

scheme for representing the Japanese road system (albeit with a specific database developed only within the 11 sq. mile test site);

5) human factors experience with an in-vehicle display giving immediate turn instructions, lane advisories, and urgent messages;
6) monitoring of the deployment of a fleet of emergency vehicles and provision of signal preemption in their behalf;
7) a testbed upon which other experiments could be run (including a millimeter-wave communication link which was to explore the transmission of a fixed-frame video display from ground-to-vehicle. This broadband link can be looked upon as a precursor to the beacon communication medium used later in RACS);
8) a substantial experimental evaluation, with 1,000 trips conducted by equipped and unequipped vehicles between 7 pairs of origins and destinations (whose results showed that CACS afforded travel time reductions of 9 to 15%);
9) a limited exposure of the public to the concept of interactive systems giving real-time route guidance. (While the level of public awareness of CACS was probably minimal, the study team no doubt benefited from learning the opinions and reactions of the 300 "voluntary participants" who used the system.)

Although the CACS concept did not incorporate onboard navigation, its general architecture is very much like that of the Siemens Ali-Scout system. In both cases, a network of spot-communication devices serves to give route guidance by directing vehicles from one instrumented node in the network to the next. Both systems use vehicles as probes and weight the route selection on the basis of the system's surveillance of traffic status over the whole network.

As noted earlier, the JSK organization was created to follow-up on CACS and the new-found vision of cooperative systems. A new specification for the CACS communications interface was prepared and deployed for a six-month experiment on the road between the Tsukuba '85 Exposition and Tokyo.[25] The Tsukuba experiment was to examine the practicability of the inductive-communications interface, now operating at 9,600 bps and with enhanced signal modulation and coding schemes.

Clearly, CACS was a watershed for stimulating Japanese industrial and government interests in what has become a burgeoning IVHS process.

7.2.2 The AACS Project

At least from 1981 through 1987, JSK has conducted a variety of studies under its "Automobile-Automobile Communication Systems" (AACS) project. The project has not sought to produce a single system per se, but rather has explored the broad area of autonomous digital communications between vehicles in relatively near proximity to one another (at least partially analogous to the "handshake" communication between vehicles that is being explored in the European PROMETHEUS program). Communications using inductive radio, low-power UHF, and packet radio schemes have been reported.[26] Some twenty-one functions for automobile-to-automobile communications have been considered in this work, ranging from simple relay of traffic information beyond the range of spot communications at intersections, to accident-site warnings, emergency messaging, and even warnings to avoid head-on collision.

7.2.3 The AEDIC Project

JSK developed plans for a project entitled, "Advanced Easy Driving and Informatic Car" (AEDIC), although budgetary constraints prevented the project from going forward into a research phase. Examining the elements of the plan developed in 1987 and 1988, however, one notes many of the aspirations that have later appeared in the Personal Vehicle System and Super-Smart Vehicle System projects of JSK outlined later in this section.[26] The AEDIC plan is based upon the long-term view that increasing levels of intelligence must be employed within automotive electronics in the twenty-first century to better adapt the vehicle to an environment having increasing demands. Technology elements include improved displays, speech recognition and synthesis, increased friendliness through intelligent integration of user interfaces, assistance to improve the safety of elderly drivers, development of roadside database technology, a common gateway for communication to automobiles via several media, and high-speed information transmission among small in-vehicle modules. Even though AEDIC was not carried out per se, it figures as one of many exercises in which the technical community in Japan was structuring the conversation on IVHS technology.

7.2.4 The RACS Project

The Road Automobile Communication System (RACS) involves a beacon-based communication architecture providing spot-coverage of the road system through thousands of strategically-placed communication zones, each of which covers a 60-meter-long piece of roadway. The transmissions, in the 1-3 GHz microwave band, provide for highly localized functionality such as location-specific traffic messages and routing as well as toll-collection. Vehicle location can be precisely determined relative to the beacon such that on-board correction of navigation errors is affected at each beacon site. Because the transmission zone is so narrow, the link operates at a very high data rate of 512 Kbps in order to communicate a data volume up to 400 Kb with vehicles travelling at speeds up to 62 mph.

The high level of data capacity provides for FAX transmission as well. Because each equipped vehicle reports its travel time and distance covered since passing the last beacon site, the control center can deduce traffic flow over the inter-beacon distances.[22]

The RACS design departs fundamentally from that of CACS in that the vehicle incorporates on-board navigation and makes its optimal route selection by means of an on-board computation. The road map database is, of course, also kept on-board the vehicle using the CD-ROM storage medium. Since the whole map is present in the vehicle, it is straightforward to provide the driver with either global or highly localized display of traffic conditions. (Note that one complaint of drivers in the CACS experiment was that route guidance by means of turn-arrows only made operators uneasy.[15] The expressed desire for more global information seems to be confirmed in the continuing Japanese preference for map displays within the vehicle.)

In the RACS experiment, the Ministry of Construction's Public Works Research Institute provided for the deployment of a beacon network and the provision of real-time communication services. Twelve private companies participated in the fielding of nine different versions of in-vehicle equipment.[17] By this means, the RACS experiment served to educate many of the automotive and electronics companies that wished to sort out the technical, institutional, and market issues for navigation-based products which must interface with an architecture based on localized beacon communications.

As mentioned earlier, the Ministry of Posts & Telecommunications has ruled that the use of a microwave uplink from vehicle-to-beacon, as was intended in the original RACS design, will not be permitted.[27] Accordingly, without a reversal of this policy, there is concern that the limited functionality of a one-way beacon architecture may prevent its widespread deployment. In this context, it is interesting to note that a cost/benefit evaluation of the overall RACS design showed that the 185,000 beacons needed to cover the Japanese road system could be deployed at a cost around $1 billion.[21] Considering the case in which on-board equipment would cost around $1,250 per unit (in 1989 dollars), this analysis showed that the benefits in travel distance and time would exceed costs up to the point of 50% penetration of the vehicle population (after which, costs would begin to exceed benefits). If only the communication downlink is available, however, vehicles do not serve as traffic probes and the quality of the traffic flow assessment reduces to simply that provided by the system of hard-wired detectors. Thus, the magnitude of the benefits assumed in Reference [21] may not hold up as envisioned. Beyond that, of course, the many other benefits of a high-bandwidth spot-communication uplink are also out of reach.

7.2.5 The AMTICS Project

The Advanced Mobile Traffic Information and Communication System (AMTICS) employs in-vehicle equipment which is similar in many respects to that of RACS except for the communication interface. (Note in Figure 7.3, for example, that a Toyota diagram of its Electro-Multivision package shows that it can be supported by either RACS or AMTICS interfaces to its central computer unit.) The AMTICS data link is essentially by means of a one-way broadcast of traffic data from a cellular system of teleterminals operating at 900 MHz. The data rate from this transmission system is 9,600 bps. An uplink capability is also available through the teleterminal system, but no vehicle-to-central communication was required in the basic AMTICS design. A complete update of traffic and parking data for the Osaka area was provided by the broadcast scheme once per second early in the Kansai experiment, but was later relaxed to one update per minute at no sacrifice in serviceability.

The central costs for the original six-month Kansai experiment were cited as approximately $2.5 million, although costs borne by the many companies that provided in-vehicle packages are not included and are thought to have been much higher. An additional $800,000 has been provided for a continuation of the Kansai project in 1991 to determine the value of the AMTICS package for miscellaneous road users including police, fire, ambulance, utility companies, and taxis, in addition to private autos.

A survey of persons who had been introduced to the usage of AMTICS-equipped vehicles revealed the following (in 1990):

- 67% indicated that they were "very interested" in the system;
- 44% said that they want AMTICS functions "very much";
- 36% said that they found the AMTICS package to be "very usable" (or very effective);
- 3% were interested in purchasing AMTICS services at a package price of $3,300;
- 16% were interested in purchasing AMTICS services at a package price of $2,500;
- 70% were interested in purchasing AMTICS services at a package price of $1,600;

Both in AMTICS and RACS designs, the system infrastructure provided for absolute error correction in order to make on-board navigation sufficiently accurate. In RACS, a "location beacon," using a special modulation technique applied to a 2.5 GHz signal, located the vehicle within 3 feet of an absolute position. In AMTICS, a 13 GHz coded signal was received by the vehicle as a position update. Such provisions are not seen as absolute requirements in either architecture, however, since location correction "may become unnecessary if (the accuracy of in-

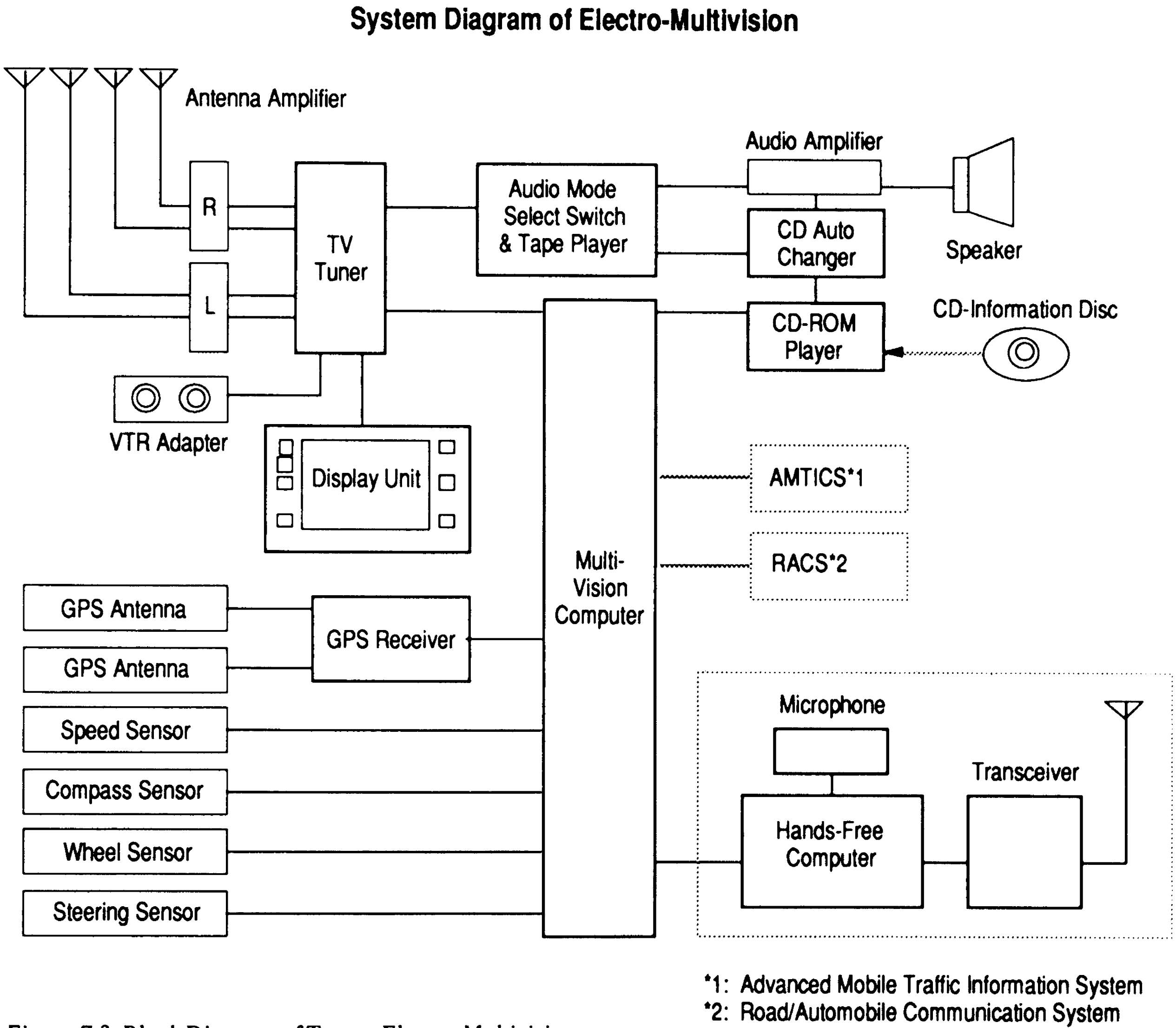

Figure 7.3 Block Diagram of Toyota Electro-Multivision System (showing general provision for computer interface to either AMTICS or RACS communication links).

vehicle navigation systems) is improved in the future."[18]

While it was expedient for the AMTICS project to employ the digital cellular teleterminal system, this approach may well yield to an alternative broadcast method in the next generation. The primary candidate in this regard is "FM multiplex" which offers a high data-rate downlink that, if incorporated in FM broadcast stations across Japan, would provide low-cost nationwide coverage (see also Section 8.4). Moreover, both AMTICS and RACS were seen as exploratory "vehicles" upon which a host of collaborating players could examine system-level and in-vehicle issues. Both projects are viewed as having been very successful even though neither will probably ever be built quite as prototyped during the 1988 to 1990 time frame.

7.2.6 The NeGHTS Project

The Ministry of Construction has initiated a new project under the management of HIDO called "Next Generation Highway Traffic System" (NeGHTS)—although the name seems likely to be changed—which is to extrapolate from the RACS project with a new emphasis upon safety systems. It is to address infrastructure enhancements, perhaps with cooperative dependence upon in-vehicle systems, and consider their deployment as part of a massive construction project to build the "Second

Tomei Expressway" running south from Tokyo to Osaka. The new highway will run extensively through tunnels and will entail various areas which are frequently foggy. Thus, innovative treatments of roadway lighting and fog warnings are to be considered among other candidate functions. As previously, the project will start with modest expenditures on feasibility studies and then focus upon specific technologies which show promise for large-scale experiments.

7.2.7 The PVS Project

A project to explore the feasibility of autonomous operation for automobiles was initiated in 1987 under the name "Personal Vehicle System" (PVS). The project was conducted by Nissan from 1988 to 1990 with funding from the Mechanical Social Systems Foundation which is supervised by MITI. A van was equipped with instrumentation for supporting autonomous steering and braking functions based upon stereo imaging, laser range-finding of obstacles, and ultrasonic sensing of adjacent guardrails. Fujitsu Ltd. provided the image processing system for deducing the location of road edges. A "fuzzy logic controller" was developed for the PVS vehicle in order to represent human behavior and provide a learning mechanism for gradually improved performance.[28] In later stages of the project, speeds up to 37 mph were achieved. Nevertheless, the imaging system struggled with anomalies posed by rain-covered and shadowed surfaces, and during nighttime conditions.

7.2.8 The SSVS Project

During 1991, MITI's JSK organization has begun feasibility studies on a very long-range project called "Super Smart Vehicle System" (SSVS). This project is looking toward major enhancements within the vehicle, perhaps with roadside complements, by which unusual levels of control assistance will be given to the driver. The subjects of the study are intended to cover accident recognition and avoidance, assistance to the driver's control manipulation task, and control supplements that may improve highway throughput. The outcome of such technologies would desirably be improvement in road capacity, increased safety and convenience, and greater ease of vehicle operation, especially by aged drivers.

It would appear that the SSVS project covers most of the functionalities that are identified within the "Advanced Vehicle Control Systems" (AVCS) portion of the American IVHS program.[1] (A Nissan engineer observed that the objectives of SSVS are similar to some of those in the PROMETHEUS program in Europe, while the NeGHTS project is closer to activities contained within the EC's DRIVE program.)

7.3 The VICS Phenomenon

Although this section deals with another collaborative program involving virtually all of the players engaged in the projects listed above, it is organized as a separate discussion because it is shaping up differently than the others. Namely, the "Vehicle Information and Communication System" (VICS) program was formed under the combined direction of the MC, NPA, and MPT agencies to establish a consensus on the architecture and operational practices for a cooperative driver information and routing system. Thus, it is not developing as another system demonstration project. Rather, it appears that VICS seeks to determine an architecture and associated protocols so that an infrastructure supporting this system can be implemented throughout Japan well within this decade.

To recap the setting, we note that the RACS and AMTICS projects arose from two federal agencies which have had a substantially competitive relationship with one another relative to highway matters. That is, the MC builds roads, but the NPA is in charge of traffic operations on those roads (with the exception, as mentioned earlier, that expressway operations are in the hands of the expressway public corporations). The competitive nature of the MC/NPA interaction is characterized in a joke that goes like this: The MC will say to the NPA, "you can put up a signpost, but not if you have to dig a hole." The NPA will say to the MC, "you can put up a beacon, but not if you have to close a traffic lane" and the MPT chimes in that either one of them can put up a beacon or a signpost so long as no electromagnetic radiations come out of them. Perhaps the reader finds it refreshing, in a lame sort of way, that at least some things are the same all over the world!

Notwithstanding the bureaucratic traditions, a number of people remarked to the IVHS Study Team that the competitive nature of AMTICS versus RACS was probably the best thing that could have happened for the Japanese IVHS program. Since both projects ran more or less simultaneously, there was an obvious element of pride in making each one very productive and as polished as possible. Nevertheless, with a need to focus the national effort toward a compatible Japanese architecture, there is a common view that the time for competitive development of infrastructure designs is past. Thus, the VICS program convenes the most thoroughly integrated of all Japanese collaborations since the IVHS process began in the early seventies.

The formal launching of VICS began with one-day conferences in Tokyo on March 1, 1991 and Osaka on March 4, 1991. The IVHS Study Team was privileged to attend the Osaka meeting on the first day of the study mission to Japan. The conferences' main event was carefully orchestrated such that leading persons from the MC,

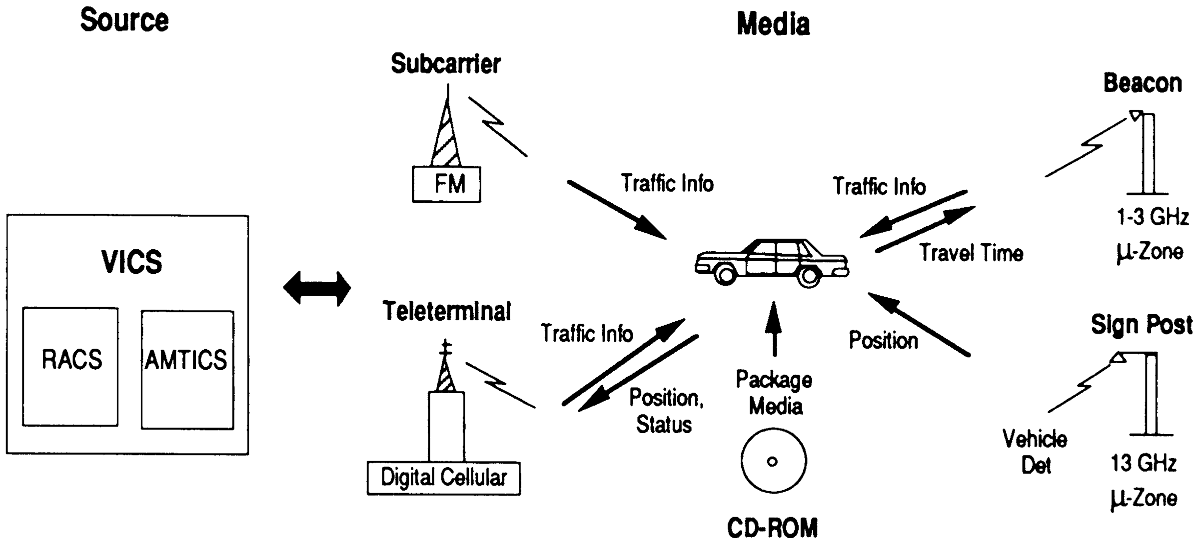

Figure 7.4 Diagram of candidate elements from which the VICS collaboration will determine an architecture for an advanced driver information system.

NPA, and MPT were all placed together on the same podium. Each, in turn, acknowledged that they were committed to a cooperative effort to "amalgamate" the AMTICS and RACS approaches into one harmonious system. Apparently, professional custom in Japan is such that a public pronouncement under these circumstances virtually guarantees that the needed cooperation will, in fact, occur. In their respective remarks, both the MC and the NPA representatives were rather tuned to the issues of user costs and market assessment, suggesting perhaps even a trial period using rental packages at different cost levels in order to assess the users' financial thresholds. They also cited the need to expand the functionality of the national system to add safety warning features that were present in neither AMTICS nor RACS.

Of significant concern to both the MC and the NPA is the need to consolidate traffic surveillance data being generated on the expressways by the MC-supervised corporations and on the surface streets by the NPA-supervised traffic control centers. Another aspect of the traffic surveillance issue pertains to the ability to assess travel times along the links of the network. Regarding the latter, there seems to be a general desire to both further expand the deployment of conventional ultrasonic detectors and vigorously pursue improved means of speed sensing—recognizing the less-than-ideal speed characterization that comes from a network of detectors installed to support intersection signal control.

As for communication media, Figure 7.4 illustrates that VICS will consider the possible future use of the 900 MHz teleterminal system, FM Multiplex, microwave beacons, and signposts. Nevertheless, the candid view is that the teleterminal is all but eliminated as an option because of its relative cost, where currently installed, and because of the impracticality of gaining complete nationwide coverage using such a cellular grid. As mentioned earlier, there is also a current exclusion by the MPT, of the uplink transmission from vehicle-to-beacon via a microwave link. As suggested by the figure, the provision of a road database via CD-ROM is more or less a "given" in the VICS deliberation, even though lower levels of system functionality can certainly be obtained without a high-resolution map database.

Moreover, it has been proposed that the VICS collaborators settle on the elements of a national system for driver information and routing by 1993. The expectations from VICS have been characterized in an interesting context by Sumitomo Electric, as shown in Figure 7.5. Titled the "Synergy Effect of VICS," the pair of timelines indicate that, while the early market success of static navigation products has encouraged the development of a communicating infrastructure; the rapid deployment of that infrastructure in the mid-nineties is expected to result in greatly magnified sales of in-vehicle equipment—first for receiving congestion information, then travel time data, and later robust personal message services. The general argument is that the emergence of navigators stimulated a spiral of activity which will have broken free of the chicken and egg syndrome and resulted (via VICS) in a widely deployed, multifunctional infrastructure within this decade.

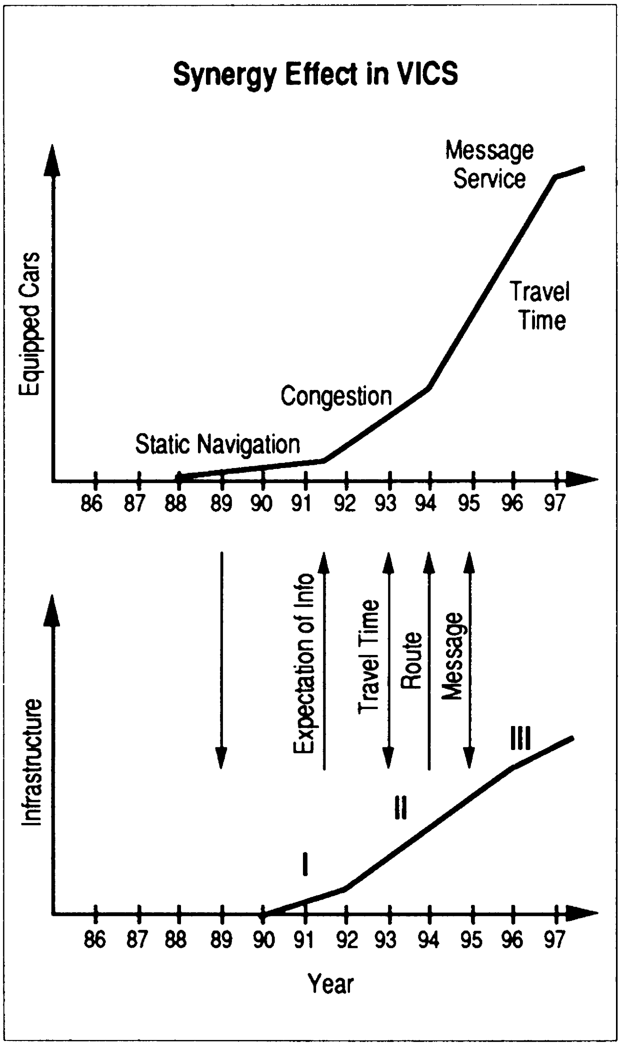

Figure 7.5 An illustration by Sumitomo Electric of the synergy which is occurring between the deployment of IVHS infrastructure and the marketing of in-vehicle products (to be accelerated strongly by the agreements expected from VICS).

7.4 Conclusion from these Programs

Having briefly summarized the many IVHS collaborations in Japan, one is struck by the following:

1) the role of MITI in stimulating a very long-range vision and nurturing its development through stages in which high levels of corporate investment would be financially unjustified;
2) the opportunity provided for many industrial players to develop internal capability through the highly-leveraged mechanisms of these projects;
3) the peculiar willingness at each stage to proceed ahead with a certain "project technology" without excessive hand-wringing and cost/benefit studies on the front-end. That is, each of the litany of projects involves a plausible design which was considered *carefully, but not extensively,* at the outset. The premise seems to be, "we have so much to learn, we simply can't lose by selecting a plausible system and running with it." In short, it's learning by doing;
4) a complementary blend of problem-solving—on the part of mission agencies concerned with the public good—and product development by companies seeking to find new markets;
5) the important role played by the early commercial success of in-vehicle navigators in catalyzing a determined thrust toward a nationwide infrastructure to be agreed upon through the VICS program.

Although the thrust of CACS, Tsukuba, AMTICS, and RACS are all toward driver information and routing, with apparent closure on a national architecture to come shortly, it is reasonable to assume that Japanese development of driver control assistance and the many other forms of AVCS (to use the American acronym) will also proceed with an increasing pace in the future. Recognizing that the inexorable rise in highway demand will continue to put heavy stresses upon the MC and NPA agencies in the foreseeable future, and that industrial companies are already well into the subject; the prospect for many and varied collaborations on advanced controls seems certain.

8.0
Observations on Elements of IVHS Technology

The intent of this section is to give a run-down of modular technologies being developed, and in some cases marketed, for IVHS in Japan. Again, the discussion is in no way an exhaustive coverage of Japanese technology nor is any particular subject considered in technical depth. Rather, taken together as a sort of collage, it portrays movement beyond the research and demonstration mode and into current or pending markets. The discussion covers the subjects of map databases, the CD-ROM interface, communications media, navigation devices, in-vehicle displays, traffic predictions, safety technologies, automatic control systems, human factors, and "spin-off systems." While the last two items are somewhat odd within this list of technology modules, they are added as important complements to a consideration of the overall state of IVHS in Japan.

8.1 Map Databases

As indicated earlier, the Digital Road Map Association (DRMA) was created in 1988 to produce and maintain the digital road map of Japan for use in IVHS and other applications. A database covering the so-called "Basic Road Network" in all of Japan was generated by DRMA in 1989 and has been used as a resource in the creation of proprietary databases for automotive navigators. (The Basic Road Network is comprised of all roads classified as prefectural level and higher as well as all municipal roads whose width is at least 5.5 meters.) The DRMA data file covers some 160,000 miles of road by means of a node-and-link structure including road attributes which identify the administrative designation, access type, physical class, traffic volume classification, and traffic regulatory constraints for each road, as well as major landmarks associated with certain links. The first version of this file has a volume of 300 Mbytes.[24]

While this database serves as the basis for display and route-searching over major roads, its maximum scale of 1/25,000 is not generally sufficient for conducting a map-matching type of enhancement to navigation. Thus, individual automotive and electronics manufacturers have undertaken to create their own databases to support map-matching. Sumitomo Electric, for example, has developed a 1/2500 scale coding of all roads in the ten urban areas shown in Figure 8.1. The added map detail also incorporates landmark details for display and, perhaps eventually, the detailed regulatory attributes needed for route guidance (although there is substantial disagreement in Japan as to whether the latter feature will be widely implemented). It is noteworthy that Sumitomo Electric incorporates 3 million nodes in its 1/2500th scale

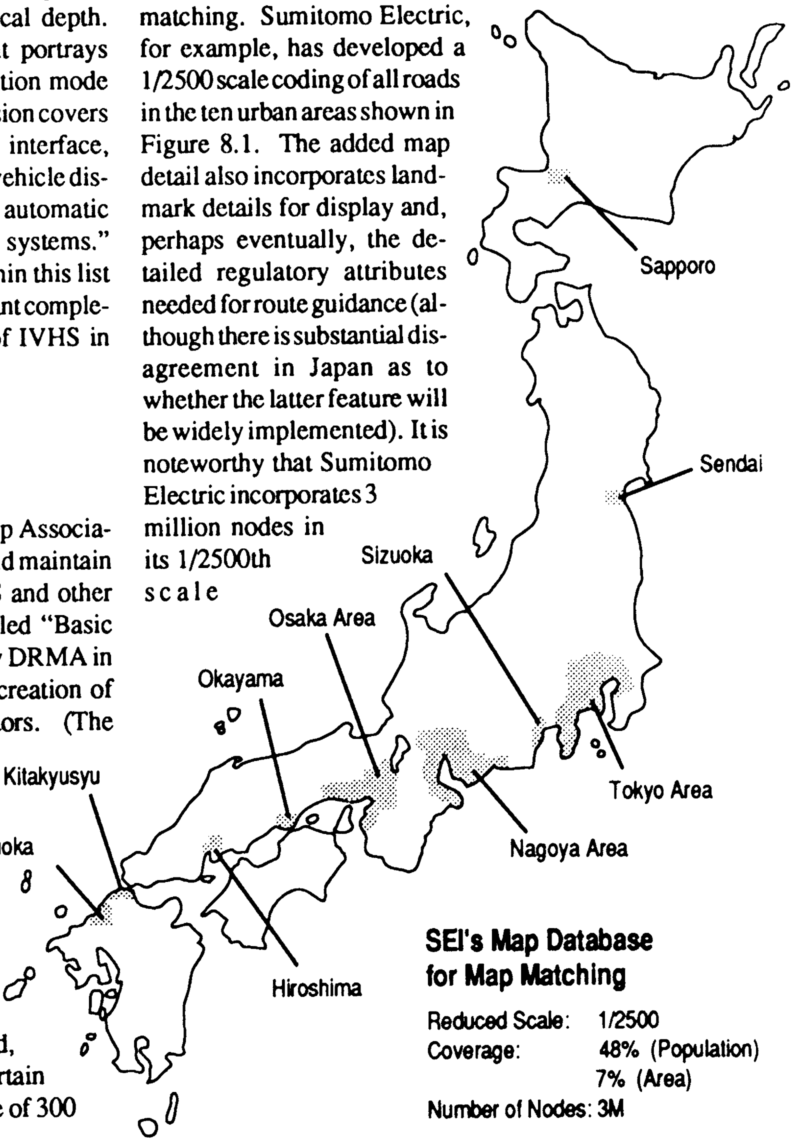

Figure 8.1 Japanese cities digitally mapped at a scale of 1/2,500 by Sumitomo Electric.

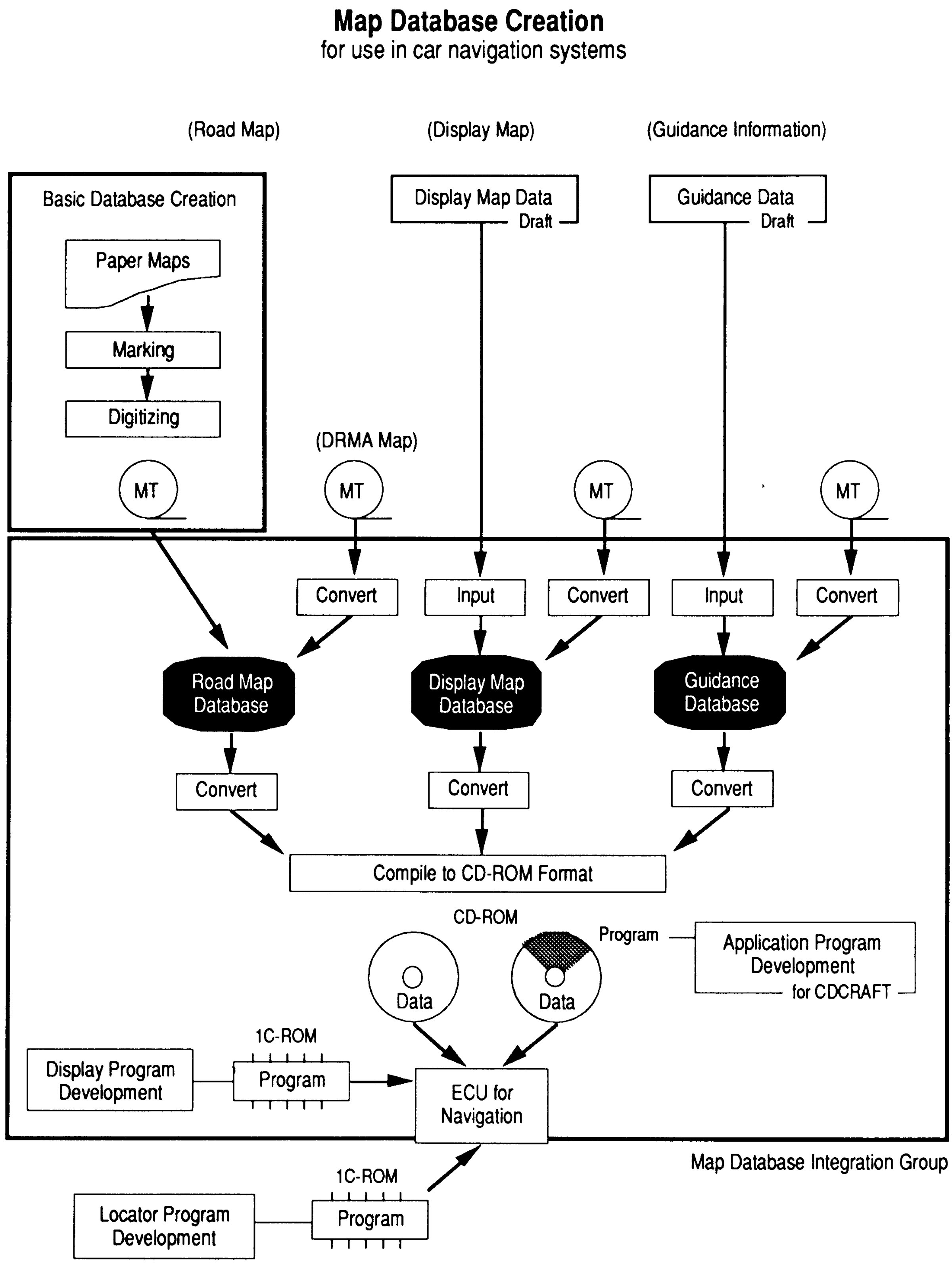

Figure 8.2 Flow chart describing Sumitomo Electric's program to develop a map database.

coverage of the ten major cities, whereas the DRMA's Basic Road Network of all Japan involves only 0.35 million nodes.

Shown in Figure 8.2 is a flow chart illustrating the steps which Sumitomo Electric has taken to create their map database. The upper left of the figure shows the "road map" itself providing the data set upon which navigational computations are based. To produce the high resolution data covering the major urban areas, a large effort was carried out by a Sumitomo team located in Okinawa to produce digital coding from paper maps provided by city planning departments. These data were combined with the DRMA file to produce the overall road map database.

Also, supplementary databases were generated for display and guidance functions and were formatted for recording on a CD-ROM. The display data provides for visual presentation of the map picture at three levels of scale. The guidance data represent the coordinates of special facilities such as railway stations, golf courses, hotels, ferry ports, etc. which are recognized as popular destinations. This feature has unusual significance for making automotive navigators feasible in Japan since the country's address system is very complicated and does not make explicit use of the street name as in the U.S.[29] Thus, one uses the navigator, typically, by selecting a known landmark which is nearby the actual destination or a node locating a nearby intersection. Then, when the screen displays an image of the map surrounding the location of the facility or node, the user can, hopefully, identify the specific nearby site toward which he is actually headed. To date, no navigator can direct you to the front door of any site in Japan which is not one of the popular destination facilities, or a street node, because of the address conundrum.

When the IVHS Study Team was hosted by Sumitomo Electric, the map-integration activity at an office in Osaka was visited. Extensive confirmation of the integrated map data was being undertaken including steps to ensure con-

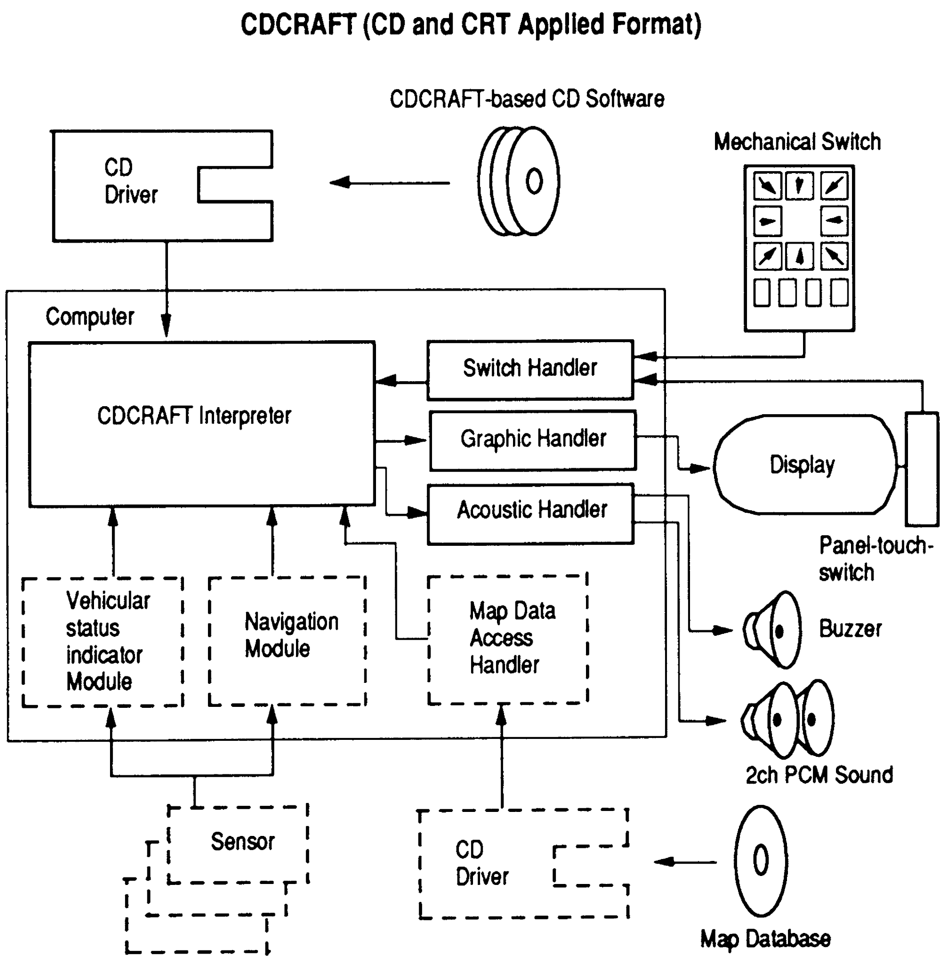

Figure 8.3 Block diagram, provided by Sumitomo Electric, showing the CDCRAFT convention for interfacing a vehicle navigation system with application software and a map database introduced via CD-ROM's.

tinuity of road coverage, visual examination of all display details, and direct usage of the finished data set in emulations of the navigation process. One is struck by the enormity of both the original task of generating the data and the implied effort to maintain it on an ongoing basis.

Toyota likewise informed the IVHS Study Team of its development of a detailed database as a major enhancement beyond the DRMA data. Toyota's CD-ROM of map data and application software is an integral element of its navigator package (manufactured by Nippondenso and sold in a multi-function Toyota option called, "Electro-Multivision"). The CD-ROM carries a Toyota part number and can be purchased, with updates every two years, from Toyota dealers.

8.2 CD ROM Interface

The CD-ROM, with 600 MB capacity, is seen by the Japanese IVHS community as the preferred mass storage element for map databases and application software. In order to define the interface between application software borne on CD-ROM's and various on-vehicle equipment, Japan developed a standard called the "CD and CRT Applied Format" (CDCRAFT). This convention is seen as the central "interpreter" within an example system diagram in Figure 8.3. The CDCRAFT interpreter handles multiple interfaces for input/output devices, computational modules, and CD drivers that support navigation and other in-vehicle functions. The CDCRAFT specification has cleared the way for the intermingling of a rich variety of both application software and hardware modules produced from differing manufacturers. (An analagous standard was proposed in the U.S. by Honey, et al.[30])

8.3 Navigation Devices

Clearly, the major success story of an early IVHS market is that of the navigation instruments being sold on Japanese cars, beginning with Toyota's introduction of its "Electro-Multivision" system in 1987. Shown in Figure 8.4 is a diagram of navigator production (and prediction) provided to the IVHS Study Team by Toyota. The retail cost of each of the Japanese systems is also listed on the figure. Sumitomo Electric, which produces the navigators being sold by Nissan and Mitsubishi, has indicated that it expects the price to drop from $2,350 to around $750 by the end of this decade. An example installed navigator is shown in Figure 8.5.

The first navigation system being sold in Japan incorporated a dead-reckoning computation only, and thus, required frequent manual resetting by the operator. Kawashima[15] estimates that the drift errors in such dead-reckoning devices are on the order of 5 to 10% of the travelled distance—up to 500 ft. per mile. American visitors, while impressed with the market leadership of Japanese industry in introducing navigation products so quickly, have marvelled at the willingness of the Japanese buyer to accept the low level of functionality that resulted with dead-reckoning only. Of course, to some degree, the driver may still value even an approximate tracking of

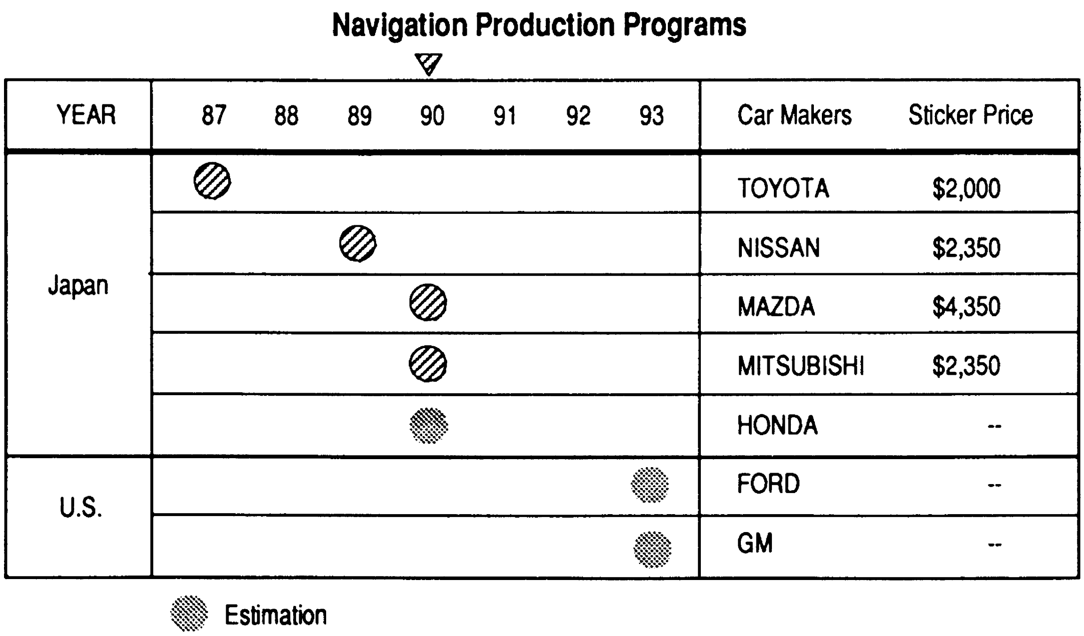

Figure 8.4 Production of Navigators in Japan (and expectations for introduction in the U.S.), courtesy of Toyota.

Figure 8.5 Photo of navigator screen installed in RACS experiment vehicle (with illustrations, from top to bottom, of screen display for traveler service information, guidance, and vehicle location on the map).

position when in unfamiliar areas. Nevertheless, one frequently hears that the typical buyer has been a corporate executive who simply orders the vehicle "loaded" with options. His vehicle may even be driven by a chauffeur who knows the road system very well and never actually relies upon the navigator function. Thus, it is portrayed that a large fraction of the approximately 200,000 navigation units that have been sold from 1987 through 1991 have been purchased by an unusual group of customers, many of whom have not rigorously evaluated the product. It is difficult for one to determine the extent to which the sales success of these products to date foretells a favorable market among customers who will be keenly interested in the navigator's functionality.

Later-coming navigators have incorporated map-matching capability at somewhat greater cost. The map-matching function is supported when travelling in those major cities for which the denser map data had been completed.[31] In such systems, of course, the incidence of errors requiring manual resetting of the navigator are much reduced. In navigators sold up to early 1991, the driver was "guided" only in the sense that one's current location and that of the selected destination (landmark) were highlighted by icons on the street map. When the destination lay off the displayed map, a bold arrow appeared at the edge of the screen to indicate the compass heading toward the destination.

In May of 1991, Toyota introduced an advanced Electro-Multivision system with dead-reckoning/map matching/absolute error correction via a GPS (Global Positioning System) receiver. The system also computes a specific route to the destination and highlights the route on the displayed map.

Shown in Figure 8.6 is a plot provided by Toyota characterizing the respective accuracies provided by dead-reckoning, map-matching, and GPS. The figure shows that map-matching accuracy is about 20 meters, but map-matching cannot "initialize" the vehicle's coordinates at start-up—and dropout can occur whenever the map database is missing a piece of road. Absolute location backup is thus provided by GPS with an approximate 70-meter accuracy, but occasional dropouts can occur when occlusions, especially around the tall buildings in urban Japan, prevent acquisition of the needed satellite signals. The bottom line is that for a total navigator price of approximately $3,000 in 1991, the new Toyota system affords "hands-free calibration." Estimates of the total production rate in Spring 1991 of navigators by Toyota and the other automakers in Japan were around 7,000 units per month.

The issue of absolute error correction with automo-

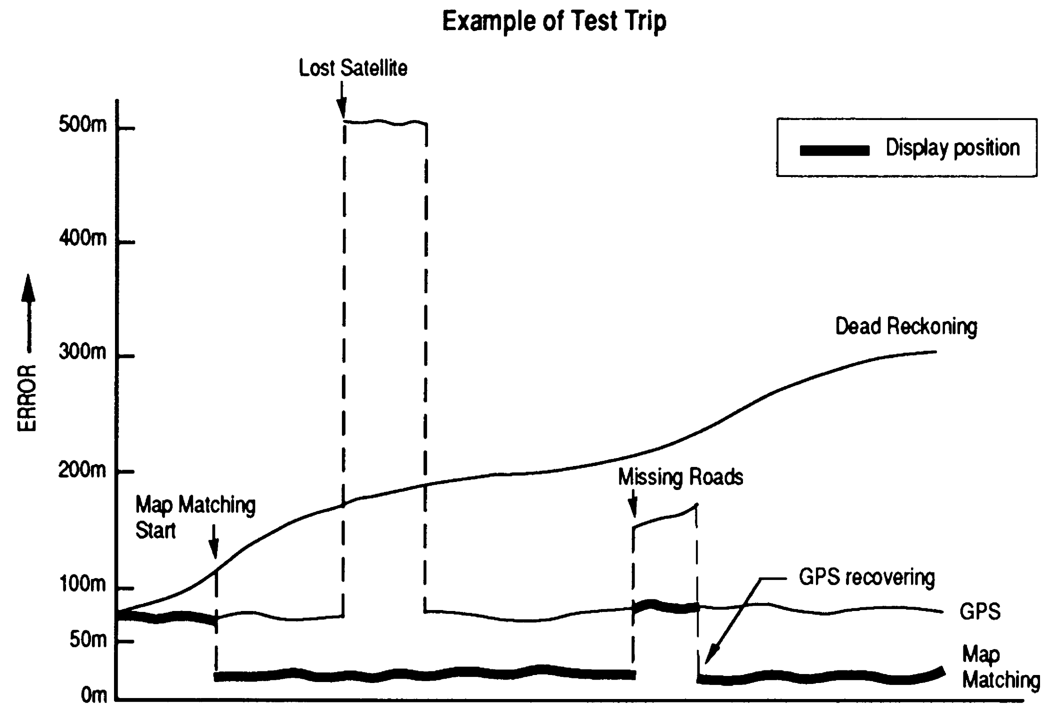

Figure 8.6 Illustration of error characteristics for dead-reckoning, map matching, and GPS elements of the 1991 Toyota Electro-Multivision system which incorporates GPS for absolute correction of location.

tive navigators is at the root of a lingering architecture question being considered in the VICS program. Namely, the placement of signposts in the AMTICS system and "location beacons" in the RACS architecture were for the sake of providing absolute correction. While a GPS receiver can effectively provide the absolute correction mechanism, there is some concern over the long-term availability of GPS (whose satellites are ultimately under the control of the U.S. Department of Defense) and there is a basic issue of the economics of the privately-purchased GPS receivers versus publicly-installed signposts. The VICS deliberation will resolve at least the near-term Japanese position on whether to provide an error-correcting infrastructure or simply expect that in-vehicle equipment will be suitably error-free.

8.4 Communications Media for IVHS

A broad variety of radio data links are under consideration for application to IVHS in Japan and elsewhere. Japanese demonstration experiments have employed two-way inductive radio in the CACS program, two-way microwave transmission in the RACS program, and a 900 MHz one-way data broadcast in the AMTICS program (which could also have supported full duplex communications if needed). While there has been a consortium of companies gathered to build a network of the 900 MHz teleterminals to serve a broad variety of applications, there seems to be little expectation in Japan that this system will be adopted by VICS. On the other hand, the Ministry of Construction maintains a strong interest in deploying the microwave beacon. There is also an expectation that a large number of the estimated 40,000 traffic detectors to be added to the existing network throughout Japan in the next few years will be microwave devices capable of giving absolute location data and an increasing set of dynamic information to a passing vehicle. The beacons can also employ a speed-sensing function which is to enable a more careful assessment of link travel times. The fact that such devices will provide data communication obviously requires microwave receivers in vehicles (a version of which will be actually sold to the public on some new Nissan models beginning in the summer of 1991).

As a relatively new development, there is a strong emerging interest in FM multiplex which can provide a nationwide system using the virtually unused sideband capacity on the nationally-owned FM stations throughout

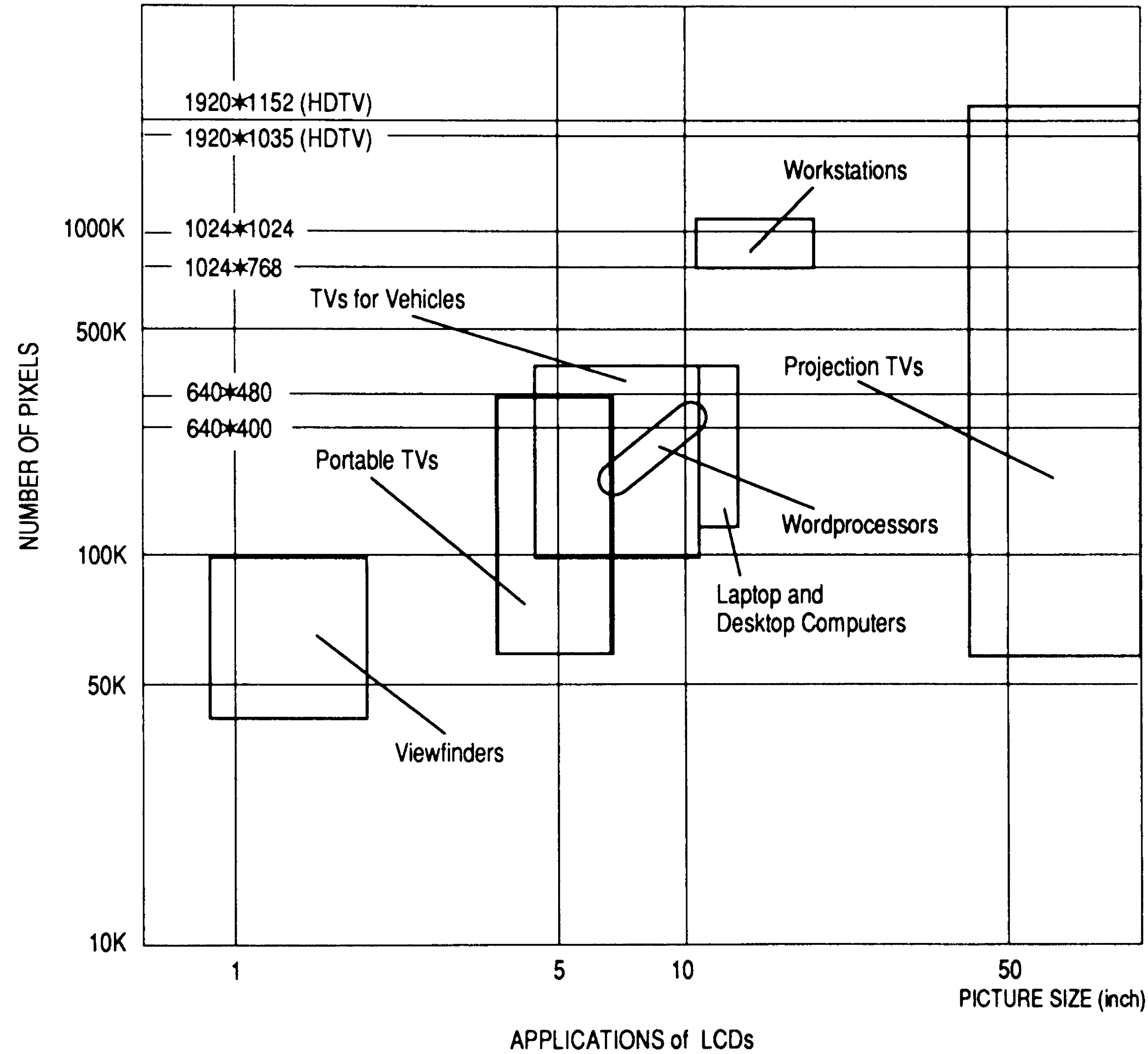

Figure 8.7 Graph showing the domains of size and pixel count which correspond to various LCD product applications (provided by Toshiba).

Japan. The cognizant entity, the Japanese broadcasting organization known by its Japanese acronym, NHK (for Nippon Hoso Kyokai), operates the stations and is eager to see fuller utilization of their sideband capacity through IVHS and other applications.

NHK has developed special schemes for digital modulation and error correction to gain a high delivery rate through FM multiplex for the mobile environment. Currently, a data rate of 9,600 baud is assured and rates of 12 to 15 Kbps are being studied. The data throughput is said to reflect the net rate accounting for loss factors in mobile reception which reduce the 45 Khz bandwidth of the FM subcarrier to an effective value of 35 KHz or so. If the primary function of an IVHS data broadcast is to transmit link-times covering a metropolitan road network, the 9,600 baud capability would appear to be more than adequate. This is especially apparent if link-times are to be updated only every minute or so and if the transmitted data include only those link-times which have changed substantially over the last minute (i.e., data by exception).

Interestingly, NHK currently offers round-the-clock television programming which is paid for through a directly-collected "tax" from all television owners. This rather unique taxing authority is noted by some as a possible means of financing the costs of a communications infrastructure serving IVHS. While the FM sideband modulation is inexpensive to install as an enhancement on an existing entertainment station, the implicit cost will rise in the future as increasing demand for all communication capacity causes the value of the FM sideband resource to rise.

Recognizing the possibility that both a broadcast data link and localized communication beacons could be deployed, it should not be surprising that some auto manufacturers in Japan are already making contingency plans for dual receivers as the basic in-car communication device. A few of the veterans of Japanese IVHS programs indicated to the Study Team that they fully expect such dual-mode communications to be implemented for the long term.

8.5 In-Vehicle Display

There is a definite preference in Japan for a high-resolution video display device within the vehicle. One reason for this predisposition is the popularity of in-vehicle entertainment television, albeit displayed when the vehicle is stationary. Apparently, many car owners in Japan spend substantial amounts of time in their cars while they are parked—and during those periods they enjoy watching television. Another curious cultural phenomenon which can be supported by an in-vehicle video display and CD-ROM, is "Karaoke" (meaning, literally, "empty orchestra") which provides a sing-along display. The suggested scenario is of a Japanese husband staying entertained in the parking structure while his wife is shopping. She spends while he sings!

As was indicated earlier, there is a general view that the motorist receiving navigation assistance (especially if it involves guidance along a specific route) prefers to see the overall map, at least in a preview sense, while stationary. The vehicle designer can also multiply the functionality of a video screen by using it with a touch overlay to provide access to the cellular phone and climate controls, as well as warnings, maintenance information, and other services. Thus, one can assume that there will be a very high usage of in-vehicle video displays in upscale cars sold in Japan.

Both CRT and LCD devices are currently being employed to support automotive navigators. LCD technology, in particular, is undergoing intensive development for a host of applications as illustrated in Figure 8.7. The Figure shows that LCD's in the 5-to-10 inch size for vehicle usage will benefit greatly from the various other product families whose anticipated future markets help to finance development and reduce individual production costs. Shown in Figure 8.8 is Toshiba's projection of total production for LCTV's in Japan. A total of 1.4 million units per year for vehicle usage is projected by 1995. Further, by that time, the cost is expected to be reduced (to about $150 for a 6-inch unit) due to an overall production

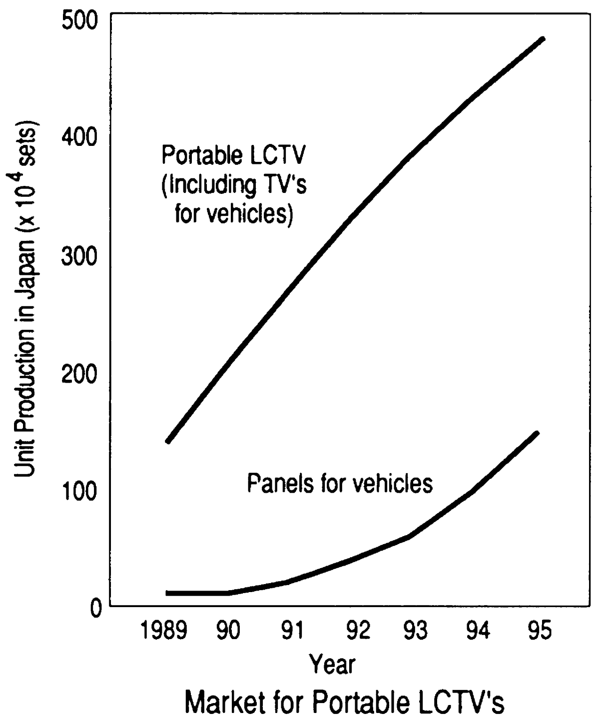

Figure 8.8 Projected growth in Japan's production volume of LCTV panels (provided by Toshiba).

volume near 5 million portable LCTV's.

One version of the LCTV that offers flexibility in packaging for either after-market or OEM installation is the Toshiba concept that is sketched in Figure 8.9. The 4-inch screen is contained in a package which is just over 1 inch thick and fits into a push-to-release hideaway enclosure.

Beyond displays mounted in the dashboard area, there is interest in application of Head-Up Display (HUD) approaches for presenting limited pieces of information to the driver. In its implementation of a navigator enhancement within the RACS program, Nissan developed a HUD presentation of upcoming turn instructions showing the vehicle's suggested path overlaid on a simple graphic of the lane layout. Nissan reported to the IVHS Study Team that its research showed the HUD arrangement removing one third from the driver's "recognition time" relative to the time required using the same display material in a center-dashboard location. Nissan also showed a laboratory set-up for studying the extent of sight obscuration occurring when the motorist needs to perceive a roadway feature directly in line with the HUD image.

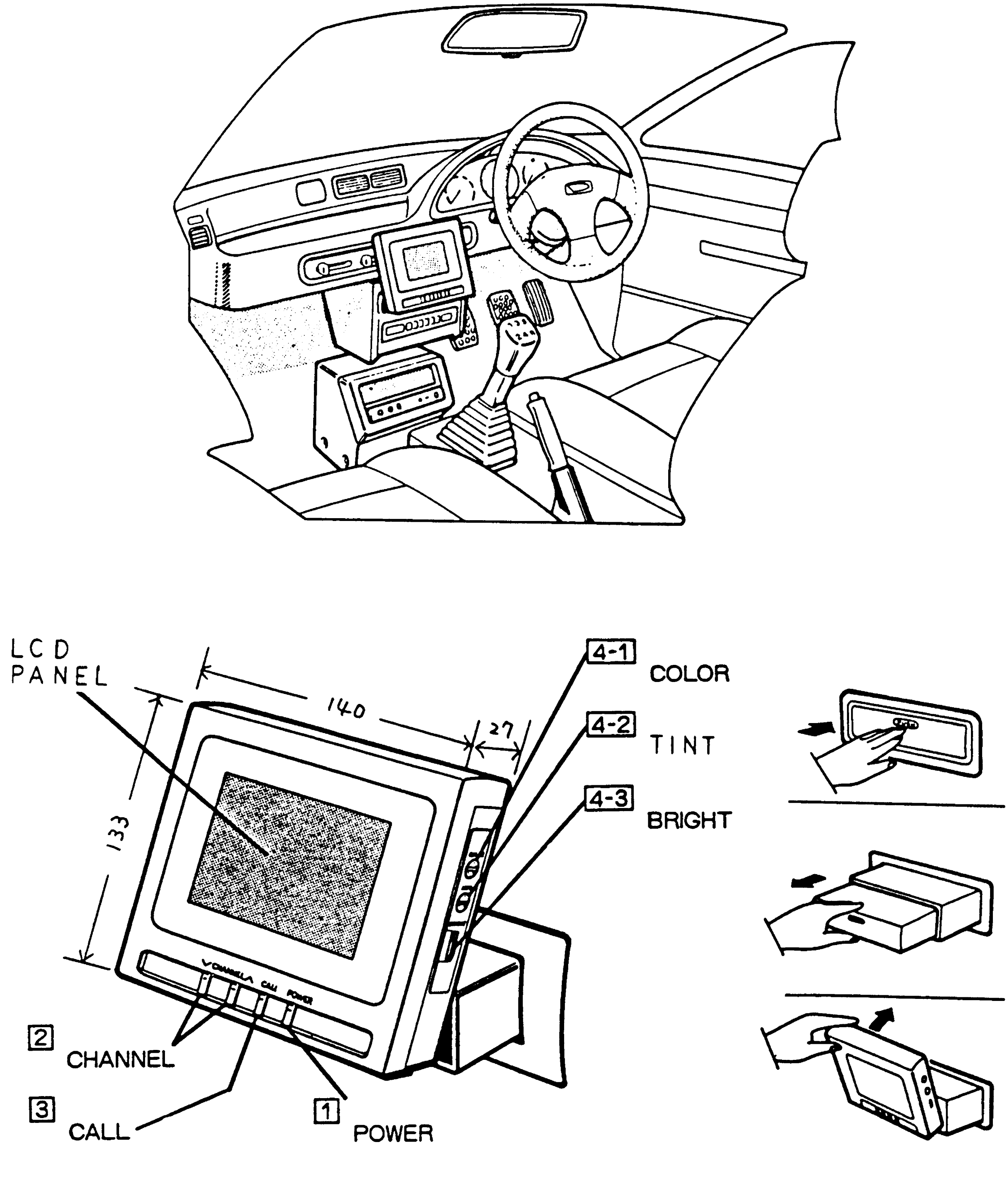

Figure 8.9 A hideaway packaging concept, by Toshiba, for a 4-inch LCTV device.

8.6 Traffic Prediction

There is broad recognition in the Japanese IVHS community that a central requirement for any advanced motorist advisory or route guidance system is the ability to predict link-times across a large metropolitan network of surface streets and expressways. For the general case, in which either incidents on the network or the commuting transient create rapid changes in traffic flow; predictions of future, as well as present, link-times become essential for providing optimal advice or guidance on routing. In this regard, it is noted that the original network of detectors which have been placed to support signal control on surface streets is not well suited to system-level predictions of link-times (in part, because vehicles are frequently stopped under these detectors, waiting for a red light). Thus, the detector data must be averaged over rather long time periods in order to deduce general flow characteristics. Nevertheless, some success has been shown in predicting travel times along individual arteries using existing detectors.[32] Also, as mentioned earlier, the Hanshin and Metropolitan Expressway systems offer rather good quality estimates of travel time covering major branches in their urban networks. The latter estimates are based upon either spot-speed assessments or the actual clocking of individual vehicles going into and out of each branch using automatic imaging of license plate numerals.

A brochure printed in 1989 by the Metropolitan Expressway Public Corporation showed that they were engaged in developing a one-hour prediction of traffic based upon immediate traffic monitoring, current and historical trends, and overall system modelling.[33] Other experts in the Japanese traffic engineering community, however, suggest that the quality of such predictions is still far short of what is needed for effective route guidance.

One deficiency in the ability to model traffic in Japan (or elsewhere) is the absence of a good current origin-to-destination characterization of travel behavior. Thus, an IVHS architecture that provided for tracking vehicles as probes (such as the original RACS design with duplex beacon communication) would provide the added advantage of long-term OD characterization as the core database which is needed for operating a high-quality traffic model. Such matters are of current concern to those who are seeking to achieve link-time prediction across the road system of Japan.

8.7 Safety Technologies

There is a distinct interest within Japanese auto manufacturing organizations to develop products which offer advanced safety protection. The author is struck with how parallel these interests are to those of the European manufacturers engaged in the PROMETHEUS program. Namely, there appears to be a rather high level of interest in Advanced Vehicle Control Systems much as have been defined as "Stage 1 AVCS" functions by Mobility 2000 in the U.S.

When the IVHS Study Team visited the Toyota Technical Center in Toyota City, the corporation's outlook included the following expectations for control enhancement:

1) active **subsystems** (like semi-active suspensions, 4-wheel steering, antilock, etc. already rising in popularity since the late 1980's);
2) **integration** of vehicle systems in behalf of safety by 1995 (covering obstacle detection and lane sensing; incorporating the monitoring of steering, braking, and throttle actuation, turn signal activation, etc. within an intelligent safety warning algorithm);
3) **advanced actuators** by 2000 (incorporating drive-by-wire actuators which achieve some forms of autonomous control—the most likely of which appears to be automated headway control and rear-end collision avoidance).

Toyota made reference to GM's Trilby project as a corresponding effort to develop such advanced electronics-based functionality in the U.S. They also noted, however, that their own expectations for items (2) and (3) above, involve nearer time frames than the U.S. projections of market penetration (that have appeared, for example, in the University of Michigan's Delphi survey on IVHS[34]).

Relative to item (1), Toyota researchers showed data illustrating how antilock, traction control, 4-wheel steering, 4-wheel drive, and active suspensions together extend the vehicle's maneuvering envelope to the virtual limits of prevailing friction. The envelope is described in terms of the full ellipse of lateral and longitudinal accelerations in the ground plane. The argument is that current technology enables us to realize the full maneuvering limits which friction affords. What remains is to build an intelligent supervisory layer above the controls, and eventually automate the control actuation to achieve optimum timing and trim.

Relative to item (2), Toyota anticipates that the integration of multiple on-board sensors within a centralized package for intelligent safety warning and perception enhancement will require a high-speed LAN for linking all the elements and will depend in certain ways on the advanced driver information systems that will be maturing within the same time frame.

Regarding item (3), several examples of partial and fully-autonomous operation were presented. While stimulus in this area has come from government sponsorship of the PVS and SSVS projects, it is clear that individual manufacturers are proceeding with their own in-house research. Toyota showed videotape of autonomous vehicle operation using both cooperating lane markings and other non-cooperative system features. A headway control system was seen to adapt reasonably to rapid intrusions by other vehicles into the headway space. Relative to cooperative roadways, Toyota researchers showed a strong interest in exploring infrastructures to support safe control features on the vehicle. They consider such infrastucture more feasible within Japan than elsewhere; because of the relative simplicity of institutional jurisdiction and the economics of a more compact, but already very expensive, road network.

Similar interests were seen during the Study Team's visit to Nissan's Central Engineering Laboratories in Oppama. Nissan has developed and marketed, on a limited basis, a Laser radar system for warning of frontal collisions. The system is said to have been upgraded with considerably improved software and beam pattern since it was evaluated by the U.S. National Highway Traffic Safety Administration (NHTSA).[35] Being currently applied in a field trial on one hundred Nissan Diesel trucks in the Tokyo area, the system costs around $3,500 and detects laser light reflecting from the corner-cube geometry within the tail lamp lenses of preceding vehicles. The processor determines range and range derivatives with the driver manually selecting a preferred band of headways (near, medium, and far) which are varied with forward speed. Nissan anticipates that systems for rear-end collision warning, such as they are currently marketing, will be offered domestically by most Japanese automakers by 1995—a timetable which is approximately five years ahead of the Delphi projections for a U.S. market.

8.8 Automated Highways

If one were to extrapolate the discussion in Section 8.7 above into the future, a vision of fully automated highways would likely emerge. Nevertheless, no explicit interest in full-blown highway automation was noted either on the Study Mission or in the Japanese technical literature. For this discussion, "full blown automation" might be characterized by a highly cooperative central infrastructure which supervises travel on the automated network while a distributed architecture controls ingress/egress, platoon formation, etc., and the high frequency control of immediate position and headway is done autonomously within each vehicle and between more-or-less adjacent vehicles. Over this range of functionality, the thrust of Japan's automation interests seem to be currently focused upon the last item; whereby the vehicle autonomously controls its immediate movement and, perhaps, conducts near-term path planning.

Such interests are certainly revealed in the PVS project conducted by Nissan and in Toyota's in-house research. Whether the SSVS project leads to the broad system's questions embraced by full highway automation remains to be seen. In any case, the general subject of advanced vehicle control systems is certainly being pursued, but action on automated highways is not evident.

8.9 Human Factors

There appears to be a general need in Japan for applying the discipline of engineering psychology to the development of IVHS products and systems. The IVHS Study Team saw repeated reference to the need for human factors (HF) expertise, although few direct examples of HF activity were noted. In more than one industrial facility involved in the development of navigators, there were no HF professionals on the staff.

By way of exception, one study of the relative friendliness of on-board navigators was reported by Nissan (although it is presumed that other OEM's conducted similar studies). Nissan's experiment was conducted using multiple vehicles and competitive navigators. Each unit was graded by the frequency and dwell time of glances which the driver required in consulting the map screen during different modes of vehicle and system operation. On the basis of such experiments, Nissan and other manufacturers recommended a guideline for HF assessment of on-board navigators to the Ministry of Transport. An evaluation method was agreed upon. Observations of human interaction with navigator screens has led to a general industry practice of eliminating the smaller streets from the display while the vehicle is moving. Nissan also reported enhancement of screen legibility through careful selection of displayed colors.

Relative to voice interaction, there is obvious interest in speech recognition functions for facilitating driver inputs to information systems. As for audio instructions, however, Nissan expressed concern over voice-based route guidance because of an artificial sense of authority that becomes associated with the human voice. The concern is that drivers may respond to turn instructions without due care for immediate road conditions and obstacles.

On a similar vein, the members of the IVHS Study Team learned from Toyota that the display of a specific suggested route by the new Multi-Electrovision system is provided with the implicit assumption that the driver is still completely responsible for noting all prevailing road signs. Where a regulatory sign conflicts with the suggested routing (such as in one-way and turn restrictions), the driver must overrule the navigator and adopt a legally-allowed route. Such conflicts are more-or-less likely since the current map database contains no turn-restrictive attributes. The American reaction to this situation, of course, is to blanch at the implications for tort liability.

This particular technical detail flushes out an essential point. Namely, while there is plenty of evidence that Japanese auto manufacturers are keenly interested in safety improvements and advanced safety products for their vehicles; there appears to be a different calibration, contrasting with U.S. manufacturers, on the level of responsibility that can be assumed for the driver. The matter is obviously explained by the fact that all of the IVHS products under production in Japan are presently for domestic sale only, and tort liability in Japan is essentially a non-issue (also see Section 9.1).

8.10 Spin-off Systems

It is an implicit part of the IVHS vision that, while cooperative infrastructures may be rationalized on the basis of specific in-vehicle devices and specific functionalities, the prospect of real-time data communications with motor vehicles will open the door to a variety of unexpected and perhaps profound innovations. While it is still very early in the Japanese IVHS process to confirm this expectation, a couple of examples do suggest that many levels of opportunity are likely to be explored.

When the IVHS Study Team visited the Toshiba Research and Development Center in Kawasaki, both organizational and product innovation were found to be underway. A newly-created unit called the Automotive Systems Division had been formed to reposition the company for marketing systems-level IVHS products, and thus, emerge from the role of providing only components to automotive assemblers. One early example of this unit's activities is the "AMTICS Radio," illustrated in Figure 8.10. A physical sample of this device was demonstrated. It is essentially an after-market alternative to the complete navigator package seen in the AMTICS-equipped vehicles. The device involves a lap-top computer which is outfitted with a teleterminal receiver to accept the AMTICS link-time broadcast. The road network of interest, for example, in metropolitan Tokyo, is represented by a map database stored within the device. After the user enters current location and destination, both a graphical display of congested streets and text information are presented on the LCD screen. The device can be used for trip planning by individuals or fleet dispatchers, or could alternatively be carried within a moving vehicle. It represents an example case wherein a manufacturer looks at an infrastructure and says, "What else could we do with that?"

Another interesting example was seen at the Aisin-Seiki Head Office in Kariya. Shown in Figure 8.11 is the "G-Map," a GPS-based navigator which has been available as an after-market system through Toyota dealers in Japan since December 1990. The navigator is unusual in that one selects a route beforehand with the aid of a standard paper map, and then receives route guidance

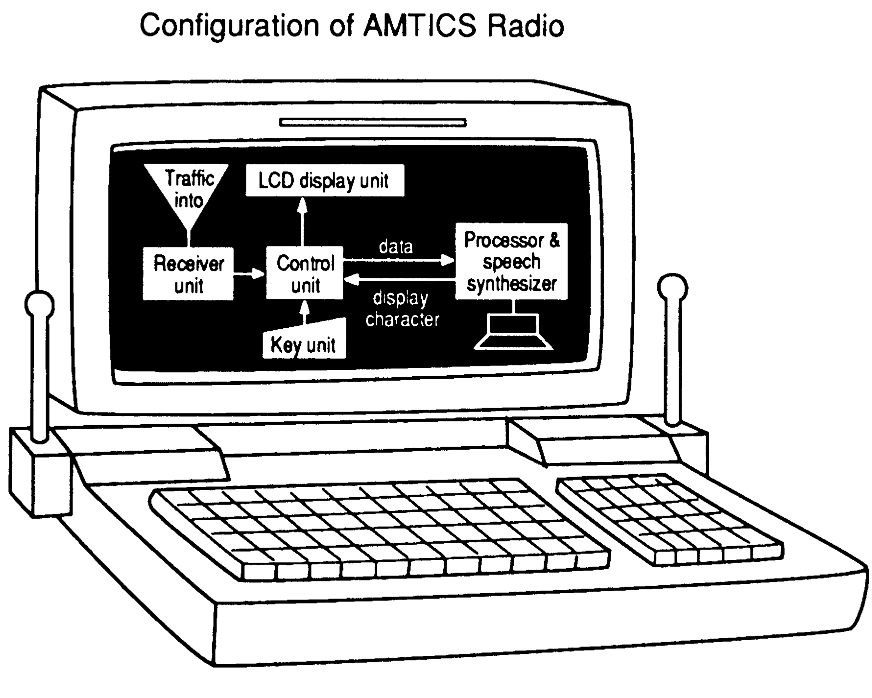

Figure 8.10 General configuration of Toshiba's prototype "AMTICS Radio."

Figure 8.11 G-Map Display unit, at left, constituting an aftermarket GPS-based navigator built by Aisin Seiki and marketed through Toyota dealers.

while underway. The map pages of interest are inserted within an X-Y digitizing frame which is illustrated in Figure 8.12. The route is characterized by points which are downstream of each intersection at which a turn is required. The coordinates of these match points are entered into the system's memory by means of tracing points on the paper map with a stylus. When an "enter" button is pushed, the stylus interrupts the LED array that surrounds the digitizing frame, thereby registering the point coordinates in a route memory.

When driving, the motorist observes a dashboard display indicating the distance to the next match point and the compass heading to that point, based upon GPS location to within 100 meters. As the turn approaches, the distance indicator on the dash shows that a turn is imminent and the compass heading becomes clearly oblique to the direction of travel showing which way to turn.

On the one hand, this package may seem somewhat demanding of the user in its current embodiment, and the human factors of the display show room for improvement. Nevertheless, it represents a major departure from the map-display navigators and it offers a number of innovative, attractive features. Ninety units at an installed cost of $2,300 had been sold to the public in the first three months since delivery to Toyota dealers.

Most importantly, the AMTICS Radio and G-Map navigator serve to remind us that an unpredictable, entrepreneurial spirit is likely to surround IVHS development. The spirit will be prompted by the many new avenues of opportunity that may have never been charted and by the short development time for products that depend primarily upon software and microcircuitry.

Figure 8.12 Package of G-Map components showing, upper right, a Standard Road Map inserted within the LED Digitizing Frame, for entering reference points comprising a desired route.

9.0 Application Issues

The IVHS concept involves new products and systems which become employed within an existing legal, economic, and social environment. In many fundamental ways, the applications are steered as much, or more, by this environment as by the technology upon which the hardware is based. In this section, each of a set of application issues will be touched upon as they appear to influence IVHS implementation in Japan. While many of these items have been mentioned within the preceding text, they are collected here for summarization of the issues.

9.1 Traffic Safety and Tort Liability

The safety quality of newly-manufactured motor vehicles in Japan falls under the jurisdiction of the Ministry of Transport. While the MT has played an apparently minor role in IVHS-related development so far (such as in approval of navigators from the viewpoint of driver distraction), they are likely to play a greater role as active-safety products (like collision prevention) are brought forward to the market. Thus, manufacturers will need to satisfy the MT on the safety-suitability of IVHS products (although the interaction doesn't seem to be adversarial in nature).

Traffic safety, considered in terms of highway operations, is a primary concern of the National Police Agency. The NPA will be stumping for IVHS safety benefits, although primarily in the context that centralized NPA functions (like traffic control centers) play a role in regulating, warning, or advising motorists using the street system. Autonomous safety enhancements within the vehicle are beyond the arena of the NPA's jurisdiction.

Since there are almost no lawyers in Japan, tort liability does not serve as a supplemental means of ensuring safe products and roadways. The most significant implication of this situation is that Japanese manufacturers are free to market any type of safety enhancements in Japan as soon as they are approved by the MT. In the U.S., of course, manufacturers are extremely sensitive to any product changes which might appear to transfer responsibility from the driver to the manufacturer.[36] Thus, we can expect great reluctance by U.S. companies to market any product whose long-term liability risk has not been scrutinized through painstaking research prior to sale.

The bottom-line issue is time. That is, because the domestic Japanese market is virtually litigation-free, manufacturers can refine products quickly based upon the most valuable of all types of iteration—those based upon field experience. American manufacturers will not have the benefit of a domestic market in which to develop and refine safety-critical technologies until such time as the reliability and packaging of the product show it to be highly mature and virtually immune to allegations of fault.

The author contends that it is unfair to portray Japan's domestic initiatives as if the public is being placed in a "guinea pig" role by "experimenting" with new products in the marketplace. Rather, we recognize that zero risk doesn't exist and that all real products evolve through experience. Obviously, professional judgment is involved in determining where a reasonable risk lies. In the U.S., delay in developing these safety-critical technologies is inevitable due to the steps which American manufacturers must take to find protection against modern litigation practices. These protective features, in many cases, relate not so much to the actual safety-effectiveness of the product itself, but to the product's ability to show itself to be demonstrably defect-free at the time of any accident. The engineering "overhead" associated with this demanding task is not borne by Japanese manufacturers when marketing domestically.

Moreover, there is profound contrast here between the U.S. and Japan. Active safety enhancements of the motor vehicle will penetrate the domestic market in Japan well before they do in the U.S. Therefore, since virtually no non-Japanese manufacturers participate in Japan's domestic auto market, we can anticipate that Japanese manufacturers will refine an active safety technology well before U.S. manufacturers do.

9.2 Privacy

The issue of personal privacy comes up in the IVHS discussion wherever one's personal travel behavior may be tracked by "The System." The classical concern associated with automatic vehicle identification technologies (AVI) has been raised within the Japanese IVHS community, but no architectures under current consideration require such a function. Interestingly, privacy was mentioned by officials at the Hanshin Expressway when they presented to the IVHS Study Team their infrared imaging system for capturing license plate numbers as a travel-speed determinant. They acknowledged a wariness over intrusion into the privacy of Japanese citizens and were quick to point out that they captured only the four large numerals out of a total of six plus a Japanese character on the plate. Further, after the Hanshin system matches the before- and after-images for obtaining travel speed, the license data are discarded.

One gets the overall impression that privacy is the same type of issue in Japan as it is in the U.S. Namely, although it is a matter to be taken very seriously, one should not assume that no room exists, whatever, for the logging of individual identifications or the recording of data pertaining to individual vehicle usage. Such practices will only be tolerated, however, when no alternative to identification exists (such as in a debit to one's personal bankcard) and when the benefit to the individual is persuasively greater than the risk of privacy abuse.

9.3 Personal Security

Crimes of personal assault are relatively rare throughout Japan. Thus, one does not hear of interest in technologies for assuring the personal security of the individual. By contrast, for example, one of the primary attractions of the so-called Mayday function, as envisioned in the U.S., is for summoning police assistance to a vehicle whose occupant fears assault. (The Mayday function involves a data transmission of precise vehicle coordinates, together with a code indicating the emergency need, to a nearby police facility). Thus, if the Mayday function were to be attractive in Japan (and it doesn't seem to be very high on the list), the primary value would be in summoning rescue personnel to the scene of an accident, rather than for intercepting criminals.

9.4 Aging Drivers

Another slant on the personal security question involves the needs of the elderly population for emergency medical assistance at the roadside. In this and other respects involving older drivers, the interests in Japan qualitatively mirror those in the U.S. Namely, the Japanese population is definitely aging and retention of mobility by the elderly is certainly a recognized goal. Nevertheless, the American visitor gets the impression that the need for personal mobility by senior citizens in Japan is, altogether, less than in the U.S. because elderly Japanese are:

- not as isolated, geographically, from their children as in the U.S.;
- perhaps better cared for by their families due to traditions of ancestral respect; and,
- better served by the mass transit options which abound in Japan.

Other aspects of IVHS which address the special needs of the elderly are recognized in Japan, although early-coming products are not necessarily configured to deal with these needs. Among them are the need to tailor the presentation and pacing of driver information and warning systems so that they aid rather than burden the elderly driver.

9.5 Commercial Vehicles

The application of IVHS concepts to commercial vehicles was not evident to the IVHS Study Team which visited Japan. Thus, while there may be some level of activity in promoting automated aids for highway weight enforcement, regulatory administration, etc.; it did not surface as an area of special interest.

On the other hand, it is clear that the role of the motor truck in freight transportation in Japan has changed dramatically in recent years and is suffering considerable stress. By way of perspective, 85% of all freight in Japan was carried by rail and coastal shipping prior to 1960. With wide expansion of the highway network; however, the trucking industry has boomed, now carrying 90% of all freight tonnage and logging 50% of all ton-miles.[37] Further, the business has trended toward service-driven dispatching such that high numbers of vehicle trips involve small lots of differentiated products in trucks which make many intra-urban stops. (The IVHS Study Team observed thousands of such single-unit trucks comprising on the order of 50% of the vehicle mix along a major surface arterial entering Tokyo from the Yokohama area.) The general observation is that trucking in urban Japan would seem to benefit from a dispatch-routing activity which reflected the real-time disposition of the road system. Presumably, trucking operations will be among the early users of the VICS-established architecture when it becomes deployed in the next few years.

9.6 Automatic Toll Collection

No practice of automatic toll collection in Japan was noted by the IVHS Study Team. Nevertheless, the subject was included as an aim of the RACS architecture, assuming that two-way beacon communications are permitted. Since RACS is promoted by the Ministry of Construction with central concern for the toll road and major highway system, automatic toll collection would seem an obvious long-term interest. Nevertheless, one observes that time saved by the motorist due to automated toll collection is relatively small given the high state of congestion on the system. Also, since daily commuting by auto is relatively uncommon, many users of the toll road at any given time are irregular customers for whom the purchase of a toll tag is less attractive. Regular commercial users, on the other hand, might be attracted to automatic toll collection as a financial convenience, even if it did not save time.

Accordingly, even though Japan's entire expressway system is comprised of toll facilities, no emphasis on automated toll collection was noted. There is, however, considerable study underway on the application of smart, RF-activated cards which may eventually be applied in the collection of transit fares, tolls, and other such transactions.

9.7 Financing the Infrastructure

The infrastructure for collection of traffic data, processing, and communications to vehicles will be expensive. An estimate for installing the RACS infrastructure, for example, placed the cost of the national project at approximately $1 billion.[21] Since Mobility 2000 did not estimate the cost to deploy an ATIS communications infrastructure per se, no corresponding U.S. figure can be cited. Nevertheless, it suffices to say that any high-level ATIS functionality will require a large capital expenditure. The question here is, how might it be financed in Japan?

The clear expectation is that the VICS architecture will have a publicly-financed infrastructure. A RACS leader in one of the auto companies indicated to the IVHS Study Team that the MC is quite ready to pay for a full beacon network. In fact, the Ministry considers the cost to be rather minor. (Again, the matter of cost for highway infrastructure is relative. In Japan, the investment for the roadway itself is already enormous.) But the MC is concerned that a large number of users may not materialize—such that the IVHS infrastructure will have been a bad (perhaps, embarrassing) investment. Thus, as the time approaches for a decision on national deployment, MC officials increasingly question the manufacturers, "how many equipped cars will you sell?"

As evidence that users will materialize, the automakers point to the dramatically increasing sales of the $2,500-$3,500 navigator packages. Part of the MC's dilemma is that these purchases may be prompted, not so much by the package's functionality, as by its status value. Still to be determined is the attractiveness of an interactive system to the much larger number of less affluent, pragmatic, buyers (who may also be quite susceptible to status purchases, by the way, if the cost is much less). Of course, the root issue underlying system usage is the perception of benefit by motorists. If the benefits are not valued, the cooperative system will have been a novelty having no enduring usage.

In short, the MC is portrayed as quite ready to build the RACS-like infrastructure if it becomes convinced of its usage. In any case, both the MC and the NPA are proceeding quickly to further enhance traffic detection and develop the practice of link-time estimation over their road networks. Even if a datalink to individual vehicles is delayed, it is clear that the investment is already being made to present travel time estimates to motorists via the many thousands of changeable-message signs.

NPA views on financing an AMTICS-like infrastructure include the prospect that, while the traffic control centers are publicly funded, the provision of a signpost network (for absolute position correction) and a one-way communication link might be financed by user fees. One example for collection of the fee involves the NPA in its role of controlling driver licensing in Japan. Namely, the road user would pay an additional amount upon renewing the driver's license. The license itself could be a smart card that enables the de-scrambler portion of an RDS receiver in the vehicle. The motorist then receives advisory and route-guidance services from on-board equipment which is able to convert the broadcasted data from its scrambled format.

An alternative mentioned earlier is that the NHK could exercise its authority to charge for transmission of the special RDS services by a direct fee. The problem in this case would be the task of keeping track of the current operators of the receiving equipment so as to assess only them.

Whether, in the case of the MC where no user-charging was portrayed, or the NPA which has envisioned user charges, capital investment in the infrastructure is by public moneys. If IVHS services are seen to have broad public benefit (like general traffic management services, for example), then the agencies may dismiss the question of user fees altogether. Further, there is clear realization that early investment in public infrastructure is needed in order to enable the in-vehicle market. The fact that public monies would be supporting private opportunity is of little concern, reflecting the broad basis of cooperation between industry and government in Japan.

One interesting case showing that the public versus private issue is minor involves the "Toyota Car Park" system. An extensive motorist advisory infrastructure, mentioned earlier, was built in Toyota City to guide users to available parking among eleven downtown parking structures. Although five of the structures are privately owned, and the other six are owned by the City itself, municipal funds paid 90% of the $5 million cost for the information system. The explanation for the high public subsidization of this project is that "It makes the City itself more attractive." Clearly, such broad interpretations of the public good bode well for the ready implementation of public IVHS infrastructure in Japan.

9.8 Cross-Jurisdictional Cooperation

This subject has been discussed at length earlier. We note, simply, that the number of jurisdictions having cognizance over IVHS-related matters in Japan is far, far fewer than in the U.S. Most significantly, although there are local road authorities in Japan, the matter of local traffic control is ultimately under NPA's supervision. Further, despite the competitive nature of the MC/NPA relationship in certain respects in the past; the agreement to proceed quickly toward a uniform plan for a VICS infrastructure appears to be solid.

Perhaps most importantly, the jurisdictions which have responsibility for the implementation of an IVHS infrastructure in Japan can be uniformly characterized as (1) accustomed to a substantial rate of technological innovation over at least the last twenty years, (2) well informed on the IVHS subject as a result of extensive involvement in collaborative projects, (3) apparently enthused to see IVHS implementation, and (4) well funded. If we think in the U.S. of the many state, county, and municipal agencies which must buy into IVHS; one is sobered by the lack, in many cases, of a match with any of the four items listed above. (In fact, simply concerning the last item, the fiscal condition of state and local government in the U.S. has been steadily worsening since 1986 with a total deficit in 1990 approaching $50 billion. While state and local jurisdictions experienced such deficits previously during the 1960's, that period was marked by investment in human and physical capital—i.e., education and highways. By contrast, the current period is marked by spending for medicaid and correctional facilities.[38] Thus, "buying into" IVHS in a literal sense may be problematic over the near term for many local jurisdictions in the U.S.)

Moreover, Japan is, in this context, aided greatly by a centralization of the authority needed to deploy IVHS infrastructure and by availability of the apparent financial resources for the needed public investment. Further, the involved agencies appear poised to act.

10.0
Expectations for an ATIS Architecture

A number of persons in the Japanese IVHS community have expressed to the author a more or less uniform expectation for the type of architecture that will be adopted under the VICS initiative. Although these expectations are somewhat speculative, they are worth restatement here.

Most expect a dual mode of data communication with the vehicle. The more basic mode involves a one-way broadcast where the prime contender (in the summer of 1991) is FM multiplex (i.e., subcarrier). This function could be deployed nationwide very quickly using the unused subcarrier capacity throughout NHK's national network of FM stations. The broadcast would contain travel link-times for the local road system as well as other pieces of information. If the anticipated data rate of ten kbits is realized—and assuming that a one-minute update of link-time data, by exception, suffices—the system will have plenty of spare capacity for other functions.

A microwave beacon network is expected to provide a complementary mode of communications for giving highly-localized functionality. If two-way beacon communications are authorized, this network would provide for automatic toll collection, vehicles-as-probes, yellow-page and reservation requests, local hazard warning, personal-type data communications, and other functionalities.

Supporting both means of communicating traffic data would be the existing system of acoustic detectors and the mainframe processors within traffic control centers. As the conventional detectors are increasingly supplemented by microwave speed detectors, the quality of link-time estimates will improve with more predictive travel data made available. Of course, if vehicles begin to serve as probes across the general road system, a very advanced traffic surveillance and prediction capability could be realized—and public financing of the communication infrastructure would be more easily justified.

Vehicles would be equipped with either, or both, modes of data receiver (or transceiver). With the expectation of a rather cheap FM multiplex receiver, the basic system could be quite economical, indeed. In its simplest implementation, a package similar to the "AMTICS Radio" which Toshiba has developed (see Section 8.10) could provide a rather low-cost, intelligent aid for driver advisory—short of navigation, but still giving individualized routing advice.

With only a microwave receiver, the vehicle could obtain at least the local static information at beacon-equipped intersections, thus finding directions from point-to-point through the beacon network to major landmark destinations. Later, enhancement to include dynamic traffic information via the beacon downlink could still be utilized with a rather modest in-vehicle package.

At the next level, the addition of a navigator would render the functionality of the AMTICS' Kansai demonstration system or the basic RACS, one-way system. The CD-ROM map would be (a) derived from the DRMA database, (b) formatted to comply with the CD CRAFT standard, (c) augmented with fine-scale data to support map-matching and landmark locations, (d) supplemented with commercial listings that are locatable on the map, and perhaps, (e) link-coded with regulatory restrictions to enable a complete form of route guidance. The latter coding could also be updated from day-to-day by means of the downlinked information, although this would require extensive coordination with local and prefectural road authorities.

If the driver travels widely over the highway system, he may opt for both the FM and microwave communication equipment. An integrated receiver/processor could maintain communications with whichever infrastructure is locally available—in a manner that is completely transparent to the driver. A driver might also choose the dual-receiver package during a transition period in which both infrastructure deployments are incomplete such that better geographic coverage of the road system is enabled by operating both receivers. Complete harmonization of the data elements delivered by both communication infrastructures must be attained if a fully transparent interchange is to be realized.

Location signposts may or may not be part of this architecture, although such absolute location reference is provided "for free" wherever the microwave beacon network is deployed. The rate of decline in the cost of GPS receivers may drive the policy on signposts more than other factors. The coordination of traffic signal timing with routing information is a conceivable enhancement of the overall system, since all of the traffic data will have been generated through the same control centers that are computer-linked with the signal network. Nevertheless, there will always be uncertainty at the downtown control center over individual route choice, by this architecture, since the router itself is assumed to be on-board the vehicle (unless some form of uplink is eventually approved and the vehicle transmits its selected route back to the control center).

11.0
Preparation for IVHS-based Business

From a business perspective, IVHS poses a perplexing paradigm in Japan as it does elsewhere in the world. In particular, for the private-side market to materialize, manufacturers must depend upon those that a Toyota executive called, "the outside people." That is, every IVHS-based business plan is tenuous to the degree that it requires action by people outside the company, primarily in government agencies, but also in other collaborating (but soon to be competing) organizations, none of whom have exactly the same agenda as the company itself. Recognizing that the stakes could be very large, however, the Japanese companies that see opportunity in IVHS have turned out in large numbers to participate in the long-range explorations directed through JSK and the near-term implementations now being settled through VICS. Whatever headaches are posed by interacting with the "outside people," many Japanese manufacturers have pursued IVHS with a good deal of vigor.

Within individual companies, one sees examples of reorganization to focus strongly on "systems-level" products and upon the integration of what is becoming the exceedingly complex collection of automotive electronics. What we see here is not unique to Japan—there is a great effort to capitalize on automotive electronics throughout the global auto industry. IVHS, however, ushers in RF data communications, a smart infrastructure, and the need to integrate with systems far outside the vehicle itself. In this context, Japanese industry and their complementing infrastructure agencies are, if not unique, further down the road toward integration than anywhere else in the world.

Thus, the author concludes that IVHS will become a viable business first in Japan if anywhere. And if such business is highly successful, we should expect that Japanese manufacturers will develop substantial expertise within this decade as they meet the needs of the domestic market. To the degree that these needs are peculiar to Japan, perhaps the industrial experience will have only modest value in transferring to other markets. To the degree that they are generic, Japan's early adoption of IVHS will have prepared its industry for a leadership role wherever IVHS is deployed in the future.

12.0
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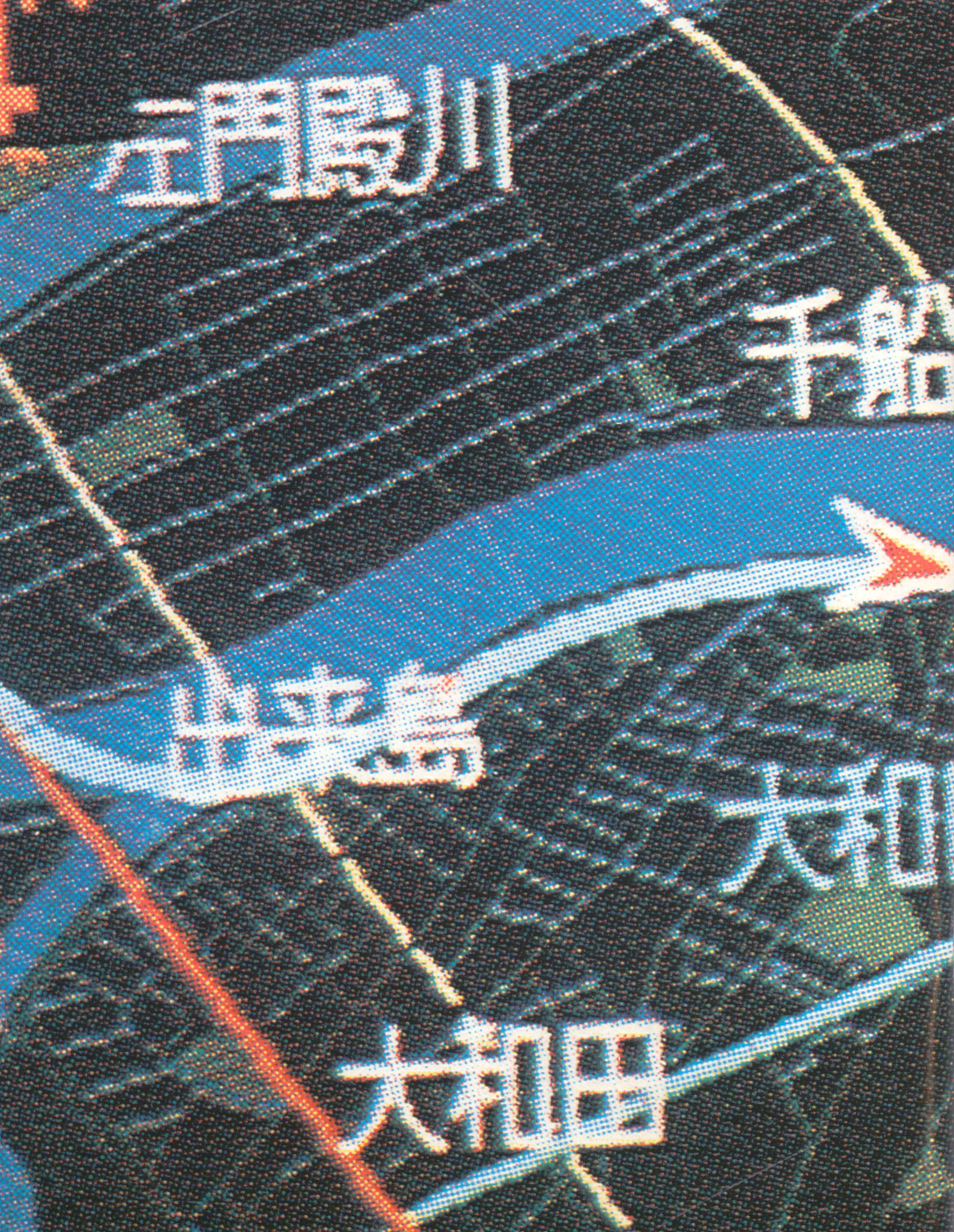
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