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In-Vehicle Signing Concepts: An Analytical Precursor to an In-Vehicle Information System*

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ABSTRACT

The purpose of the project described in this report is to develop alternative In-Vehicle Signing (IVS) system concepts based on allocation of the functions associated with driving a road vehicle. In the driving milieu, tasks can be assigned to one of three agents, the driver, the vehicle or the infrastructure. Assignment of tasks is based on a philosophy of function allocation which can emphasize any of several philosophical approaches. In this project, function allocations were made according to the current practice in vehicle design and signage as well as a human-centered strategy. Several IVS system concepts are presented based on differing functional allocation outcomes. A design space for IVS systems is described, and a technical analysis of a map-based and sever beacon-based IVS systems are presented. Because of problems associated with both map-based and beacon-based concepts, a hybrid IVS concept was proposed. The hybrid system uses on-board map-based databases to serve those areas in which signage can be anticipated to be relatively static, such as large metropolitan areas where few if any new roads will be built. For areas where sign density is low, and/or where population growth causes changes in traffic flow, beacon-based concepts function best. For this situation, changes need only occur in the central database from which sign information is transmitted. This report presents system concepts which enable progress from the IVS system concept-independent functional requirements to a more specific set of system concepts which facilitate analysis and selection of hardware and software to perform the functions of IVS. As such, this phase of the project represents a major step toward the design and development of a prototype IVS system. Once such a system is developed, a program of testing, evaluation, an revision will be undertaken. Ultimately, such a system can become part of the road vehicle of the future.

INTRODUCTION

America is a nation built on the concept of individual, personal mobility. The surface transportation system comprises a complex mixture of transportation modes: private and commercial road vehicles, commercial rail vehicles, and ships. In the 21st century, pertinent and current information about all these components of the transportation system will be thoroughly integrated for presentation in road vehicles to aid drivers in safely and efficiently completing their travel. An In-Vehicle Information System (IVIS) will integrate, manage and present all this information to drivers of road vehicles in a way which facilitates travel for people and at the same time aids in the shipment of goods. For travel on roadways, the information included in an IVIS system comprises the set of services called Advanced Traveler Information Systems (ATIS), as well as other information systems being developed under the Intelligent Transportation System (ITS) program. The integrated IVIS will be developed utilizing human factors guidelines currently being developed by a team led by the Battelle Seattle Research Center (1).

This paper presents a summary of an In-Vehicle Signing (IVS) system concept analysis reported in the "Draft In-Vehicle Information System Analysis: In-Vehicle Signing Concepts" (2), which is part of a larger project on In-Vehicle Information System development funded by the

Federal Highway Administration. While the IVIS concept is broadly concerned with the processing and display of all ATIS information to be presented to the driver, the effort in the project reported here focuses only on IVS information. Subsequent phases of this IVIS project will address the integration of other ATIS information sources. Using modern digital technology to make roadway information more salient to the driver can greatly enhance driving, and can help counter the effects of crowded highways by enhancing travel at night and during inclement weather. Brought into the vehicle and properly displayed, information about the driving environment and strategies to cope with it will aid drivers in maintaining or improving their mobility because the sign information will be more effective. The key to achieving this goal is efficient, timely and appropriate display of information which provides the vehicle's information management system with pertinent facts about roadway signage, the vehicle, the overall environment in which the vehicle is operating, and the driver's characteristics and routing intentions, so that the IVS system can select and display needed items. This paper presents the development of several IVS system concepts based on different schemes for the allocation of previously defined functions (3) to one of three agents in the present driving milieu --the driver, the vehicle, and the infrastructure.

IVS SYSTEM FUNCTION ALLOCATION AND DESIGN SPACE

An IVS system design space can be defined by three function allocation schemes to provide three "anchor points" within which other system concepts can be arranged. Over the past 80 or 90 years, the allocation of driving task functions has evolved as the result of a variety of influences which have been exerted throughout the history of driving -- customer preferences, automobile design and re-design as a function of accident analysis and/or human factors input, and infrastructure design. Such an allocation system might be referred to as a de facto allocation strategy, since it emerged without the type of overall planning represented by the present ITS efforts. The first anchor point, therefore, is based on this strategy and reflects what we are presently driving with, the "current driving milieu". The other two anchor point allocation strategies use the leftover allocation (4) strategy -- all possible functions are assigned to the hardware (vehicle or infrastructure) without regard to practicality, cost, or any other criteria. Whatever is left over is then assigned to the driver. Thus, a second anchor point is based on assignment of all functions possible to the vehicle, and the third is based on a similar assignment to the infrastructure, with the remaining functions defaulting to the driver. These latter two schemes represent the hypothetical concepts of the "smart vehicle" and "smart sign", respectively. A variety of other function allocation schemes exists in the systems engineering literature (4). An adaptation of the humanized approach (5) allocates functions in such a way that full use is made of human skills (which machines do not possess), and human shortcomings are compensated for. The argument can be made that such an allocation scheme reduces human (driver) workload and maximizes overall system efficiency, conditions which are fully compatible both with good human factors practice and with the goals of the ITS program. This is the allocation of functions strategy used to create the IVS system concepts discussed the the following sections.

Allocation of Functions

The IVS system functional requirements specification described in (3) yielded 28 functions which must be performed in order to operate a motor vehicle with respect to the roadway signs and markings. In Table 1, the results of allocating these 28 functions are presented for five allocation schemes. The first three schemes provide the anchor points for the IVS system design space discussed previously. Under the column labeled "Curnt", the functions are allocated to the three driving milieu components as driving presently happens. The totals shown in the top row of Table 1 are greater for the other four schemes. This results from a set of "implied" functions, which emerge as requirements when IVS system concepts are developed by the allocation of functions to specific agents. For example, a "detect vehicle" function is only required by the system concept "sign", which places most of the signing burden on the infrastructure. In this concept, the sign must determine vehicle location in order to calculate when to display its message. Thus, the implied functions emerge in the context of one or another specific system concept, whereas in the function specification task no specific system concepts were considered. As implied by the totals in Table 1, different numbers of implied functions emerge from different system concepts.

Trilinear plots

Because the three components (driver, vehicle and infrastructure) must exhaust all required functions in the driving task, this system is ideal for use of a little-known but powerful graphical data visualization technique known as the trilinear plot (6), which provides a simple method for representing three-dimensional data in two dimensions.. A trilinear plot, as shown in Figure 1, (technically known as a three-dimensional probability simplex) depends on the fact that what is plotted is a three-number set whose components sum to 1.0 or 100%. That is, the structure of the data is illusory (if two of the numbers are known, the third can be computed). As can be seen in Figure 1, the graph for a trilinear plot is an equilateral triangle, with a vector drawn from the midpoint of each side to the opposite apex A point on each of these vectors represents a value for the percentage of that vector's contribution to the driving task. Thus, a vector representing the altitude of the triangle in Figure 1 is labeled "Driver", and depicts the driver's involvement in the driving task from 0% to 100%. Similarly, two other can be defined vectors in Figure 1 to represent the proportion of the driving task components performed by the infrastructure and the vehicle. Once the percentage of each component is computed and plotted in the trilinear plot, the three values are combined into a point representing that allocation scheme.

IVS SYSTEM CONCEPTS

This section presents an analysis of two different IVS concepts, one based on a map database stored on CD-ROM disk or a PC-card, containing static sign data. The other technology uses beacons to transmit sign data to the vehicle. An in-vehicle signing system must contain three fundamemtal components to function properly: 1, a data source and storage system; 2, an in-vehicle information processing system which filters and prepares the sign informaiton for display (3); and 3, an in-vehicle display system which provides the output interface to the driver. These functional components are described more fully in the section below on IVS system design. The two system concepts presented here differ only in the first component, the data source and stroage mechanism. It is assumed that a single design of the in-vehicle components (information processing and display) is sufficient for any type of external or internal data source.

The two right-most columns of Table 1 present the totals from an allocation of functions for systems which utilize technologies which are either currently on the market, under development, or being considered for development. While these two systems represent very different concepts in terms of sources of data for the IVS system, they are actually quite similar in two important aspects. First, the function allocation totals, as shown in Table 1 and depicted in Figure 2, are not very different. Second, the in-vehicle aspects of the IVS system (i.e., the information processing and display components) do not change as a function of changing external data sources. Consequently, the sections that follow treat only the first component of an IVS system -- the Database/memory section. The information processing and display components are treated in the IVS Technical Analysis section.

Map-based IVS system

A map-based system takes advantage of recent developments in both digital maps on CD ROM, and in map-following routines which run on relatively inexpensive lap-top computers. A system such as that presented by Sweeney et al (7), contains a digitized map of the region in which the driver wishes to travel, along with a sophisticated map-following algorithm which places the vehicle on the map congruent with its actual location. However, it should be noted that the concept of a map-based system does not necessarily imply that the IVS system will present a visual map to the driver. Rather, the system uses the map and map-following algorithm as a database for obtaining and presenting sign information. The Table 1 column labeled "Map" presents the function allocation totals for such a map-based system. The table shows that 92% of the functions are assigned to the vehicle and 8% to the driver. In this scheme, only weather, traffic, and other VMS information is conveyed by the infrastructure, through a wide-area wireless broadcast. Note in Figure 2 that the map-based system lies at the apex represented in the allocation space as the "smart vehicle" point, illustrating that the smart vehicle concept originally developed merely as a design space anchor point is also a practical one.

For any IVS system, three types of data are required, and the sources for each must be specified. Those data types are: sign data, situation data, and driver-related variables.

Sign data comprises three types, information about static (permanent) signs, dynamic information from VMSs, and temporary signs such as those used to designate detours. Static sign data (sign type/message and location) for the map-based system can be stored in the digital database comprising the digital map on the fixed data storage medium (CD-ROM or PC-card). Dynamic sign information must be transmitted to the IVS system from the infrastructure. A precoded set of standard messages used on regional VMSs can be stored in the digital database, reducing the amount of information which must be transmitted.

Situation data is information about the general driving environment which affect driving speed and route selection. Situation data consists of three types, static vehicle information, dynamic vehicle information, and extra-vehicle information about traffic patterns and weather conditions. Vehicle information is obtained from the vehicle. Information about local traffic conditions and weather patterns, as well as other types of information necessary to safe vehicle operation and calculation of appropriate IVS display (such as ambient light and noise) must be either broadcast from the infrastructure or obtained from vehicle sensors, as appropriate.

Driver data include preferences relating to display charcteristics (brightness or loudness) or route to be followed, and personal variables which might affect driving, such as age, visual imparement, etc. Input of driver preferences is accomplished by use of an IVS system input device. Input of trip preferences must be accomplished prior to departure, and safety considerations must determine availability of preference modification during vehicle motion. Should driver preferences for a trip be updated or changed at any point in the trip the system will immediately and automatically adapt to the new preferences. Failure to input trip-specific preferences will result in automatic selection of default preferences selected by the driver at initiation of the system in the vehicle. In turn, failure to specify driver-specific default preferences must result in automatic selection of a default standard set of system preferences. Driver variables comprise relatively long-term (quasi-permanent) characteristics of the driver, such as age and general health conditions which might affect driving. Such data can be entered onto a PC-card for storage, and transferred to the IVS system when the driver enters the vehicle. Such an arrangement permits multiple drivers to operate the vehicle, with the IVS system being simply tailored to each driver by the information contained on the smart card.

The sources for a map-based system are presented in Table 2. For a CD ROM- and/or PC-card-based system, most data can be stored on the memory device, and accessed by the IVS computer as needed. There are problems with data stored in read-only memory (ROM), in that even "permanent" signs such as STOP signs occasionally change location or are removed, and therefore periodic updates to the ROM databases must be made. For CD-ROM this requires a new disk, for the "smart card" system a new card is required. Users who do not update their system present a potential safety risk on the road.

Beacon-based Systems

Beacon-based systems use technology which transmits sign information (static, and possibly dynamic) from the infrastructure to the vehicle. The same kinds of information are required as for a map-based system, only the information sources vary. Similarly, the same information processing and display procedures apply. With beacon-based technology, the information contained in the map database for the previous concept must be transmitted to the vehicle by a number of transmitters or beacons. The number of beacons per area has fixed bounds: the upper limit is one beacon per sign, while the lower limit is one beacon for a large geographical area. Between these two extremes lie an almost unlimited number of options. Factors to be considered with beacon technology include the number of beacons for a given area, the bandwidth of the transmission necessary to carry all the needed data, and the costs of building and installing beacons. The latter two variables are dependent on the number of beacons. The fewer the number of beacons used to cover a given area, the larger the bandwidth must be to transmit all the sign information. On the other hand, the greater the number of beacons, the greater the cost for that area.

One Beacon Per Sign

At one extreme is the model that normally comes to mind when the term "instrumented sign" is mentioned. In this system, each sign transmits its identity (static sign information) to the vehicle as it approaches the sign. Dynamic information, of course, must still be broadcast to the vehicle. This concept has been demonstrated on an experimental basis by the 3-M Corporation (8), in a system in which a STOP sign and a YIELD sign transmit a radio signal causing an appropriate sign icon to appear on an LCD screen inside a vehicle. Another concept uses a passive transceiver built into the sign to modulate and reflect back an energy transmission from the vehicle. These two types of instrumented sign, each with its own set of liabilities and assets, represent the two extremes in terms of per-sign cost -- the radio transmitter being the most expensive option, the passive modulating reflector being the cheapest. Nevertheless, the one-beacon-per-sign concept creates the highest infrastructure cost, and it seems likely that this cost would be borne by some governmental entity.

Narrow Area Regional Broadcast (NARB)

Toward the other extreme, the NARB concept uses one beacon for a larger geographical area. The beacon transmits static sign data (message, location and direction of applicability along the road) and can also be used to relay dynamic information for traffic and weather. Because many fewer beacons are needed than for the preceding concept, the infrastructure modification costs are reduced. However, the complexity of the information and the number of signs per beacon create a larger bandwidth requirement than the one-beacon-per-sign model At some point, the required bandwidth could be greater than the off-board system can transmit and the on-board system can process in real time. Moreover, there would be a considerable amount of unneeded information transmitted, since a vehicle typically only needs a fraction of the information available from the fixed sign base currently in the infrastructure. Other problems exist with the NARB concept. The spacing of signs along a rural interstate highway makes that setting ideal for use of relatively few beacons, as does the fact that there are few intersections which require signs and where vehicles can change direction and hence need new sign information. On the other hand, a metropolitan area with many intersections and a consequently higher sign density, presents a significant challenge to the NARB concept.

An example of such a broadcast system has been implemented with the Traffic and Road Information Communication System (TRICS) in Europe (8). The TRICS system uses a 5.8 GHz radio communications technology to bi-directional transmission between vehicles on the roadway and roadside beacons. Two bandwidths are used for the roadside-to-vehicle (downlink) transmission, 500kbit/sec and 250 kbit/sec, to accommodate various equipment suppliers. For the uplink, 125 kbit/sec is used. This technology has a number of technical standards created (such as the bitrates just cited), transmission protocols, and data formats. Such a system demonstrates the feasibility of a mechanism for a NARB system. The TRICS technology also includes the ability to provide various types of traffic information gleaned from the uplink portion of the system, or to serve an automatic toll-debiting function.

A hybrid IVS system

A hybrid IVS system can be created by combining map-based and beacon-based concepts to cover all regions. Such a system requires that both tehcnologies be installed in vehicles, but the cost would not be excessive because the vehicle requires a receiver for wireless broadcast even with the map-based system. In metropolitan areas where sign and poplulation density are quite high, a map-based system used as a database for the IVS system may be more economically attarctive to commercial database providers. In less densely populated areas, including rural ones, beacon technology could more easily provide the signage information. This approach also permits the flexibility of broadcast signals to operate in areas where population growth is most likely, which results in changing traffic patterns and therefore in changing signage. Beacon technology would require only changes to a single database, the one from which sign information is transmitted, rather than to all the databases which reside in individual vehicles with the map-based concept.

As with the other system concepts, there are problems with this hybrid concept which must be solved during the design process. One of the biggest problems is defining the transition stage from map- to beacon-based information sources. Issues such as the sizes of the metropolitan areas which can best be served by the two different technologies, and the prediction of where population growth is likely to occur, must be addressed. Of course, there is no reason why an area could not be served at different times by the two different technologies, depending on whether signage is static or changing.

IVS TECHNICAL ANALYSIS

The technical needs for an IVS system fall under three broad areas: data or information needs, information/data processing, and information display. Figure 3 depicts these three major areas, including details of data content and data processing in each area. The primary underlying assumption of this section is that the IVS system hardware will consist of a digital computer, with a CD-ROM or PC-card (formerly known as PCMCIA "smart cards") as the primary source for permanent (static) data. These assumptions stem from the fact that the information processing required to perform the functions can best be performed by a digital computer, and the vibrations present in road vehicles would seriously degrade the performance of a standard hard drive, such as those found in desk- and lap-top PCs. For safety, this computer should either be permanently mounted inside the vehicle, or should have a latching docking station which secures the device against movement when the vehicle is in motion. In either case, there must be a data connection between the vehicle and the computer to permit communication of data (such as vehicle speed and location which originate in the vehicle, and sign displays which are prepared by the computer) between the vehicle and the computer. The assumption of a computer at the heart of the IVS system means that the data and information storage system as well as the displays must be suitable for use with a computer.

It should be noted that the overriding concern for the IVS system is that all data and information must be available for display to the driver at the proper time and in the proper manner. This means that all necessary information and data must be available to the IVS system, and all calculations and displays must be prepared, prior to the vehicle's reaching the point in the road at which the information is applicable. The frequency with which the vehicle reaches a point of information applicability is related to a number of factors which must be taken into account in the IVS system functioning, and which are detailed below. Foremost among these are frequency of geographical sign placement along the roadway, and vehicle speed. Vehicle speed, in turn, may have an impact on sign/message frequency, since sign frequency increases with speed for a given spatial distribution of signs. Sign frequency has a direct impact on required bandwidth, whether the transmission is by beacons or wide area wireless broadcast.

In the discussion which follows, the functional requirements of this project are used to guide the consideration of how current and near-future technology can be used to implement an IVS prototype system, within the constraints of good human factors practice. The discussion of the functions is necessarily brief due, but the reader is referred to In this process, the driving milieu is considered from the standpoint of its three major components. The driver is the person operating the vehicle. The vehicle is any road vehicle, commercial or private, being operated by the driver. The infrastructure is any item or agent which is not attached to the vehicle, such as a sign, a radio transmitter, a beacon, or a traffic control center, including its personnel.

IVS Information Processing System

The functions for this set of requirements are presented in Figure 1 above in the section labeled Information Processing and Calculations. The information processing system will consist of a digital computer capable of calculating all the sign display parameters and characteristics required by the Functional Requirements: filtering, optimizing, adjusting display salience, and turning the sign display on and off.

<u>Message selection and filtering</u>

The algorithm for message selection and filtering must access appropriate stored data and perform message selection and filtering to enable real-time presentation of information. The algorithm will access stored data about sign type and priority, as well as data about the relevant driving conditions such as weather, time of day and traffic conditions. Vehicle position must be updated continuously while the vehicle is in motion. Sign and message information must be updated often enough to permit display of the requisite information when it is applicable. Using these data, along with driver preferences, the algorithm will filter messages and assign them to the appropriate presentation channel.

Safety-related and regulatory information has special limitations regarding what can and cannot be done with it by IVS system. It must be displayed whenever it is applicable, and can not be de-selected by driver preferences. In the event that more than one message of this type is present, the multiple messages must be presented to the driver simultaneously. Safety-related and regulatory information also must be displayed in a manner which capitalizes on existing stereotypical characteristics, such as the color and shape of a STOP sign. In addition, such information must be displayed in a consistent manner (e.g., location of display) from one display occasion to the next.

<u>Message placement in queue for assigned mode</u>

Messages must be assigned to the proper sensory channel queue so that appropriate and timely presentation of IVS information is accomplished. Determination of sensory channel assignment is a design strategy, and will not be treated here. Some safety and regulatory information will always be presented visually, while other information will always be presented acoustically. Messages must be placed in the appropriate queue at their relative position based on the message urgency.

Message prioritization

The computer system must prioritize all signs in the presentation queues (visual and auditory) to facilitate real-time presentation of IVS information. This prioritization is based on sign/message content, ambient driving conditions, and driver preferences which were input prior to or during the trip. Message priorities must be updated each time a new piece of information is added to the message queues, with priority for safety-related and regulatory information maintained at the highest level.

Message timing for presentation

The system must calculate all combinations of the display characteristics related to message timing. Calculation of message timing is based on sign type and/or message content (sign type) and on vehicle position and speed, as well as a variety of other factors discussed in the In-Vehicle Signing Functional Requirements Specification (10). These calculations include those for message **ON** point, **DURATION** (when needed) and **OFF** point. Duration of many messages and signs is dependent on vehicle location rather than calculated duration, and for others, on time and/or external factors such as traffic density or weather.

Message urgency

Both initial sign or message urgency, and changes in urgency over time must be computed such that appropriate changes can be made in the information display. Initial message urgency is determined by sign or message type, and is determined at the time of selection. Changes occur in urgency as a function of dynamic conditions related to vehicle movement in surrounding traffic and weather conditions, and dynamic driver characteristics. Therefore, computation of urgency must be a continuing process, capable of permitting the IVS system to adjust sign/message salience in a perceptually continuous fashion. This is reflected in the feedback loop from the video and audio outputs back to the section which adjusts message salience shown in Figure 1.

Information Display Characteristics

The functions for this IVS system component are presented in Figure 1, in the section labeled Information Display. The information display system will consist of appropriate visual and auditory displays capable of displaying information whenever the information processing computer finishes its calculations and outputs display information. The IVS information display must be capable of performing the functions specified by the In-Vehicle Signing Functional Requirements Specification (10) and discussed in Tufano et al (3). Design of the information display part of the system is of critical importance in the IVS system as well as in the broader IVIS, since this is the system element which has the most direct impact on the driver. It is the display interface which determines whether the IVS functions in a manner which supports safer and easier operation of the motor vehicle. The display system must be capable of presenting both visual and auditory information. For example, a natural way to direct the driver's attention to a new visual display which might not be noticed is to sound an auditory alerting signal when the visual display is activated. Similarly, the salience of a visual display can be increased by an acoustic display of the message by sounding a tone or buzzer of increasing volume when the visual display is not responded t properly. It is not anticipated that there will be need for a sensory channel other than visual and auditory.

SUMMARY AND CONCLUSIONS

The purpose of the work reported here was to develop alternative IVS system concepts based on allocation of the functional requirements developed in a previous phase of the project. In the driving milieu, tasks can be assigned to one of three agents, the driver, the vehicle or the infrastructure. Assignment of tasks is based on a philosophy of function allocation which can emphasize any of several philosophical approaches. In this report, one function allocation was made according to the current practice in vehicle design and signage (the current driving miliue). This system serves as a starting point for both understanding the point to which the interaction of driver, vehicle and infrastructure has evolved, and where it should or might progress. A second allocation scheme was presented which assigned all possible functions to the vehicle, creating a hypothetical "smart car". The "left over" functions were then assigned to the two remaining agents of the triad. A third system was created in the same manner, but with as many functions being allocated to the infrastructure. These three system concepts define the system design space within which any reasonable IVS system can be expected to fall.

Additional system concepts were presented which reflect system philosophies intended to provide drivers with in-vehicle sign information which aids driving by making it safer, and more efficient wherever possible. The system concepts represent technology which obtains and stores sign and other types of information, performs several data processing operations on it, and then displays the sign information to the driver inside the vehicle. The systems differ in the sources of the sign data, and in the manner in which the sign data are stored in a database. It is anticipated that the information processing and display components of the IVS system will be the same, regardless of the data source.

The results of the process described here will lead to the design and development of a prototype IVS system which will bermit the testing of these concepts. Another task in this project has created a verification and validation (V & V) plan which describes the process for doing the design and testing of the IVS prototupe. As this development progresses, both the system analysis document and the V & V plan are expected to change and mature. The final result of this process will provide guidance for producing a viable IVS system which will ultimately evolve to encompass other ATIS functions.

ACKNOWLEDGEMENTS

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ENDNOTES

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Functional Requirements	Curnt	Veh	Sign	Map	Beacon
TOTAL Functions	28	42	55	39	42
Infrastructure/Signage Functions	12 (43)	1 (3)	37(68)	0	3(7)
Vehicle Functions	1 (4)	38 (90)	15(27)	36(92)	35(84)
Driver Functions	15(53)	3 (7)	3(5)	3(8)	4(8)

Table 1. Results of allocation of functions to infrastructure, vehicle, and driver for various conceptual IVS systems (percentages are shown in parentheses).

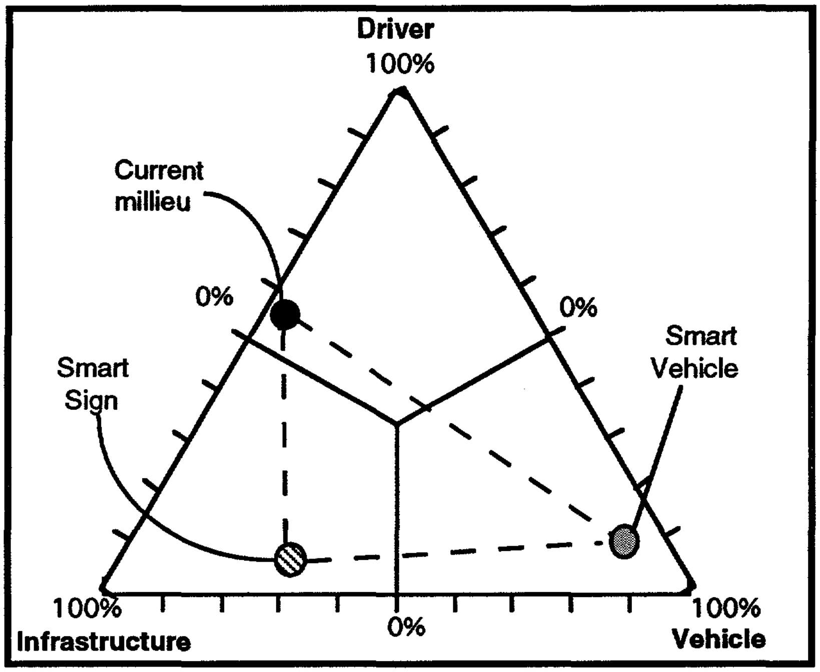

Figure 1. A plot of the three anchor systems: current milieu, and the hypothetical "Smart Vehicle" and "Smart Sign".

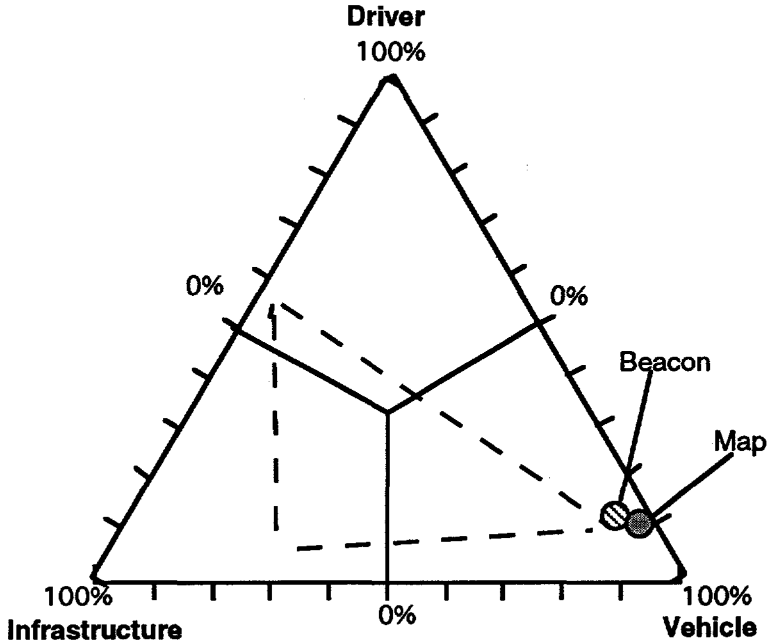

Figure 2. Trilinear plot showing placement of Map- and Beacon-based IVS systems.

Map-Based System	
Data Type	**Data Source**
Sign Data	Digitized Map
Situation Data	Broadcast data, vehicle data
Driver Preferences	On-board Data Input
Driver Variables	PC-card

Table 2. Data sources for the three types of data required for a map-based system.

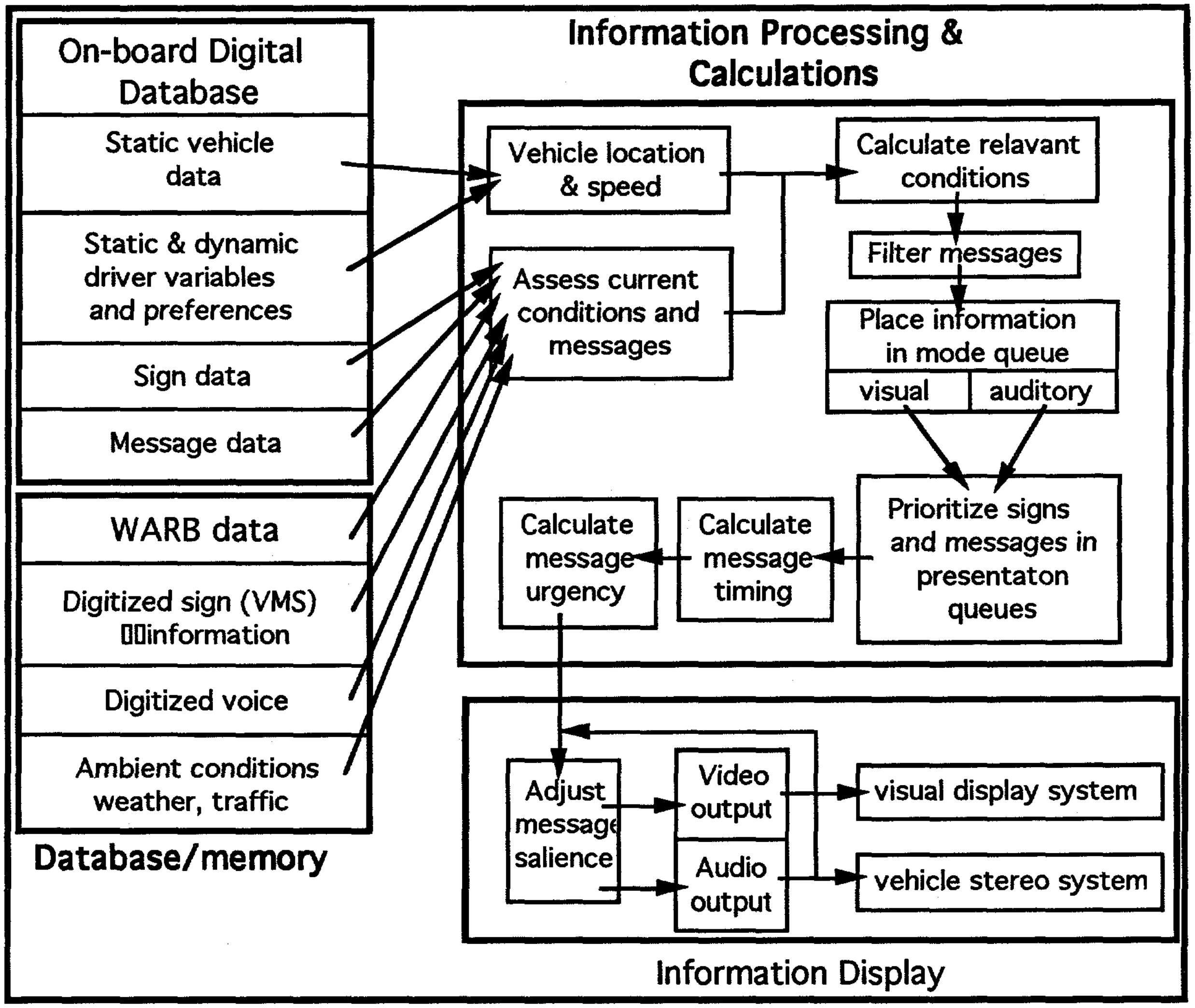

Figure 3. IVS computer-based information processing system.

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