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Vehicle Navigation and Route Guidance Technologies: Push and Pull Factors Assessment

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The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

May 1990

This paper has been mechanically scanned. Some errors may have been inadvertently introduced.

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PREFACE

As the names of the authors' names indicate, the work reported here is a collaborative effort. It represents the first product of an exchange between the Institute's PATH Program and the French Institut National de Recherche sur les Transports et leur Sécurité (INRETS). One of the authors, Mr. J.L. Ygnace, is a visiting researcher from INRETS spending the year with the PATH Program in Berkeley. The collaboration that resulted in this report extends beyond the other two authors, H. Al-Deek and P. Lavallee, both Berkeley graduate students. While on this exchange visit, Mr. Ygnace took the opportunity to interact with researchers associated with the PATH Program here at Berkeley as well as on the Davis campus.

This report has benefitted from the many ideas sparked by this interaction. We are confident that both research organizations have benefitted from this collaboration between them, and we welcome further opportunity to repeat this experience.

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Abstract

This study focusses on the development of navigation and route guidance technologies with an emphasis on existing systems, industrial strategies, market approach and human factors considerations.

By considering the different situations in the US, Europe, and Japan the report analyzes the conditions under which one reasonably could assume a wide spread of these technologies with social and individual benefits.

INTRODUCTION

If we can learn from history (Garrison, 1986), we know it is not unusual for a technical invention to take half a century or even longer before emerging into the market with a large scale diffusion. This has been the case for the washing machine, the elevator and the camera, to list just a few examples. In other cases however, such as the transistor and the typewriter, this delay has been reduced to less than ten years.

Within the field of vehicle navigation technologies it looks like we are falling into the ‘long-term process’ category. Scientific articles give evidence of research activities in this area for at least the last twenty years and even more when considering some automated car prototypes shown in the late 1950’s.

Today, as a result of the commercialization of some navigation devices and due to important research programs in Europe, Japan, and the USA, it’s fitting to investigate the push and pull factors affecting the implementation of these technologies. We will try to consider the global factors involved in this process.

This paper will examine:

1. Selected technologies [without in-depth analysis of the numerous papers in this field. Such an in-depth analysis has also been presented by (Kanafani 1987, Gosling 1987).]
2. Position of different economic and institutional partners and the complementary/conflicting strategies they develop;
3. Market evaluations and research programs;

4. Human factors and their impacts on social acceptance;
5. Lessons from the customers.

I. ASSESSMENT OF TECHNICAL CONCEPTS

We can point out five principal activity domains which tend to promote navigation and guidance technologies through R and D programs:

*in-vehicle autonomous devices

*infrastructure-oriented technology with the aim of collecting and transmitting traffic data in order to optimize route guidance information

*assessment of communication link between vehicles, road and central computers,

*network traffic models

*digital map data bases

Different economic and industrial sectors, each with their own strategy, integrate software development to propose route algorithms. Some give the potential driver a specific indication of the position of the car on a given network (i.e. navigation). Others suggest the best route to take based on time and/or distance costs (i.e. guidance or dynamic guidance).

It's difficult to say which of these proponents are "pushing" the emerging technology. Many concepts are under development and to our understanding there is not a general incremental, joint effort due to competitive R and D investments.

1.1. Autonomous Navigation and Guidance Systems

These devices are based on improved dead reckoning technology augmented by map matching. These combined technologies give a 2.5% accuracy in relation with the driving distance and the position of the car within the network. An overview of dead reckoning and map matching can be found in (French, 1989). Basically dead reckoning allows one to track the position of a car by taking into account its relative movement based on the heading direction and distance covered.

Assuming that a car stays exclusively on the road, it is possible to correct the accumulated error by comparing actual vehicle turns with a digital map to determine where such turns are possible. Then the device corrects vehicle position in its memory. That is a so-called map matching technique. Research into alternative technologies to determine the direction of the car (geomagnetic sensor, gyroscope sensor...), is trying to improve the cost benefit of devices.

Targets for study are:

- 1) sensor disturbance by electromagnetic fields
- 2) position and routing algorithms.

In order to minimize the calculation time and to present information close to real time, the information processed to the driver (position or guidance instruction) must be as close as possible to the geometric position of the car on the network, in order to help the drivers to make the right decision in safe conditions. These technologies have been commercially developed, primarily for navigation, to help the driver find his/her way

between the current position of the car and the destination points presented on a map display. We can mention the ETAK system which some years ago came on the U.S. market. Toyota and Nissan are also marketing such devices in Japan as well as guidance systems (a method in which the driver receives information suggesting the roads to follow is also under development).

In Europe, Bosch is proposing a “travel pilot” under an ETAK license and PHILIPS aims to distribute a CARIN guidance system in 1991.

CARIN allows the driver to select a destination and the route is planned and stored in the microprocessor memory. Then during the trip, the driver is given step by step spoken instructions. In some situations, the spoken instructions (turn right, turn left) are supported by simple intersection diagrams, presented on a small display, similar to those on road signs. If the driver doesn't follow the instructions, the CARIN system automatically reroutes the journey to the original destination.

In the near future this system will be able to receive digital traffic information through an RDS (Radio Data System) equipped auto-radio. The CARIN computer can identify the reports (via an FM sub-channel) that affect the planned route. In such cases CARIN seeks other routes to avoid delays.

1.2. Infrastructure Oriented Technology

In order to adjust the vehicle location due to the accumulated error from dead reckoning and, above all, to transmit and to get real time traffic information to and from cars, beacons have been installed in some experimental sites in Japan (RACS, AMTICS)

and in Europe (London, Autoguide), (Berlin, LISB). These beacons allow different data transmission technologies like infrared in Europe and radiowave or inductive radio in Japan.

Always under cost-benefit analysis it is necessary to assume the best compromises between the following two essential factors:

1. The importance of the technology on the road versus the car;
2. Interbeacon distance necessary to address the best accuracy of the continuous position of the car. This accuracy can be determined by the average minimum distance between two crossroads, which can vary from city to city and country to country. It is also necessary to evaluate the number of beacons necessary to obtain an acceptable area covering.

Unfortunately, cost-benefit analysis consists mainly of cost analysis. These factors are strongly correlated insofar as guidance instructions reaching the driver sufficiently in advance in all situations. It may also be necessary to equip a car with a dead reckoning/map matching system to allow the driver to get precise navigation support in areas that are not covered by beacons. This would allow the drivers to have a precise navigation function, from door-to-door, even outside the equipped infrastructure surface, but on the other hand it also implies a lot of intelligence within the car. It must again be considered that transmitting information from the road to a car takes an appreciable amount of time (depending on the technology used) but it can also take even longer to compute a rerouting vector.

For the RACS experimentation in Japan, (Saito, 1989) mentions that it takes about 90 seconds to compute an alternative route based on the reception by the car of a

congestion vector. It has also been shown in different experimental field tests in Japan and Europe that routing vectors can be received in a range of 50 meters from beacons and that acceptable accurate guidance is obtained within a 2-3 km. interbeacon distance.

In theory, a real dynamic guidance system would need a beacon at each intersection to maximize the drivers' benefits. This cannot be addressed in real life by these systems because of the cost of such a solution, and we must consider that as inter beacon distance increases the less dynamic the guidance information can be. (Meyer, 1988) argues that for a 20 minute trip between two beacons the average of guidance "age" information is 10 minutes. Furthermore, as we cannot alter the number of beacons depending upon the state of congestion we can also argue that the more important the congestion becomes, the greater the time necessary to reach another beacon and the less dynamic the guidance instructions become.

1.3. Communication Network

Most of navigation and guidance technologies deal with a planned communication link between cars and a dispatch or traffic information center in order to achieve this ultimate stage of dynamic guidance. Capacity, cost effectiveness and efficiency of this goal depends again on the balancing of intelligence within the car and/or on the roadside.

Two strategies can compete here:

1) Mainly Road Infrastructure Oriented Technology:

Infrared beacons in Germany and England are able to transmit a lot of data in a short time (64.000 bps.) and this is planned to be augmented through PROMETHEUS research projects. To illustrate this figure we can consider

that a routing vector can be transmitted within 0.5 seconds when a car passes a beacon. This infrared technology is very suitable to transmit a lot of information for a short range distance at an effective cost, even though transmitter devices can be impeded by fog or dust. Inductive radio is experienced in Japan with apparently a less impressive performance (9600 bps) but planned to reach 512K bps very soon (Yoshizo et al 1989).

2) Broadcast;

Radio transmission is another possibility under development, called RDS (Radio Data System) in Europe. This communication link uses a digital data broadcast superimposed on an FM channel or TV channel.

This technology, which uses existing infrastructure is very cost effective but has some limitations:

- It is limited to one way communication towards a vehicle.
- It covers a large area but gives little information and at low speed. Thus, information cannot be relevant to a specific car on a network.

These channels can be used, for example, to transmit detected changes between link travel times (non-recurrent congestion). In that case we can consider it takes 2 to 3 minutes to transmit at 350 bps, a vectorized link travel time for a part of a network, let's say about 1500 links.

This technology can also allow the transmission of digital information concerning unusual and temporary obstructions of roads, in order to reroute a vehicle equipped with an on-board navigation computer.

As one cannot identify one specific vehicle nor use a two way communication link vehicles cannot be used as moving detectors and traffic information has to be collected by other means.

Similar to this technology, cellular phones could have the same function with even a faster data transmission speed (- 2400 bps).

For RDS and for the cellular phone medium, allocation of frequency bandwidth is more important than technical problems, particularly from the institutional and political point of view. Considering also that cellular phones are becoming more and more popular (in the U.S. alone, there has been a 30% sales increase in the last few months (Tomasula, 1990)) it could be interesting to study the potential of this traffic data communication support for route guidance.

1.4. Network Analysis Procedures and Their Potential Impact on Route Guidance Effectiveness

In order for a route guidance system to be effective, it must be able to provide the driver with timely information on the “best” route. The definition of this ‘best’ route however is open to some argument. In a user optimal strategy the ‘best’ routes are ones which minimizes some cost (usually travel time or distance) to the individual drivers. In a system optimal strategy, routes are chosen to minimize the impact to system as a whole. This becomes important when one considers that each new driver added to the system

affects the travel times of other drivers sharing his route. Unfortunately, pursuing a system optimal strategy may result in routing a driver on a less than optimal path (from his point of view) in order to minimize the effects on other drivers. Routing drivers individually without regard for network effects can cause problems if many vehicles attempt to use the ‘best’ route simultaneously. Such actions will result in a substantial increase in congestion on that route, thus increasing travel times and negating any benefits associated with choosing it in the first place.

If minimum travel time is used as the basis for determining the best route (from either a user or system perspective), some means must be found for determining current travel times on each link in the network. Also, since the route determination is made not just on where drivers are, but where they will be at some time in the future, it is necessary to predict how traffic conditions will change during the course of a trip. The driver is faced with the potential problem of having to change his route as conditions change during the trip. Unfortunately, there do not appear to be any very good methods for determining and predicting travel times on a real-time basis. This is especially true on urban networks where signal effects must be considered along with link travel times. Also, if network wide optimization is desired, it is necessary to know the origin-destination patterns of all drivers. Such information is extremely difficult to obtain at the level of detail expected to be required for real-time route guidance.

Assuming suitable information about the traffic conditions on the network are available, the next step is to use this information to determine the ‘best’ route. This route may be computed by the in-vehicle guidance unit itself, by a centralized or semi-centralized computer system, or by a combination of the two. Regardless of the approach used, if a sizeable fraction of the total vehicles are equipped with guidance units, it becomes

absolutely essential that the individual vehicle routings be coordinated to avoid problems with too many vehicles attempting to use the same 'best' route at the same time. This essentially dictates that some form of centralized computing facility exist with the capability of performing multiple dynamic vehicle routings.

Current research is being directed to developing network models which it is hoped will be able to provide the necessary routings on a real-time basis. A good summary of the types of models being considered and associated difficulties is contained in Boyce (1989). The primary problem however is that models capable of providing dynamic vehicle routing are computationally intensive, and can handle only very small networks. Also, as noted previously, knowledge of origin-destination patterns is required.

Using a continuum approach in an idealized corridor, Al-Deek et al (1989), estimated that travel time savings of the order of 3-4% could be achieved from route guidance under recurring congestion conditions. The savings were measured by comparing system optimal assignment, achieved by route guidance, with user equilibrium, which was assumed to occur in the absence of route guidance. It was recommended that future research should focus on potential opportunities for using route guidance in managing networks under conditions of non-recurring congestion (accidents/incidents).

Some thought is currently being given to the adaptation of existing traffic models (e.g SATURN, CONTRAM, CORQ, etc.) for route guidance applications (Gardes and May, 1990). Unfortunately, unless extensive modifications are made, it is doubtful that any of these existing models will be able to fulfill the route guidance requirements. Work on developing a new network algorithm capable of performing dynamic vehicle routing is being pursued by Van Aerde (1989). The model, known as INTEGRATION, tracks vehicles as they proceed through the network and updates routing based on traffic conditions. Although

still at an early stage of development, results so far have been promising and the model has even been interfaced with a prototype navigation system (Van Aerde, 1988). It is not yet clear that this approach will be suitable for large networks.

A second approach which holds some promise is subdivision of the overall network into many smaller sub-networks. Such an approach is exemplified in systems such as Autoguide which is currently being developed in the U.K. (Catling and Belcher, 1989). With Autoguide, a driver inputs his desired destination into the in-vehicle unit which then provides an indication of the general direction of travel. As the vehicle passes a roadside beacon, specific routing information within the local network is transmitted to the in-vehicle unit which can then provide specific instructions on where to turn.

A variation on this approach would be to have different types of networks for different types of trips. For a typical commuter who normally travels along a freeway, the network may consist simply of the freeway and a few parallel arterials. Within a suburb the network could conceivably be only the major arterials, while within the downtown core of a city it may have to encompass all the local streets.

These problems, along with others such as determining how often to update driver information, deciding what other information should be provided, and estimating what effects drivers who do not have or choose to ignore in-vehicle information will have on the system, must be carefully considered before a route guidance system is implemented.

1.5. Digitized Map Databases

This can be considered as the core of all the different technologies briefly presented above.

Whatever the communication link utilized and whatever the relative importance of the intelligence within the vehicle versus the infrastructure, a complete updated map database is needed.

For economic reasons, it must be pointed out that these databases could contain more than just road attributes, and we consider here a large range of commercial activities. So the database could not only answer the question “How to go there?“, but also “what to do?” or “what to buy there?“. Considering the network alone, road database technologies confront two important issues:

- 1) Definition of attributes necessary for guidance.
- 2) Digitizing techniques.

For the first point, although some competitive aspects exist on the business side, efforts are being pursued in Europe with Demeter (Eureka) and Pandora (Drive) projects, and in Japan with the Digitized Road Map Association in order to define standards for completion of these maps. Based upon geometry and topology, these vector maps contain attributes such as: direction of traffic flow, turn restrictions, type of way, speed limits, parking locations, and addresses by blocks. Today in the U.S., ETAK Inc. recently oriented mainly in this activity, proposed the most extensive coverage of the American cities. These maps had initially been developed for navigation and due to high cost or to unresolved liability uncertainties, turn restrictions and one way streets are not presented. Navigation Technologies Inc. is also providing a more detailed database in the U.S. but, at this time, with less extensive land coverage.

The uncertainties about the definition of the attributes have to be resolved in the near future to allow the diffusion and application of guidance technologies. Turn restrictions and one-way streets are really necessary to propose route guidance information between A and B, even if the continuous updating process of these digitized maps is somewhat costly. Considering this aspect, infrastructure oriented guidance technologies (i.e. beacons) could be most cost effective, being that only one central database has to be updated and maintained. For the second point, one can say problems arise since it is necessary to have accurate data in addition to an optimal digitizing process. The scale of the support to digitize has an effect on the accuracy of the database. A digitizing procedure of 1 millimeter uncertainty from a 1/25000 scale original map source gives an average accuracy of 25 meters. By adding another 1 millimeter uncertainty on any in vehicle information display we reach a 50 meter accuracy, which could eventually create some problems in dense city networks, also knowing it takes about 5 seconds to drive this distance.

II. ACTORS INVOLVED WITH THESE SYSTEMS

The aim of this brief technological presentation was mainly to point out that navigation and guidance technologies make reference to a lot of various activity sectors which usually don't work together with the same goals. On the other hand, the implementation of these technologies demands a high convergence of funds and knowledge. Looking at the current situation in different countries we find the same actors with different levels of implication:

- research (public or private)
- automakers
- electronic suppliers

- infrastructure industry
- traffic engineering
- customer/citizens (taxpayers)
- public policy makers

The multiplicity of these actors creates some difficulties upon implementation of an incremental process. In fact one main thing has to be considered here: the process of development can delay financial returns for some entrepreneurs and also can delay the possibility to recover immediately the investments necessary at a previous stage and without any application for some later stages. The feasibility of the systems implies a shared investment strategy on a common basis with different return benefits during the various stages of the technological advancement. The database business is an illustration of this problem. To provide an effective guidance system, the databases must initially include different attributes that will be used only in a later stage of the technology implementation. If this is not done we can consider that the surcharge for a later introduction of these attributes will be significant, and so the overall implementation would be delayed.

Taking these factors into consideration, we can mention that only in Japan have these problems, in the area of the data base business, been partly solved. In a Digitalized Road Map Association has been set up to include the financial participation of different automakers and suppliers. In general, one can consider that route guidance technologies encompass a large amount of industrial strategies; this is unique since these sectors have their own historical and marketing background to deal with the transportation industry.

On one hand, automakers and electronic suppliers to a lesser extent, schematically analyze the individual auto market and consumer behavior. The infrastructure industry and traffic engineers are more involved in the public market business and are better prepared

for presentation of social cost-benefit analysis. In all cases there is a lack of cost-benefit analysis involving the three most important levels of application:

--SOCIAL

--INDIVIDUAL

--INDUSTRIAL

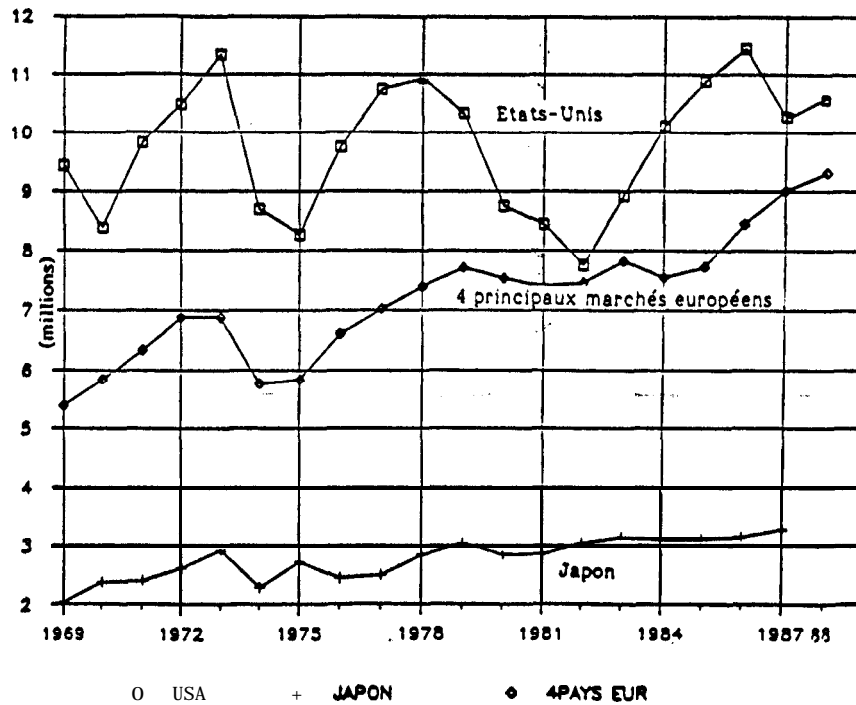
III. MARKET ISSUES

III.1 Automakers and Suppliers

The viability of these technologies may depend on the predicted 18% of the cost of a car with electronic components by the year 2000. Sensors developed for various ranges of functions, i.e. ABS, guidance, auto-diagnostic, etc., are very much based on some industrial agreements for multiplexing technologies implementation. Multiplexing could be a key to larger developments of in-car devices based on electronic technology.

We can also consider the potential increase in car demand for the next decade which can give some idea of the scale effects due to the introduction of the “smart” technologies. It is assumed that in Japan, Western Europe, and the United States (the biggest market areas in terms of car production and consumption) the growth of total fleet is not increasing much due to some saturated demand, especially in multi-car families (most notably in the U.S.). This rate is between 1 to 2% with some variances if we look at some historical data.

When comparing the car demand for these three biggest markets, it appears the biggest increase is in Europe. (fig. 1)



**fig. 1: Evolution of Automobile Sales
in the U.S., Europe and Japan.**

(in FIA: assises mondiales de l'automobile PARIS 1989)

Within this market, navigation and guidance technologies are considered most often as individual pieces of broader concepts based on communication needs. The aim of the automakers is to look towards an integration of packages, including auto-diagnostic, FAX

machines, phones, T.V. etc. Following these “carcoon” concepts, Japanese industry tests these technologies at first in their own local market, and only in top-of-the-line models.

Usually, market approaches try to consider potential buyers among “high-tech” consumers without many concerns regarding the specific needs in the navigation area. Navigation needs are assumed to be in some cases, equivalent to the acceptance and the willingness to pay for other electronic options. For example, in France 3 million auto radios are sold yearly and 3 to 5% of these cost in excess of \$1000. This population could be a target for navigation marketing people and we can point out that initially BOSCH in Germany was considering distributing its navigation device (ETAK like) through its BLAUPUNKT subsidiary, who specializes in auto radio production.

On the other hand, the navigation market can also be approached by analyzing the sales of cellular phones, which are increasing as the costs decrease. These sales represent about 50,000 units in France, 250,000 in the U.K. and 2.4 million in the U.S. But these last technologies are based on after-market sales and supported by a strong industry.

This however is not the case for navigation and guidance technologies. This could be solved by the development of OEM’S navigation supplier, in order to reduce the installation cost, but this is still not done in the U.S. or in Europe (with maybe the exception of PHILIPS in the near future). Due to these difficulties, also to the small car price elasticity, industries tend to consider the commercial market, i.e. rental fleets, delivery trucks, etc. To our knowledge this trend is not a reflection of effective market analysis in this sector, but essentially indicates the possibility to discuss cost benefit analysis with the fleet operators. As mentioned in an AMTICS Japanese study, from a commercial point of view, there is little noted evidence of differences in the willingness to pay between

commercial users and other customers regarding these devices. (fig.2) [Presented by OKAMOTO Hiroyuki (unreferenced paper).]

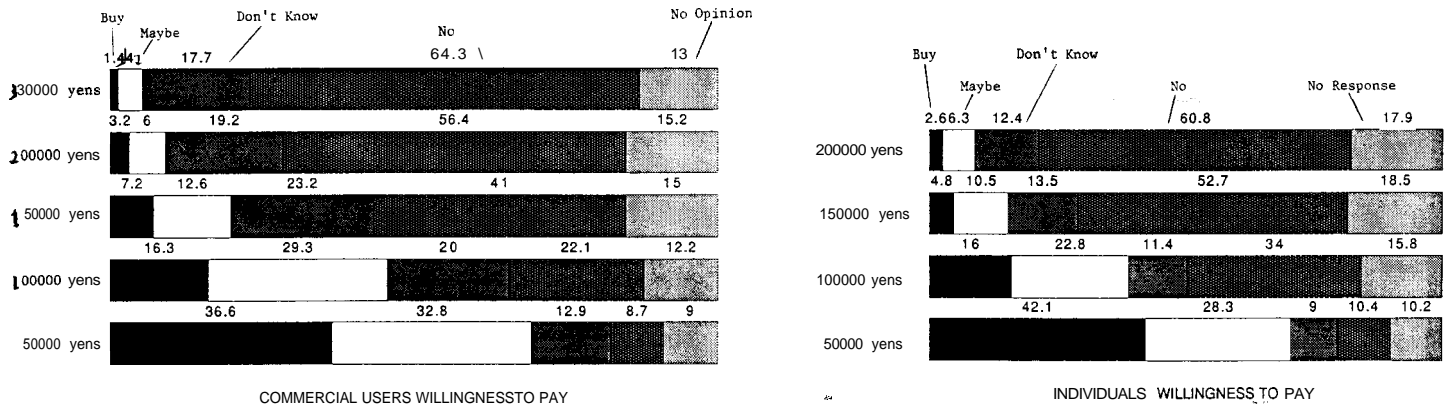


Fig. 2: Market Evaluation of Navigation Devices

Even in the case where the user is not necessarily the payer, strong assumptions have to be made about the real motivation for a driver, who is paid by the hour, to minimize travel distance or travel time.

III.2 Infrastructure

Considering the development phases accomplished, from the simple traffic signs (and later traffic signals and changeable message signs), today dynamic route guidance technologies seem to be a new challenge for the industrial sector of road equipment. From

this point of view it appears that public bodies (states, cities, and counties) are the first interested customers and very often provide the financial support for road infrastructure technologies.

Suppliers, like SIEMENS for example in Europe, are accustomed to dealing with these sectors, where potential benefits are presented mainly as social benefits. Following these concepts, some public funds are invested in small or large scale experiments like AMTICS or RACS in Japan, and LISB in Berlin. The London Auto-guide demonstration is more oriented towards private investments with G.E.C.

Due to the recent experimental implementation, it is quite difficult to have a clear understanding of social benefits. Cost analysis shows a \$20,000 average cost to equip an intersection with beacons. An evaluation of the operating costs for the technology required for a middle range city in France equipped with 60 intersections (MAYER 1988, op. cit.) indicates the need for 7,000 user subscriptions based on a \$160 yearly fee for individuals and \$350 for commercial drivers. This figure doesn't include the cost of the in-vehicle unit which could be priced around \$200. Similar evaluations in London show a total operating cost (including roadside beacon maintenance, line connection rental charges, and central computer) of 3 to 4.5 million dollars per annum for about 750 equipped junctions (Jeffery, 1987). In all cases where these technologies are under experimentation, subscription fees are essential, and this creates some complications:

- 1) The network user has not been accustomed, until now, to pay for traffic information provided by any medium such as: traffic lights, changeable message signs, radio reports, etc.

- 2) As a lot of intelligence is planned to be on the road (versus the car) there are not many cities, or parts of cities which will equip the network and the in vehicle devices cannot be used in an unequipped city or neighborhood.
- 3) The potential cost-benefits analysis is essentially based on network traffic modeling. These models don't consider individual cars but flows. In this case, it is quite difficult to have socio-economic feedback about specific drivers and their willingness to pay versus their specific contribution to the congestion. It is important to consider this willingness to pay, which plays a very important role in the overall economics of the system. (TAKADA, 1989) demonstrated (through a cost-benefit analysis of the RACS system in JAPAN) that 50% of cars should be equipped before the benefits, only in relation to infrastructure investments, exceed the costs.

III.3 Competitiveness and Cooperation

When considering the list we have established regarding the different actors involved in these technologies, one can assume that customers and users are not really represented under this process in progress. All of this remains a supply problem and the demand has not really been clearly analyzed. These technologies are related more to the global perception of problems arising from mobility patterns and the increasing congestion levels which are observed worldwide.

One other complication when implementing these driver information systems is the fact that driving habits from the non-commercial world are imposed upon the commercial world. Until now, drivers don't have direct perceived financial cost to find their way or to

avoid congestion except maybe in buying maps or extra gas consumption (due to unnecessarily longer routes). Therefore, extra gas consumption is not evaluated very efficiently. In other transportation markets, new technologies are implemented step by step after receiving feedback from customers. It seems to be different, however, for guidance and navigation technologies in so far as a lot of research is carried out in the labs without many commercial applications. This may be due to the public funds allocated here and more importantly to the so-called “precompetitive” aspects of the research developed in cooperation with different industrial partners. This is especially noteworthy in Europe with the PROMETHEUS program.

In Japan the related programs are more “competitive” than “precompetitive”, with at least 12 automakers and electronic suppliers of navigation systems involved with RACS or AMTICS. However, all R and D programs deal with two important aspects:

- 1) technical
- 2) political and economical.

To some extent, these aspects seem to show a strong competition between Europe, Japan, and the U.S., even if (in regards to the U.S.) public policies and industrial collaboration do not appear to be well defined. In fact, this competition is limited because:

- 1) Guidance and navigation technologies and the devices proposed cannot really come into the market as self-contained products. As we mentioned earlier, many different actors must be involved to operate these systems in the most efficient way so that its users may benefit, but they could be operated efficiently without some of those actors.

- 2) Instead of speaking about competition among countries (or economic blocks), it's more suitable to point out the competition among multinational groups, like SIEMENS, NIPPONDENSO, PHILIPS, etc., who are oriented towards a worldwide market for economies of scale knowing that in such a situation, a relatively small number of customers is necessary in each country.

Cross relationships between start up companies and big groups on an international scale create some difficulties in understanding the goals of public policies in this technological domain. For example, the PROMETHEUS program (at the policy level) is sometimes presented in the EEC as a pan-European project with the aim of strengthening the European industry within the worldwide market. On the other hand, private industries involved, have joint ventures with U.S. start-up companies (which have developed some pieces of advanced technology in that area). The same thing is happening between Japan and the U.S. This situation can be explained by the relative ease of access to venture capital at an early stage of development on the U.S. market by private investors and perhaps the lack of public aid for the U.S. industries. In this case, the biggest risk for these U.S. industries is to import manufactured devices at the second stage of development. On the other hand, the biggest advantage is the potential to maximize the benefits of this "emerging" technology.

From the global policy level it must be mentioned that one of the results of the European or Japanese programs (to a lesser extent) is to enlarge the research and development sector and to create new synergies between public (Universities, research institutes) and private sector which had not been achieved for a long time, especially in the automotive transportation area. It must also be understood that these technologies have

been developed to increase network capacity as well as provide a better and more comfortable use of cars. These technologies are also competing at the public policy level with other approaches to the transportation system, like:

- Urban planning and land policies dealing with the location of jobs and residential zones, and other telecommuting programs.
- Infrastructure development which is still possible in many situations; the dense overcrowded metropolis doesn't represent the standard situation of entire countries.
- Public transport oriented policies and investments appear in many cases as a solution. Intelligent Vehicle Highway Systems (IVHS) have not been well defined among these different options. Above all, the ultimate spread depends on the users' acceptance. Without considering any strong "regulations" in that domain it is necessary to evaluate the potential needs, the potential ability to use these systems and finally the willingness to pay.

IV. HUMAN FACTORS: NEEDS, CAPABILITIES AND ACCEPTANCE

By assuming an incremental diffusion of guidance technologies, we have to consider the potential acceptance of the users in order to achieve potential benefits for the entire community. This is possible on the condition that subjective and objective problems are solved. These problems exist mainly in:

- Mobility patterns within multi-motorized households
- Behavior and attitudes towards traffic congestion and “finding the way” (we will define “finding the way” as the human operational ability to use “mental maps” as a means to determine one’s location and movement in the spatial environment).
- Functional abilities dealing with information devices and safety issues
- Consumer sensitivity and potential acceptance of new technologies.

These different parameters can bring some conflicting patterns of development as we can see from others in new car technological devices. For example it can be easily shown that in some cases the best physiological ability doesn’t fit the financial capability (i.e., age factor). The reluctance of elderly Buick Riviera buyers to experiment with new touch screen panels could be an illustration. This could seem very trivial but it is important to mention that the response of the first users could either boost or hinder these emerging technologies. As mentioned before, the basic goals are to:

- 1) Give the driver the possibility to find his/her way on an unknown network.
- 2) Give the possibility of finding the best route (in time and for distance) taking into account the traffic congestion.

These two goals could be presented as a linear on-going process (Mobility 2000 Workshop, 1989). For us they represent two complementary aspects of potential needs. We can

assume that a user would like to maximize the benefits from both situations encountered on various trips.

From traffic oriented approaches, it has been a tradition to deal with trips that affect most of the congestion (commuting trips) assuming that guidance technologies could be used by commuters representing a randomized sampling of equipped cars within the traffic. This should be demonstrated in the future.

IV.I. Global Mobility Patterns and Consumer Distribution

- 1) As the multi-motorized households tend to increase, (51% in the U.S.A, for example - Kitamura, 1986) what could be the strategy of these households in choosing the car (one car could be a first step) to equip? This choice could depend on:
 - the type of trips a specific driver of a household is accustomed to make with a specific car
 - perception of the car itself (ie. year, type, make...etc.)
 - the interest in the technology itself without any consideration to specific trips or cars.
- Depending on these factors, what could be the distribution of the purchases between options on new cars and “after market” mounted devices?
- 3) Taking this into account, is it necessary to modify, or at least to question, the actual market that offers navigation, as an optional device, in only top-of-the-line automobiles (conceivable for economic reasons and the assumed acceptance of a certain percentage surcharge over the total cost of a car)?

All of these parameters could be the core of a social benefits analysis. Considering the type of roads which are used, types of trips (spatial and time distribution) and also socio-economic characteristics of households (regarding car consumption), real use of cars could define a set of variables for a predictive model of diffusion.

Knowing that social benefits could depend on the specific type of network in which these guidance technologies are applied (Al-Deek, 1989), maybe it could also be possible to assign probability coefficients to cars, representing the probability of finding equipped vehicles on different itineraries at peak hours. In a parallel to this macro level analysis, it is also necessary to assess the behavior of drivers on a micro level scale.

IV.2. Behaviors and Attitudes Towards Traffic Congestion and “Finding The Way”

How does a driver (specifically a commuter) choose his way’, and what are the different factors which can alter his/her behavior? This has not been considered much by researchers mainly because of the strong background of “Origin-destination” studies within transportation academics. It is quite difficult to deduce from actual situations what could happen with new guidance information devices.

A recent survey (SHRAZI, 1987) conducted in L.A. shows that 70% of commuters would be willing to divert from freeways with accurate congestion information, while only 15% of commuters change very often or often to an alternate route on their way to work today. These different percentages must lead us to question the way the survey has been

‘The epistemological status of the “route choice” concept would have to be defined: it could imply the existence of physical alternative routes but also the psychological ability of a driver to consider alternative path options

conducted as well as the driver's behavior involved here - may be the problem is not about the accuracy of the information itself but about the trust in this accuracy .

This survey also concludes that the knowledge of alternate routes, personal experience of a network (it's not precise what to infer from this knowledge) and finally the time constraint provide explanations for the diversion. Age, gender, and surprisingly travel time don't seem to influence the decision process. We can assume that diverting from congested freeways depends on some cognitive and cultural factors which must be evaluated. Following this idea, a study conducted at the University of Washington (Haselkorn, 1989) shows again that time constraint is an important factor which helps to explain the commuter behavior. The more important the time constraint is to the commuter, the higher the probability is that the driver will change departure time in accordance with traffic information, instead of changing his/her in-route choice pattern. It appears also that there is a relationship between the degree of this constraint and the income of this "time changer" group: lower income people have a higher time constraint. On the other hand, the route changers group has a higher income. This means that it is possible to target different populations by various traffic information aids. The main difference with in-car real-time navigation and information devices, as compared to home TV or radio reports, is that in the first case people should adapt their behavior to changing situations. Human beings do not react exclusively as a stimulus-response process and we can assume that there are some different levels of inertia (considering the ability to react immediately to guidance instructions, especially when the instruction does not really fit in with route choice habits of drivers). This inertia can be explained by the specifics of any driving situation (the proposed itinerary is very different from the known one) or by a poor fundamental ability to react to real time information. So, there are the questions of the accuracy of the

diverting advice itself and the reliability of the information. These two things are not necessarily correlated.

Far beyond the technological aspect of guidance, all these questions deal with field transportation research (especially with the necessity to understand travel behavior not only as the result of travel and activity patterns but also at a micro level). The manner in which a driver chooses and keeps a specific itinerary for a specific trip could reflect cognitive and cultural values of space and time, attached to human settlements. We can also assume that route choice strategies depend on way finding abilities which are not equally shared among drivers. Way finding and spatial progression had been studied, many years ago, through fundamental approaches by physio-psychologists and environmental geographers such as: (Tolman, 1958), (Tinbergen,1951), and (Blaut, 1971). Results from these researches show that due to a spatial learning process, animals tend to choose the shortest path from A to B. The learning process seems to be a very important factor in this way finding ability, even if it can be demonstrated that an in-born type of cerebral dominance plays a role here (Bogen, 1972).

More precisely, phylogenetic development among natural phases of learning show a diminution of spatial resolution capacities over time, essentially based on school tasks of children which tend to privilege symbolical skills based on oral communication more than on image representation (Downs, 1977). We can also say that this learning experience is not developed with the same intensity among people. As people usually don't waste time learning to find ways just for fun, we think there are current situations which make it necessary to resolve spatial problems at different levels. Following this logic, the necessity for some people to travel in unfamiliar areas under space and time constraints could give them a better chance to deal with spatial problems.

More generally, considering spatial problem resolutions we can define two sets of strategies:

- (1) Either a localized mental cartography which is involved mainly in cognitive learning tasks based on spatial relations between different areas. This can be compared to the use of an aerial photography which helps to understand global relations between specific areas,
- (2) or an itinerary learning process which is mainly a non-dimensional process where the subject tends to recognize places by adding some piece of knowledge from parts of the itineraries which have been previously experienced in that area. This is a step by step learning procedure.

Through current behaviors, strategies are evolving from the first case to the second case. The ability to go through this evolution could depend on four variables as defined by (Bogen, op cit):

- 1) Urban environment form ie. parallel or irregular network
- 2) Previous spatial experience
- 3) Duration of this experience
- 4) Age of the subject.

From the two distinctions described here above we can assume that navigation and guidance technologies respectively cover this field. Without any technical help drivers can switch from

one mode to another depending on their capabilities and experiences of the network. Very few technologies we have mentioned can match this human behavior. Considering the specific case of way finding strategies for a car driver the problems are even more complex as we are in the presence of multi task achievement. In many cases, the spatial learning process may depend on the people situation; ie., active driving versus passive driving (copilot). Both situations can participate to this process for many drivers and it could be important to consider here the specific case of multimotorized households. As I mentioned earlier, we don't know how these people would decide which car to equip with a guidance system. Furthermore, what role the past experience of the drivers would play in the route-finding learning process as a determinant of the abilities and the interest in using and buying a guidance system.

Beyond these aspects “interest” is not the only factor to be taken into account. As we have just said, way finding for a car driver is just a task added to the driving one. How can a navigation or a guidance system be proposed as help on this interface, instead of adding a competing task to complete with potential unsafe results?

IV.3. Safety Aspects of Navigational Devices and the Driving Task

To be acceptable by the users and to meet the safety and liability requirements (which ought to be issued very soon) the technologies should at least:

- 1) Make easier the route finding task to minimize the driving work load.
- 2) Correspond to normal procedures used by drivers in most situations

- 3) Increase driving safety and/or at least not alter it.

This later point has some importance in considering all these technologies as a potential increase in individual comfort, and furthermore as a potential collective benefit. Considering also the economic side of their spread we can think that something which doesn't alter the actual safety situations is a kind of benefit in itself. To do that we could try to define the population segments which are the more sensitive to the driving tasks constraints. From there potential users could be selected by taking into account the system functions and the personal abilities required to operate them. Due to the specific situations of the automobile market this cannot be achieved even if it is very common with other transportation modes like airplane pilots, train drivers, etc, where strong selection and training procedures are used. The willingness to pay is almost the only selection factor within this automobile technology. We may assume that market acceptance would go with a self selection of people regarding the abilities but this cannot be demonstrated without large feedback from users.

As with other automotive technologies the design of navigation and route guidance devices has to be adapted to average abilities. On the other hand it is also difficult to deal with average situations or at least "reasonable" worst cases encountered, as is done, for example, for climate conditions regarding the design of air conditioners or engine functions. From extreme situations like the international traveler renting an equipped car for a first visit to a foreign city to the daily commuting trip, trying to find the least congested route, one can find an almost infinite number of situations. These situations may also depend on external factors like the level of congestion, the weather (rain, sun, fog), the time (night, day) etc. In front of all of this, which would require almost a specific design for each case,

it is necessary to analyze only the basic trends of the driving task. Basically the driving task requires one to:

- 1) Follow the planned route
- 2) Deal with the traffic environment
- 3) Make the vehicle track the road

These different levels are structured so that the achievement of a certain level implies the achievement of an upper level. Each of them requires cognitive and “sensory” task achievement, depending on different driving situations encountered. For example driving in very light traffic on a highway in good weather is essentially a sensory-motor task. On the other hand, cognitive tasks are much more important on an unfamiliar dense network. Navigation and guidance technologies are supposed to meet the core of this process and so to reduce the cognitive task workload. This task consists in finding, for an itinerary, points or indices which allow one to achieve the goal of a memorized task. We can hardly find general rules to describe this process once on the road. Some work has been done on preplanning trip behavior and especially the mental algorithms at work from map reading experience (Shimazaki, 1989). The fitting with the indices found during the trip and the memorized ones can vary from individual to individual. Yet sequential aspects of this process seem to remain constant (Forestier, 1987). To that point, we can argue the same devices will allow different performances depending on the familiarity with the network: in case of rerouting the information presentation must be simple enough to balance the new cognitive workload due to the unusual change compared to a repetitive task linked to the familiar driving situation. In that case, the safety aspects refer to a system based on:

- 1) The relative knowledge of the network
- 2) Driving abilities
- 3) Various traffic situations encountered

In most cases it is difficult to take into account all these factors. Experimental designs tend to select some topics considered as important to achieve the driving task with guidance or navigation systems, and they focus on:

- 1) Attentional demand
- 2) Individual aspects explaining the ability to pick up and understand displayed route guidance information
- 3) Potential conflicting aspects within the information presentation modes specifically dealing with orientation and spatial process.

Simulation experiments and field studies have been trying to understand the safety issues in the design of these devices and the working load involved in the information processing. It seems that the attentional demand to the road is increasing with the driving task complexity. We observe at the same time a decrease of the attention to the in car device. This leads to the assumption (Dingus, 1989) that the consultation of a device could be taken from the spare time during the driving task, this spare time varying with the driving situation (traffic, weather...). These results must be balanced by individual abilities and specifically with the age factor, which plays an important role in the attentional demand and the information processing delay (Pauzie, 1989). On the other hand, from some studies which have to be carefully evaluated due to the small number of drivers considered, we can

mention that auditory communication channel is less disturbing to the driving task than other visual support. This has also been measured in terms of performance (Streeter, 1985) and also this shows a better acceptance of voice than visual information. To some extent it is necessary to point out that visual information is becoming “saturated” in new dashboards but also that it would be possible to have conflicting results for a cognitive task dealing at the same time with audio and visual inputs (Brooks, 1968). Considering all these aspects it remains to demonstrate whether visual or audio short term memory is the most effective while driving with an in car navigation or guidance system in order to give the better efficiency to the guidance information procedures.

Concerning safety aspects involved in these technologies it is also important to mention that different aspects have not been evaluated:

- 1) Learning process is generally outside the scope of presented studies. Experimental Data don't look to be recorded (or published). Either in real field experiments or simulated ones training procedures reach an average two to four hours time, and drivers are evaluated after this period. We can consider that learning behavior should be considered as a part of the studies insofar as the customer will have to ‘learn by doing’ in real situations and this can show the possibility of a learning curve with potential negative safety implications. As we mentioned earlier training is not suitable with the automobile market and we must evaluate safety from the first trial to a reasonable feeling of familiarization by the drivers. The interest of the emphasis on ‘learnability’ rather than steady-state, trained user performance has also been demonstrated in the case of the cellular phone (Hanson, 1979).

- 2) A second criticism could be the lack of obstacle detection approach during experiments. Variables observed are mainly concerning track heading, distance heading or car following. This may be due to the difficulty to optimize image processing through simulation studies. More importantly, it seems to be very difficult to simulate the route finding process. This one is typically a spatial problem which doesn't really fit with two dimensional screens used in some simulators. On the other hand, real field experiments are more often oriented towards the evaluation of a specific technology rather than the navigation and route finding process in itself.

To conclude this part about safety aspects we can say that navigation and guidance systems must eventually assume several functions like:

- 1) Route finding
- 2) Traffic congestion avoiding, (which could be interpreted as: 'best route choice')

As these two functions are not necessarily used by drivers at the same time depending on the familiarity with the network we can think of a multi function device with different specifications for the man-machines interface. In that case, a relative level of safety could be evaluated taking into account the driver's behavior without any technical help. For example, an in-vehicle guidance device could be safer than driving by reading a map on an unfamiliar city network. On the contrary, the same mode of presentation could increase significantly the workload of a driver on a familiar network and trying to follow indications to avoid traffic congestion. The most important technical challenge is still to homogenize

different functions which refer to motivational differences among the drivers under different travel situations (Locke, 1967).

On a more general approach it is also useful to mention that people tend to rely on verbal communication to find their route. Results from an experimental study conducted in the U.S. (Gordon, 1970) show that only 10% of the drivers choose to consult a map to reach a destination, the others preferring to ask the route by gas stations, post offices, etc. These results are also consistent with other studies dealing with route finding strategies for longer trips (Cross, 1977). Considering the need of social acceptance to develop these technologies we can argue that verbal communication, eg., good quality voice synthesis, fits the best with the drivers' behavior and would minimize the learning process time and thus the unsafe aspects of this situation. Yet we must also point out that a man-machine interface cannot really reproduce the communication context set up between people, and that people have also been reluctant to buy "talking cars" which give false warnings or information which is not requested.

V. SOME RESULTS ABOUT USER ACCEPTANCE OF ROUTE GUIDANCE TECHNOLOGIES

There is a lack of information about the users' willingness to pay and, to a less extent, man-machine interface specifications. This has been the main explanation of the gap observed between the technology itself and the marketing sector.

The research engineers can readily make the technical evaluation of their products, but it is much more difficult for marketing people to have an idea of user acceptance. We

can argue that the actual limited geographical coverage by data bases could restrain a wide distribution but there is also a kind of chicken and egg problem where everybody wants to be the first to come on the market - (which can have a positive effect on research teams motivation) - and also to have a good knowledge of users feedback from previous products diffusion.

Things are changing very slowly as we can see some industrial risking limited series on the market. Unfortunately these results remain in the private property domain which is understandable from consumer approach but limits the public action to boost those technologies with greatest social benefits. Considering these aspects very few results are published in this area to our knowledge.

V.I. Lessons from the Market

Although navigation and guidance technologies have to be considered worldwide due to strong industrial links between countries in this domain we can mention differences in market penetration. Sales seem to be much bigger in Japan than in Europe and the U.S. where we noticed some difficulties.

Within the U.S., ETAK inc. went to the market some years ago with the “navigator” and obtained very limited results. A few thousand devices had been sold in California before the company stopped U.S. production. This can be explained by several independent and/or connected factors such as:

- Poor user acceptance considering the price and/or the help provided.

- Impossibility to think to an Original Equipment Manufacturer (OEM) of the device due to the limited interest shown by auto makers (GM essentially).
- Difficulties for a small company to provide large financial support to an advertising campaign.

During these past years, American auto makers and even their captive electronic suppliers Ford Electronics, Delco, Acustar have been very reluctant to take the leadership as this market is considered risky.

More recently with very different commercial capacities, BOSCH-BLAUPUNKT tried to put an ETAK-like system called TRAVELPILOT on the European market. The delays observed between the initial marketing announcement and actual deployment may also point to some difficulties arising ultimately from a poor customer acceptance.

Similarly, PHILIPS has also been obliged to delay, for at least three years, the previous diffusion prospects (made in 1988) of a more sophisticated guidance device: "CABIN" (the device was said to be arriving in 1989, but now is not expected until 1992). PHILIPS, which could be considered as the main competitor of BOSCH in Europe for navigation technology, is not able at present to propose a digital data base to operate the system on a large scale. A major step should be taken to propose some limited "experimental" devices on the market through some auto makers to analyze consumer reaction but we can hardly think about it before two years in Europe and maybe more in the U.S.

Japanese technology could be implemented even before in these countries knowing that auto makers have been analyzing consumer acceptance for a couple of years in Japanese local markets. At that time 25,000 devices had been sold there at an average cost

of \$3500.00. Nissan and Toyota among others are proposing this technology as an OEM' device coming with TV and other entertainment systems. The production rate is reaching 5000 units a month. Considering that the services provided are very poor for addresses finding (due to the specific Japanese urban situation) we can think there is also a potential market in Europe and the U.S. where the "door to door" routing function could be achieved in a much more efficient way. These Japanese results can also show that in car navigation and route guidance technologies meet the basic needs of a population greedy for communication. Knowing that communication devices like cellular phones, faxes, etc. have also an exponential rate of development in Europe and the U.S., there may be a niche for in car navigation and guidance systems.

v.2. Evaluation of Navigational Aid

A survey (Ygnace, 1989) among a small number (N= 110) of potential buyers of in-car navigation devices shows some aspects of the market. It must also be mentioned that this sample of American and French people accustomed to travel in different cities within or out of their own country could represent a kind of target for marketing people. Following this it appears these people would adapt to a large majority (77%) to rent an equipped car at an extra cost. On the other hand the purchase of such an option is not so significant even if 25% would consider it very likely and 49% possible.

It is interesting to compare these results with a study (with different objectives) of the Greater Los Angeles Auto Show visitors showing also that 23.5% would buy a navigation device (Boretz, 1989). From our results, the willingness to pay is very far from the actual price range of these devices. The average willingness is around \$600.00. Considering that

this willingness is affecting mainly the “real aid” instead of a “gadget option” we can mention that 38% believe that this technology is suitable for deluxe models; 27% think it is better for compact cars. The others do not think that this option could be limited to a specific type of car. Within this broad framework, variation in these intentions can be observed according to the individual. It turns out for example that there is a quite clear relationship between the degree of interest and the willingness to pay.

50% of those for whom purchase could be very probable if the technology existed on the market would accept a cost of \$600.00; 40% would accept between \$600.00 and \$850.00. These two price ranges correspond respectively to 70% and 26% for those who believe purchase “possible.”

Other results enable the hypothesis to be put forwards that the way in which this technology is perceived corresponds more to real use in a metropolitan area than a kind of “status symbol”. This can be seen when we consider that, still among those who believe that these products are for compact cars, 83% think purchase is very probable or possible, compared to only 63% of those who think the system belongs in deluxe models. In the same way, consent to pay varies between these two groups. 37% of buyers on the compact car market are willing to pay \$600.00 to \$850.00 against 28% on the deluxe car market.

All these percentages must, however, be considered very cautiously, given the small size of this sample targeting a very narrow group of potential customers. They may indicate one or two lines to follow up. Finally, it was noted that American users seem much more convinced of the utility of the route guidance system than the French: 48% of the Americans chose the “very likely” purchasing option, against only 21% of the French. More importantly, the most interest was shown amongst users aged between 40 and 50. We just want to show here that behind technical, institutional, and financial problems the driver

acceptance is a key factor for achieving widespread use, and that a good understanding of it could lead to a better conceptualization of the implementation process.

CONCLUSION:

It could be too ambitious to give final conclusions in this report, particularly as such conclusions would address technologies which are mainly in a maturation phase. Our aim has been to point out the different implications of this process considering some main issues focused on the different products, the functions and the users.

As has been shown the relative importance of the required functions are not the same if we consider the public demand and the market supply. We could say the maximum attention is focused on “route choice” implications within the traffic engineering area assuming some potential pollution and energy benefits, all of this under safety constraints. The attention is more focused on the “route finding” process as the main target of the commercial sector, considering the customer acceptance and willingness to pay to improve personal comfort. All these aspects have to be clearly evaluated but no one could think to take into account all of these factors at the same time. This report (as many research approaches) raised more questions than it gave answers, but one result consists of the necessity to organize these questions in a way to help to define a global policy.

As we mentioned there is a strong interaction among different aspects of implementation of these technologies and each problem cannot be solved without considering the global implications in order to leave the door open to further developments. This is also necessary because time and development constraints are not the same for the different actors. For example, a schematic summary can point out the differences between the basic goals of private and public sector where the different achievements are not linked in the same way. As a matter of fact, the industry places emphasis on:

- Market analysis and definition of potential buyers
- Fund raising
- Prototype development
- Testing of the products within this frame
- First evaluations at the first stage of market penetration

The public sector through transportation agencies is more interested in:

- Trading off the global transportation problems (ie. congestion, pollution, etc.) and the available technologies to solve them
- Alternative transportation investment issues.
- Global safety aspects and legislation concerning the implementation of the technology
- Simulation studies to assess these objectives taking into account the behaviors of the potential users.

We could say that these different objectives refer to a kind of theoretical “cluster”, a natural tendency and that there are in fact some shared objectives between these two sectors. Research programs we have presented here could be an example of this collaboration between industry and the public sector.

Yet we can argue that this collaboration should be reinforced in some ways. Two solutions are possible:

- 1) Evaluation of the first introduction of some systems on the market

2) Design and evaluation of field experiments

The first solution could be more difficult to succeed insofar as it refers to specific technologies and it implies to deal with protected proprietary rights. The second solution seems more promising if it is not restricted to one technology. Here the Japanese experiments with AMTICS or RACS, where a lot of suppliers are participating, are a good example to follow.

These kinds of experiment could be very useful to learn the drivers' responses and to set up some legislative frameworks before industries go too far with their own product development. The role of the policy could be here to define the "rules of the game" in the way that everybody has more to win than to lose as a global result.

The advantage of this solution is to obtain some common methodological backgrounds among the different partners interested in analyzing the results with some common "units of measurement". The goals and the way to implement these technologies could vary over time but this can help to find some political and financial agreements considering for example the necessary cost shares between the "road" and the "car" parts of the intelligence.

On the other hand, as we mentioned there is a strong competition/collaboration between international or national groups which are developing these technologies and as the cars, if not the drivers, are supposed to be the same in different countries we can wish to extend these joint field experiments to an international cooperation to maximize the global benefits of the implementation for everybody.

For a long time the benefits have been mainly assumed; it is necessary to quantify them in the real world taking into account some parameters which can be hardly mentioned

through simulation studies like for example the drivers' acceptance and ability to use guidance information in real situations.

Simulation studies are very useful for basic knowledge. However, drivers' (in simulation experiments) are usually paid; they would have to pay to use the technology available on the market. This could bring some unknown differences about motivational aspects involved in the different performances observed in both situations.

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