Michael L. Sena Consulting AB
Mobility Research Report

Off-board Navigation

More irresistible than on-board?

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Preface

Mobility Research Reports are intended to generate discussion within the Intelligent Transport Systems (ITS) community. The community is defined in its broadest scope, and includes environmental and city planners and map and travel guide publishers, as well as the individuals associated with organizations that have thus far been the drivers behind ITS efforts. This widening of the forum for discussion is recognition of the important role that can be played by those who are responsible for designing the environments in which ITS solutions will operate, and by those who have traditionally provided the tools used for human orientation and wayfinding.

Each paper expresses the personal views of the author, with a focus on the interrelationships between the designs of the systems, services and infrastructure which are proposed to improve personal and collective mobility, and the planning and design of our habitat. The fundamental premise of these papers is that land use and built form policies are inseparable from traffic and transportation policies.

Michael L. Sena Consulting AB is an independent company providing specialist consultancy in the design and development of mobility systems for in-vehicle and pedestrian usage, including navigation, traffic information and fleet management. The principal of the company, Michael L. Sena, is an internationally recognised expert in digital map databases, location-based services, navigation and telematics. He served as an expert delegate to both the European CEN and international ISO standards committees.

The company was founded in 1983, and since then, has worked closely with decision-makers and their staff to develop successful mobility system solutions that are on the market today.

Mobility Research Reports

1. Route Guidance Systems: Luxury, Convenience or Necessity	October 9, 1997
2. A National Roads Database of Sweden: A Future Scenario	April 22, 1998
3. Digital Maps in the Worldwide Automotive Context: Applications of Digital Maps in Cars and Other Land-based Vehicles	May 1, 2000
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Introduction

This ***Mobility Research Report*** is about new developments in automated in-vehicle navigation systems, in particular moving the map data source and route calculation software out of the vehicle to a central server. An earlier ***Report***[1], written in 1997, addressed the prospects of success for route guidance systems as in-vehicle consumer appliances, and offered an opinion on how they might become convenience items that every vehicle owner would want to own. The basic premise of the earlier paper was that the then-current route guidance systems were not designed for purposeful and logical wayfinding. They did not assist the user in understanding the fundamental relationships between the paths of movement and the user's eventual destination in a way that the user could feel a sense of orientation and security that the destination would be reached quickly and safely.

Since 1997, navigation systems sales have increased significantly (see Appendix), especially in Europe, and have continued their steady penetration in Japan.[2] However, they are still luxury items. Volume sales have not materialised. Larger display screens, better user interfaces, increased map area coverage and on-board storage have contributed to making them better navigation aids, but their fundamental design has not changed.

Now, even before in-vehicle navigation systems have reached the mass market, there is a new type of system that is being readied for a possible market introduction. I will use the term *off-board navigation* to describe the new system. Perhaps it is because the integrated, self-contained on-board systems continue to be too expensive, and still not yet performing as a truly dependable personal guide, that lower-cost alternatives are being sought.

The questions that this *Off-board Navigation Mobility Research Report* will explore are whether off-board systems have a price-performance proposition that will allow them to succeed in reaching the mass market, whether they can offer an acceptable level of guidance, what the trade-offs are with the on-board systems, and what the prospects are for the off-board variation to supplant the on-board model.

[1] *Route Guidance Systems: Luxury, Convenience or Necessity (October 9, 1997)*

[2] In Europe, 1.3 million navigation systems were sold in 2002, one-third as aftermarket systems, and two-thirds as OEM installed systems. In 2003, total sales are projected to increase to 1.6 million units. At the end of 2003, the number of navigation systems in operation in Europe is projected to be approximately 5.4 million. By contrast, in the US the cumulative number of units in operation at the end of 2003 is projected to be just 1 million. In Japan, 4.4 million navigation systems were sold in 2002.

Off-board Navigation

More irresistible than on-board?

My navigation system, an early prototype of the Volvo RTI System with integrated RDS-TMC[3] traffic information, was temporarily out of service. The CD drive had jammed and I was waiting for replacement parts. So, like most of my fellow travellers, I was driving without any special assistance. I had left the office I was visiting before the normal rush hour traffic should have started. There are two routes connecting the northern side of Göteborg to the north-south motorway that eventually delivers me to my home and office south of the city. One route passes through a tunnel under the Göte River that separates the two halves of the city. This tunnel route merges along the way with two motorways that meet at either end of the tunnel, always causing traffic problems at peak travel times. The other route leads over a bridge crossing the river, through another tunnel, and to a ring road on the southern perimeter of the city. I chose the tunnel under the river route because it is almost three kilometres shorter than the other route, and it should have been free flowing at the time I was driving (3.00 P.M.), especially on a weekday in July when most people were still on their long summer holidays.

As I drove up the ramp to merge onto the main road, I saw that traffic was moving very slowly. It was too late to turn back. Without traffic, I would have been through the tunnel in less than five minutes. One hour later I was on the other side. Two overheated cars—the temperature on this July day was an unusually high thirty degrees Celsius—and one accident were the causes of the delays. I thought, if only I could have flown up above the city as I was leaving the office, I could have seen which route was the better of the two to take. If only I could have talked to someone already on the road as I approached it, I could have turned in the other direction. If only a driver at the front of the queue could have passed back the information to everyone behind, we would all have been better off, at least knowing why we were stuck on this road in the hot afternoon sun. If only my navigation system with traffic information was working.

During the day I had received the latest *J.D.Power* report on what consumers are supposed to want most from vehicle-based

[3] RDS-TMC – RDS-TMC stands for Radio Data System–Traffic Message Channel. TMC service is already available in many European countries and is expected to be widely deployed throughout Europe in the next few years. It provides a system for collecting, collating and broadcasting real-time traffic related data in a digital coded form on standard FM radio broadcasts. To be useful, it is important for both the supplier of the real time traffic feed and the routing/navigation data being used to have a cross-reference table to interconnect both data within the live system.

communications and information systems[4]. The top two items on their wish list, roadside assistance and vehicle diagnostic information, would have helped the unfortunate car owners who were the cause of the traffic jam. The third and fourth, real-time traffic and navigation information, definitely would have helped the hundreds of others who suffered along with them.

Can there be any question that drivers need information in order to make informed decisions about when and where to drive! We are still using the same methods of navigating on our roads as we used several hundred years ago. The method of transportation has changed (motorised carriages instead of horse-drawn ones), but the methods of wayfinding had been the same until the introduction of the first automated navigation system.[5]

In-vehicle Navigation – The Old and the New

In-vehicle navigation is a general term referring to any one of a number of wayfinding methods. People driving cars navigating to their destinations using visual landmarks as waypoints, following street and road signs, referring to maps, and asking people in the vicinity for directions are all wayfinding methods. The automated systems of today have taken some of these older techniques and incorporated them into their packages.

- Visual landmarks – This is the oldest form of wayfinding and one of the most effective for the person on foot. Church spires, bell towers, monuments, river edges, hilltops, or any feature that stands out or rises above the rest can be used for orientation. Cartographers have added three-dimensional forms to their maps to aid in navigation. Twenty-odd years ago, the paper maps we produced at Esselte Map Service USA had 3D buildings as one of their trademark features. I had a recent experience with this form of navigation. Last Autumn, my wife and I drove from the south of France where we were visiting friends to Lyon for the e-Safety conference. We approached the city, armed with several maps. We also had a brochure from the hotel where we would be staying, and recognized its distinct tubular form from a distance. It is the tallest building in the city. We put down our maps and "felt" our way along the maze of one-way and restricted access streets to the hotel entry. This form of navigation is being developed to a fine art by

[4] JD Power 2001 Automotive Emerging Technologies Study – Wave I & II

[5] There are different opinions on what constitutes a navigation system, and who was first to introduce one. The Etak Travel Pilot came out in the early 1980's. It displayed the position of the vehicle on a map, along with the destination. It did not provide turn-by-turn instructions, but used vector map data and provided a heading-up display. Japanese manufacturers introduced map display systems even earlier, also without turn-by-turn instructions, using waypoint routing instead. The first turn-by-turn instruction systems were developed by Bosch and Philips (now Siemens VDO) in the late 1980's. The first commercial turn-by-turn systems in North America and Europe were introduced in the mid-1990's: the Magellan NeverLost system (originally developed by Zexel), the Bosch TravelPilot (originally based on Etak technology) and the Philips Carin System.

the Japanese navigation system manufacturers with help from the digital mapmaker, Zenrin.

- Signage – When roads were few, signs at crossroads were sufficient to point the traveller in the right direction. Some signs, several hundred years old in Europe, and two or three hundered in North America, can still be seen today in small villages at crossroads. When properly done and intelligently employed, signs can be a most effective means to direct drivers to important places (e.g. city centre, train station, airport, sports arena, etc.)6 City and highway maps are based on finding places using street signage as the principal guide. Before route numbers, which were first used in the UK in 19217 and in the US in 1926, major roads were usually named after the principal destination, such as the Boston Post Road, or a geographic location, like the Blue Ridge Parkway, Mohawk Trail, Dixie Highway, Pikes Peak Ocean to Ocean Highway, or after a road building authority, like the Pennsylvania Turnpike.

- Paper maps and atlases are the most common tools used by people all over the world to find their way in unfamiliar places. Map reading is not a skill that everyone learns, or that everyone can master. It requires a significant amount of mental gymnastics to relate a three-dimensional world to a two-dimensional representation of that world. It is difficult enough to use a map while on foot, but it is a dangerous practice for a driver riding alone to try to use a map while the car is in motion. In 1911, the American Automobile Association started publishing road maps. They were not standard topographic maps, but consisted of route descriptions, describing where an automobile and its passengers could travel in relative safety. This concept was eventually developed into the AAA TripTik. In 2002, the total value of maps sold worldwide was $2.5 billion.8

- People in the vicinity – The last mile, whether it's delivering broadband services or reaching a specific destination, is usually the most difficult part. The stereotype of male drivers in the US is that they would rather drive around for hours in circles rather than stop and ask a local for assistance. In my experience, this

[6] In *Route Guidance Systems: Luxury, Convenience or Necessity,* I addressed the topic of signage, with examples of how signs can either reinforce or work against the physical structure of a city, and either enable or work against intuitive navigation.

[7] A Brief History of the Numbering System of UK Roads; James Bufford: A 1919 Act of Parliament provided funding for roads to the Ministry of Transport. By 1921, the MOT had identified the system for England and classified 97 main A roads with one and two digit numbers. The formal classification was published in 1923 by HMSO in a booklet, and the Ordnance Survey of Great Britain published a series of maps for MOT which included the road numbers. The numbers were placed on road signs at the same time.

[8] This is an estimate provided by one of the leading experts in cartography and map publishing, Dr. Michael W. Dobson.

is an unfair characterisation. It's male drivers everywhere in the world, and, according to a survey published a few years ago in a mapping trade journal, quite a number of female drivers as well.9 The problem with asking is that we have to remember what we've been told, and we rarely can. So one stop becomes two or three before we narrow in on the target.

- Radio - Landmarks, signs, passers-by, and maps. None of these methods provides the least amount of assistance to a driver who needs to avoid trouble spots or to find a hidden destination. One information source available to most drivers, the radio, does offer some relief to the dearth of information in the driving capsule, but it is usually only a chance happening that the right channel is tuned in at exactly the right time. In Europe, with RDS-TMC the radio tuner automatically receives traffic message broadcasts. These usually come at exactly the wrong moment in a radio program (when a major news item is being described or when the final score of your favourite team is being given), and concern a road that is not in the driver's vicinity. But sometimes, when the stars are properly aligned, it can be magic.

- Telephone - The mobile phone is the single most important driver aid since the public telephone booth. But using the phone to get directions has its problems. It is almost the same with phoning up the party you are visiting as with asking a passer-by, but it's even worse. First you have to admit you are lost to someone you know. You also have to know where you are and then communicate this intelligently to the person who will try to guide you. They have to visualise this, create a mental route, and then relate the route to you without any visual means to do so. It usually involves giving you landmarks (turn at the Shell station) or counting instructions (drive on Main Street past three stop lights and turn right at the fourth.) Rather than as a talking device, the mobile phone as a driver's aid holds its greatest promise in its ability to communicate data. This capability is what off-board navigation systems exploit, as we shall see.

- Automated in-vehicle systems come in many forms:

  - Autonomous on-board navigation systems that have all the data and applications software inside the vehicle. They are self-sufficient and require no

[9] IMTA Map Report published a short article containing a reference to a survey comparing the driving habits of men and women.

connections to outside information or process sources.

- Integrated – Systems that are part of the design of the vehicle and are developed with the automotive OEM. They are mostly factory-installed, requiring special connections to audio systems, odometer, and other sensors, and integration into the vehicle's display screen, CD/DVD drive, and user-machine interface. Systems that are automotive OEM options comprise two-thirds of the systems delivered today in all three major markets, Japan, Europe and North America. This trend is expected to continue.

- Independent – So-called aftermarket systems, they can be installed in a similar way as a hands-free telephone, but require more space for display, disk drive and memory management unit. They can be moved between vehicles, but they depend on connections to vehicle systems (odometer, sensors, audio) for operation.

Independent aftermarket system: TomTom Go

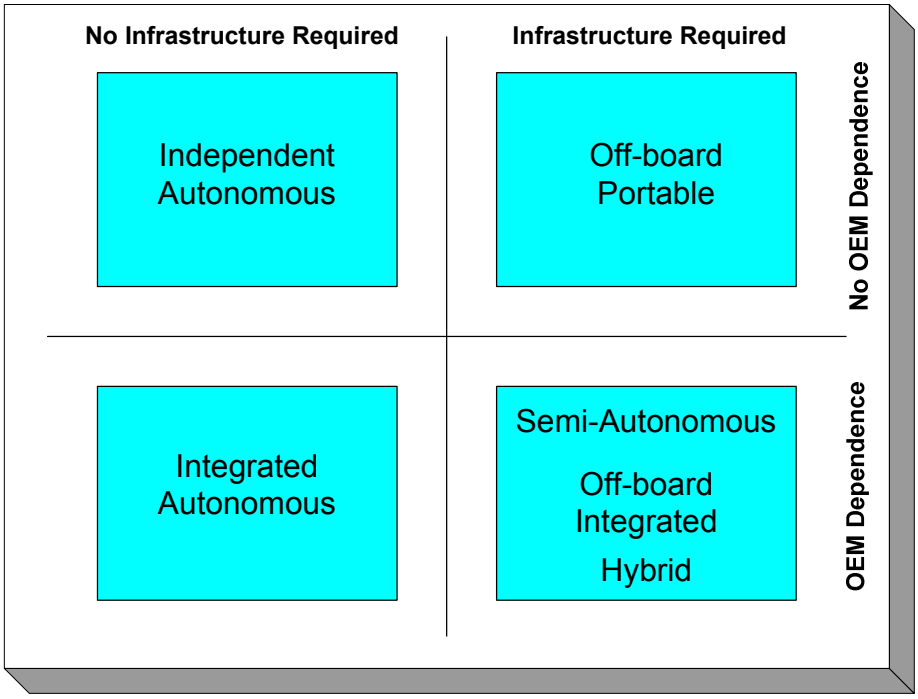
- Semi-autonomous on-board navigation systems – The systems can be integrated or independent, and combine real time traffic data delivery via radio or cellular network with on-board data storage.

- Off-board navigation – Deliver routing instructions and the necessary associated data via wireless data systems (GSM/SMS, GSM/Data, CDPD, GPRS, UMTS)[10] from remote service providers.

[10] GSM: Global System of Mobile Communication. GSM is global, operating in over 200 countries (not US and Japan) - 900/1800 Mhz
GSM/SMS: Global System of Mobile Communication/Short Message Service. Provides for 160-character messages between GSM handsets or between a GSM handset and an information source. Messages are entered via the handset's keypad, or via add-on keyboards, such as Tegic's T9 or Ericsson's Chatboard.;GSM/Data:
CDPD: Cellular Digital Packet Data. A method for sending packet data over analogue networks. Requires specific network equipment, that now covers 85% of North America to support wireless Internet connections
GPRS: General Packet Radio Service for GSM, enables more efficient use of radio resources leading to increased capacity and higher speed data servicesUMTS: •Universal Mobile Telecommunication System - Also known as 3G (for 3rd Generation) - Officially IMT-2000
(footnote continued)

The hardware for display, processing and storage can be the same as the on-board systems, or it can consist of portable devices, such as personal digital assistants (PDAs) or wireless handsets. The critical addition to the hardware package is a telecommunications module.

- Hybrid navigation – combines off-board delivery of static and/or dynamic data with some form of on-board data storage and applications support software.



Automated in-vehicle system product groups. The total value of navigation systems and data sold worldwide in 2002 was approximately $6 billion.[11]

Why Navigation Systems from the OEM

Before discussing the details of navigation systems, I would like to first address an obvious question: Why have the automotive OEMs gone to all of the trouble and cost of redesigning their vehicles to integrate navigation systems? As stated above, the majority of systems delivered to customers are built into the vehicles. Why haven't they just let the navigation system developers get on with their work and allowed the customer to choose whichever system they feel meets their requirements and their pocketbook?

These systems have been costly to develop, both for the OEM and the system supplier, and they are troublesome to integrate. No one will

–WCDMA - Wide-band CDMA. Supported by GSM countries and Japan
–CDMA-One - Developed by Qualcomm
[11] This is my own estimate double-checked with many industry experts

release official figures, but internal development costs to prepare their vehicles for integration of navigation system has cost each OEM in the many tens of millions of dollars. On top of this, the OEM's have paid their system supplier for improvements and modifications to the systems so that it meets the OEM's specific requirements. Even further, they have spent large sums on database preparation and conversion costs, ranging from 10% to 30% of the customer price for a CD or DVD. They now have recurring costs for software updates and system improvements. Still, they do it. They continue to build navigation systems into their vehicles.

The reason given by the majority of OEMs is that they began their developments for both defensive and offensive reasons. On the defensive side, even if one company had navigation, all the companies had to have it. No company can afford to have their customers and the automotive press criticising them for missing an important feature. The systems might also be mandated by law in some markets, like seat belts, or become an expected driver aid, like cruise control or ABS, or come to be viewed as an indispensable car feature, like a radio. In the early days, no one really knew what would happen with navigation.[12]

On the offensive side, many believed in the intrinsic logic of navigation systems. They saw them as necessary features, and features are a big part of selling cars. Renault engineering, for example, had three goals for its recent major overhaul of its car range that has taken place during the past several years: Innovate; Improve performance in terms of development times and costs; and, Increase the level of features for each vehicle.[13] Car manufacturers championed the development of navigation systems within their companies because they truly believed that these systems would eventually become "must haves" by all drivers. Future sales would cover the costs, and the add profit to the company's bottom line.

Thirdly, the OEM has a strong incentive to control anything that enters the vehicle and to earn money on it. Parts and accessories accounts for a large part of the profit that is earned by automotive companies today—up to 80% in some companies. The car itself has become the razor blade holder, and parts and accessories the razor blade. Ignoring the sunk costs of research and development, the car companies make money on navigation systems, just like they make money on any part or accessory that is sold as original equipment.

Automated In-vehicle Navigation

Autonomous navigation systems were the first wave to reach consumers. This was in 1995/96 in Europe with systems like the Philips Carin in Renault and BMW, Bosch TravelPilot in Mercedes, Magneti Marelli in Fiat, and Mitsubishi Electric in Volvo. Autonomous systems were introduced even earlier in Japan. The autonomous systems were followed quickly by traffic-enabled systems of the semi-

[12] As Nils Bohr is reputed to have said: "Prediction is difficult, especially when it concerns the future."
[13] Renault R&D: The Magazine of Research and Development; No. 27 (January 2003).

autonomous category. Adding traffic information to autonomous systems should have taken them from useful to essential driver aids. Many systems are now equipped with RDS-TMC receivers, allowing them to receive traffic information from public authorities or private traffic providers directly via FM broadcasts[14]. The map databases from Navigation Technologies and Tele Atlas have been coded using the special tables produced by the traffic information providers, enabling traffic incidents to be processed by the systems' software and new routes generated that avoid congested areas. Some systems use GSM/SMS as the message bearing service, but the objective is the same: provide up-to-the-minute information to the drivers.

Bosch TravelPilot Sem-autonomous route guidance system.

Making autonomous systems dynamic is one way to improve the performance of navigation systems. The downsides of this approach are the costs and complexities they add to the systems, and all of the supporting processes required to keep these systems in operation. The main problem is that the systems are only as good as the on-board data. Traffic data suppliers are constantly increasing their coverage of roads by installing new traffic flow sensors or using floating car data[15], adding more traffic reporters, improving cooperation with police and emergency authorities so that they provide faster and more accurate input. To make this data usable by their customers, they need to expand their location code tables. These new locations for which traffic information can be distributed must be added to the navigation databases. The navigation databases must

[14] Free traffic information is broadcast via RDS-TMC in a number of European countries, including Germany, Italy, The Netherlands, Sweden, Finland, Denmark, Spain, Switzerland, Austria and France. The UK has no free RDS-TMC services. A private operator, ITIS, has the license for RDS-TMC broadcasting in the UK, and it charges a fee to the hardware manufacturer or the vehicle OEM for a code that allows for decrypting the location code information.

[15] Floating car data systems collect travel time information from vehicles that are equipped with positioning technology and wireless data communications. The vehicles send their positions and speed data to a central processing point where the data is matched to digital maps. The result is a map of average speeds along segments of the road network.

then be delivered to each navigation system supplier for conversion to their particular physical storage format (PSF) on a CD or DVD or other storage medium, and eventually supplied to the navigation systems' owners.

Even in the best of cases, from the time the navigation system vendor delivers the data to the system supplier until a new release of a CD/DVD reaches a navigation system customer, six months will have passed. It can take longer. The navigation system supplier will have updated the data within three-to-six months of when it is delivered to the system supplier, so this adds further to the lack of currency.

Taking advantage of the best available traffic information requires constant re-supply of new on-board media by the navigation system suppliers, and continuous purchases of this new data by the customers. The average cost of a CD for a geographic region of coverage, say Germany or the UK, is around $150. CDs are able to hold 675 megabytes of data. Some navigation system vendors have been able to pack Germany, a relatively large country with the most detailed attributes and road coverage, on a single CD, while others require two. A DVD holds a few gigabytes, and can be loaded with all of Europe. A DVD covering all of Europe costs approximately $310-$400. The number of navigation system owners who update their on-board CD-based media has been around 10-15%. No one should be surprised that the majority of customers are not anxious to pay over $100 or $200 for an update to their data. The number who will pay over $300 for a DVD update is very likely to be much lower, especially since few customers need more than the area in the vicinity of their home and work. They are paying a huge premium for information that they will never use.

In fact, an informal survey I made of automotive OEM's confirms that the aftersale market for DVD-based navigation media has collapsed. Instead of being a positive development for customers, system developers, OEM's and data suppliers, DVDs have turned out to be a major problem for everyone.

Off-board Navigation Systems

One alternative to making autonomous systems dynamic is to move the entire data assembly and processing task to centralised servers, and provide drivers with routing information that already accounts for the current traffic conditions. This is the off-board navigation approach. There are already examples of this type of system coming into use.

DaimlerChrysler has introduced an off-board navigation system in its A-Class and Smart vehicles. Data and the software for the navigation devices, called **NaviGuide**, is supplied by ***PTV*** (Karlsruhe, Germany). PTV assemble the navigable road data, traffic data and other information of interest to drivers into a single source. On their central server, PTV have the application programs for address searching and route calculation, and for applying the information on current traffic

conditions to the generation of a route. Using the on-board interface, the user requests a route to a destination. This request is sent to the PTV server via the GSM network (GSM/Data or GPRS), the route is calculated and sent back to the driver's on-board equipment in the form of a series of voice turn-by-turn instructions and manoeuvre diagrams. NaviGuide runs on clients operating Windows CE and J2ME.

The **Polaris** system by ***Telmap*** (Herzlia, Israel) takes off-board navigation one step closer to its on-board predecessor. Rather than just simple turning manoeuvres and voice instructions, Polaris offers these plus full-colour maps that are tailored to the device being used. On an iPAQ, for example, with a high resolution colour screen, the maps are rich and detailed, similar to the best high-end autonomous systems. On a Java-enabled mobile phone, such as a Nokia 6310i, 7650, Motorola T720, Sony P800 or Siemens S45i, the detail is reduced to improve clarity.

On-board equipment for off-board navigation like these from ***Telmap*** and ***PTV*** includes, at a minimum, some form of display screen for maps or manoeuvres, an audio adapter, a positioning device (GPS receiver), and a communications interface. It can be as simple as a mobile phone with a built-in GPS, or a PDA, a Bluetooth phone, and a Bluetooth GPS device. It can be more car friendly with a hands-free set, connections to the audio system in the vehicle, and special hardware for positioning and map matching.

Motorola has developed an off-board navigation system called **Viamoto** that it has implemented in conjunction with Avis Car Rental in the US (Avis Assist), and with ***Trafficmaster*** in the UK (**SmartNav**). In the Avis instance, the in-vehicle system is a Motorola GPS-enabled Iden i88s mobile handset with Viamoto software. Drivers who rent the handset speed-dial a special number and use the speakerphone to request a destination address or place. The call is taken by an operator at Unity Call Centre Group, who have access to Motorola's off-board navigation server. The operator inputs the route request and the result is then downloaded to the Motorola phone. The driver is then given voice instructions, which are synchronised with the phone's GPS positioning.

The SmartNav system and service in the UK operates in a similar fashion. The difference is that the driver has the system installed in the vehicle. The on-board device consists of the positioning and telecommunications hardware with the associated software. A single SmartNav button is installed at a convenient location on the instrument panel. The driver pushes the button and receives a similar service as with Avis Assist. The Motorola voice-only system requires perfect map data, and absolutely perfect timing and clearly-stated instructions, otherwise the driver will become lost after the first missed turn. When I tested the system, neither the data, the timing nor the instructions had reached the necessary level of perfection.

Traditional on-board system vendor, ***Blaupunkt***, a subsidiary of Robert Bosch in Germany, has not waited to be one-upped by start-

ups. They have developed an off-board system that is integrated with a 1-DIN radio module. It includes GSM/GPRS and GPS components, as well as a special antenna that combines radio, GPS and telephone receivers. The small display is used to show manoeuvre icons, and names of streets, landmarks and points of interest. A SIM-card holder is built into the back of the radio so that the users insert their own SIM-cards and pay for communications separately from the services. The first aftermarket service will be available in Germany during 2003. TeleInfo is the service provider. Blaupunkt is also working with Targasys in Turin, Italy, a telematics[16] service provider in the Fiat family, and with Fiat to develop an OEM version of the off-board system.

Off-board Advantages

Does off-board navigation offer significant advantages over autonomous or dynamic on-board navigation? The answer is a qualified Yes. The advantages are different for each of the major players in the value chain: the vehicle OEM; the navigation system supplier; the map data supplier; and, the eventual customer.

The Vehicle OEM Perspective

One advantage for the OEM, and eventually the customer, is the potential to reduce system costs. Placing all of the data off-board eliminates the need for the media reader, unless the system makes double use of the audio CD/DVD reader. Compared to dynamic systems, there is no need for dedicated radio receivers. Hardware cost savings should not, however, be overestimated for OEM-installed off-board navigation systems. Off-board navigation requires a communications device. The cost of the device can be delegated to the customer by requiring the customer to bring his or her mobile phone into the vehicle and interfacing the off-board components through a cradle or a Bluetooth connection. If the phone module is integrated, the cost of the device and the embedded subscription (e.g., with GSM, the SIM-card) could more than outweigh the savings in on-board data storage and computer processing hardware.

Media production and handling cost is a major expense for the OEM's, and this is an ideal place to look for savings. When these costs are passed on to the customer they result in map media prices that are up to four times higher than the cost of map data received from map data suppliers. Each on-board system currently requires its own special map data format. System developers charge the OEM for compiling the raw map data into this format each time a map update or a new software release is made. Assuming that each OEM does not have its own special off-board format, compilation costs can be eliminated from the OEM equation with off-board navigation.

[16] Telematics is two-way communication between a vehicle and a service center. Data communications is a pre-requisite for all services. Voice communications is necessary for some functions, desirable for others, non-essential for most. Adding a positioning device in the vehicle and mapping capabilities at the service center enables a range of location-based services to be provided.

In addition to compilation, putting the CD or DVD into the OEM's parts catalogue, along with luggage racks, wiper blades and floor mats, involves a cost for the OEM. While it is also an income opportunity, the volumes are exceedingly low, compared to other parts, but the administrative costs are the same.

The Customer Perspective

The customer benefits in greater convenience, higher quality, and, potentially, lower cost. In theory, data on a central server can be kept more up-to-date than data supplied on media. Map suppliers are constantly updating their data, but are releasing these updates every three-to-six months. Currently, the conversion and compilation processes used by navigation system suppliers can take several months to transform raw map data provided in a transfer format such as GDF to a machine-readable physical storage format. By the time the CDs or DVDs are delivered to the customers today, they are a minimum of six months, but mostly one year out of date.

There is no guarantee that the operator of a central map server will update the data more often than the navigation system suppliers. It is still a costly and time-consuming task. However, what can be guaranteed is that all users of the service will have the latest data that is resident on the server, rather than CDs or DVDs that were delivered with the original equipment and have never been replaced with new versions.

Another strong point for off-board navigation systems is the ability for the customer to receive personalised information about events and activities, and to be guided to the places where these occur. This is a feature of location-based services on non-vehicle-based devices, but it extends as well to on-board systems. The customer also has the possibility of combining information that is stored in other data sources, both personal (e.g. address book) and public (e.g. Yellow Pages), making the address input process faster and more accurate.

The Navigation System Supplier Perspective

It might be assumed that the system suppliers have the least to gain by putting all of the data off-board on a central server. Proprietary system hardware is potentially reduced, thereby reducing the price for the system and hence the gross margins. On-board applications are possibly minimised or performed completely off-board, lowering the value added by the system supplier. Surely, system suppliers will be against off-board systems.

Not necessarily. The largest threat to incumbent system suppliers is that upstarts will take their OEM business. Companies like Siemens VDO, Visteon, Delphi, Blaupunkt, Denso, Magneti Marelli and Mitsubishi Electric among others are trying to sell ever larger components to the OEM, and control more Tier2 subcontractors. This has been a demand placed on the Tier1's by the OEM's. The incumbent system suppliers, not the small software houses or

application service providers, are in the best position to sell off-board solutions to the OEM's. They have the economies of scale to deliver the off-board services and the mandate to integrate all of the necessary hardware components.

The Map Data Supplier Perspective

Map data suppliers make money when data is sold in the form of application information. Whether the customer is receiving this information from a CD/DVD or via a map server should not matter to the map data supplier.[17] Their pricing models should cover both delivery methods so that they are revenue neutral given the same number of customers. Off-board systems should, in theory, shorten the time between data availability and customer usage, and shorten the time between when they deliver data and when they are paid.[18]

The principal advantage of off-board navigation for map suppliers is the promise of larger numbers of users. This will result when both system and data prices can be reduced to mass market levels. There is a greater chance of achieving this with an off-board navigation solution, claim the proponents of off-board navigation.

The Added Benefits of Connectivity

The benefits of connectivity that off-board navigation systems bring to the vehicle extend far beyond receiving directions to places to which the driver wants to travel. Having a communications device in the vehicle opens the door for a host of driver- and vehicle-centric services. Remember my traffic problem in Göteborg, when I could have made a better choice of route had I known about the accident and overheated cars that caused my one-hour delay?

Technology exists today that would have allowed the vehicles involved in these incidents to send a message to all other vehicles in their vicinity to avoid using the road they were on. At the same time, they could have sent a message to the closest police car—as soon as the accident or breakdown occurred. The message to the other drivers would be something like: "I've just had an accident on River Parkway, between Lundby and Frihamnen in the direction of Tingstadstuneln. I'm blocking traffic. Avoid this road until further notice." To be useful to just those drivers in the vicinity, the message is encrypted so that only those near the scene are able to receive it. This is called *geoencryption* by one of its developers, Dorothy Denning of Georgetown University in Washington, DC. The device receiving the

[17] Map data suppliers have had a difficult time coming to grips with off-board pricing because it was initially seen as a threat to their primary on-board navigation business. Selling data on a one-time basis is the simplest method. The customer uses it as often as he or she likes, and hopefully purchases an update. With the pay-as-you-go model, the revenue stream is not as controllable. The problem at this point for the map data suppliers is that there is insufficient historical data on which to base their unit prices.

[18] Map data suppliers usually attempt to charge an annual minimum license fee based on projected volumes. This fee is usually paid at the start of the year, and the customer submits monthly or quarterly reports on the actual number sold. The customer tries to keep the minimum low, while the data supplier offers lower unit volumes if total volume—and prepaid license fee amount—are higher. OEM purchasing departments attempt to pay suppliers when a part or accessory is delivered. The distributors hold stock and deliver when ordered.

message uses its location as the decryption code. Valid locations might be all geographic coordinates within a three kilometre radius of the message sender. Compared to using sensor data to gauge traffic flow, or even direct reporting by police to traffic control centres, such a method of informing nearby drivers about an incident must be quicker and much more effective. It would have the immediate effect of keeping other drivers out of the area, making it easier for assistance to arrive and get the problems fixed in a shorter period of time. When the cars are no longer blocking traffic, they can send a "The coast is clear!" message.

A company in Arlington, Virginia, called GeoCodex, is commercialising this geoencryption process. The main applications that they see in the short term are distributing movies. The geographic location of the film receiver provides the code for unscrambling the movie, and each location is tied to a specific user who is charged for the downloaded film. This same procedure can be used for encrypting a message to drivers inside or outside an invisible fence defined for a specific application.

What about fixing the overheated engine before it overheated, and sending the vehicle to the nearest workshop to get the automatic repair checked? This is possible today as well. Networkcar in the US, which was recently acquired by Reynolds and Reynolds, offers wireless systems for collecting and delivering real-time automotive diagnostic data. GM's OnStar division offers remote diagnostics as one of its premium services in the US.

Off-board's Disadvantages: Are there any?

In its simplest and least vehicle-integrated form, off-board navigation does have several disadvantages compared to on-board systems.

- Reliance on the GPS device for keeping track of the vehicle's location on the road. Reception of GPS signals is disrupted by tall buildings or heavy tree cover, and blocked completely in tunnels and parking garages.[19] Once the signal is lost, there is no way to follow the course of the vehicle and provide turn-by-turn instructions at the split second they are needed.[20] Some off-board systems perform a limited form of map matching by plotting the GPS positions, applying filtering algorithms (e.g. Kalman filter), and comparing the results to the map data. This requires that the data in the vicinity of the pre-planned route is transferred from the central database to the on-board device and stored in temporary memory. The longer the route, the more data that is required along the route corridor, and the larger amount of storage that is needed—unless the off-board system relies on downloading the

[19] Qualcomm subsidiary SnapTrack claim to have solved this problem with special hardware and software that can capture GPS signals in places that are usually impossible to reach, including inside buildings.

[20] On-board systems connect to a gyroscope for heading, and to the vehicle's odometer for measuring the distance moved. By using dead reckoning, the likelihood of a vehicle following a specific path in the database can be calculated (called map matching). GPS signals are used only to obtain the initial location and as a periodic sanity check on the dead reckoning calculations.

data during the progress of the route. This leads to a second major problem.

- Off-board solutions that rely on a constant network connection, whether it is GSM data (or another second generation technique), GPRS, or 3G, will not have any satisfied customers for quite some time. Staying connected to the GSM network is extremely expensive. To avoid the expense, some systems make a connection, download as much data as required to start the route guidance instructions, and then the connection is closed. When more data is needed, a new connection needs to be made. This happens via a modem. At 9.6 or 14.6 kilobits per second (kbps), transfer times are slow and data amounts severely limited. So companies compete on the basis of their data compaction techniques to stuff as much voice and text and graphics as possible into the first download. They also compete on their speed in preparing the data for sending on the server side.

Packet switched data (e.g. GPRS or I-mode), allows an always-on connection to access additional data, and the user is charged only when data is transferred, not for holding the connection. Data speeds are higher and the volume of data that can be sent is greater. However, maintaining a connection in a moving vehicle is not a trivial undertaking, and there is no guarantee that when more data is needed, a GPRS connection will be possible. 3G coverage today covers a small fraction of the geographic area in markets where it is being developed, so it is not really an option for anything but limited, in-city origins and destinations.

- Crash worthiness is a problem, but not more problematic than the hands-free telephone. In case of an accident, handsets or PDA's housed in cradles will fly about the cabin. But cars are filled with objects that their owners bring into them that are potentially more lethal than these communication devices.

- Turning navigation into a service function from a system function adds a completely new dimension to the application. Who provides the service; how is quality guaranteed; how is the service paid for; who pays for communication costs? These are just of few of the issues that need to be addressed by the OEM. On-board navigation is simple: the customer makes a one-time payment for the system when the car is purchased, receives the desired map data, and may never have any reason to worry about the system again unless it malfunctions or he or she wants a data update or a new area of coverage. Off-board systems require an infrastructure, one that is going to be operational and dependable for the life of the car and the system if it is an OEM integrated system.

This infrastructure is not very different from a telematics infrastructure, so off-board navigation is a natural add-on to the basic safety and security services offered with systems like GM's *OnStar* and Volvo's *Volvo On Call*. However, the vehicle OEM's in general have taken an extremely cautious approach to developing telematics infrastructures,

and prospective customers would be well advised to be wary of purchasing such integrated systems in cars sold by companies that have not shown a commitment to developing and sustaining their telematics infrastructures.

- Keeping the connection to the car brand will not be as easy with off-board navigation as it is with the integrated, on-board solution. Every OEM customises their integrated on-board navigation systems. A Siemens VDO system in a Renault is different from a Siemens VDO system in a BMW. The OEMs pay a price for these custom solutions, the biggest being the added cost for proprietary data formats and OEM-specific media. This proprietary approach eliminates the economies of scale that could result from a common format. With off-board solutions, the OEM would have to tie itself to a specific service solution and restrict hardware access to keep the brand connection. As soon as customers see their neighbour's new car with newer and better services, they are going to want to switch, just like they switch Internet service providers and network operators when they learn that prices are lower or services are better than their current providers.

Off-board is No Magic Solution to Interoperability

An argument is being made by some that an off-board alternative will solve the problem of map data media interoperability. Today, unlike the CD audio or DVD video industry, it is not possible for navigation map data provided by one system supplier on CD or DVD to be used in other systems. All formats are proprietary. It is similar to the situation in the video game market, with each system (e.g. Nintendo, Microsoft or Sony) requiring its specially formatted software and data.

Those who believe that an off-board alternative to autonomous systems is the answer to map data media interoperability will be disappointed. Without a standard in place before off-board map data processing begins to be used in earnest for in-vehicle applications, the problem of proprietary formats will become worse instead of better. High bandwidths of 2.5 and 3G telecommunications are not available everywhere, and will not be for many more years. Since contact with the high bandwidth network is not assured, smaller data packets than the high bandwidth can support will have to be used—just to make certain that data can be delivered when it is required. This compaction requirement will start a new round of proprietary data format design. Each format will claim to transfer more data faster than the competitors'. They may well do, but it will be at the cost of each system being able to access the different data sources using the proprietary formats.

Off-board data supply makes a great deal of sense because it should be much easier to update data at a limited number of central locations than it is to redistribute millions of disks. However, if every system requires its own data source, the economies of centralised data updating may well be lost.

ADAS

Totally off-board solutions are not realistic for supplying mission-critical information, such as for ADAS[21] applications. Large amounts of data will still need to be stored on-board, and the format for supplying this data is just as important for interoperability as the format for on-board media.

What's the Verdict?

Price Performance Proposition

Cheap and cheerful on-board systems are already available. These are the turn-by-turn devices (no maps) usually built into car radios (Blaupunkt, Melco, etc.), and the portable and semi-integrated systems from ALK, TomTom and others.[22] The dual function of the basic devices (i.e., radio-navigation system, or PDA-navigation system) softens the navigation system price. Even the cost of data for the on-board systems is being addressed. Siemens VDO has introduced a scheme for their aftermarket systems that allows users to pay for data used by entering a code to unlock data on the media.

Performance of off-board systems today is hampered mainly by the communications networks. I do not mean that they are short of bandwidth. Systems like Telmap's Polaris have proved that plenty of data can be transferred across simple GSM connections. The problem is making and keeping a connection, precisely where and when it is needed. Mobile telephone users experience dropped calls even when they are stationary.

So, today, off-board systems have a similar price to the low-end on-board systems with a generally lower level of performance due to the telecommunications network. Networks are constantly improving, but if anything, the switch to 3G will exacerbate the call hand-off problem, not improve it. On price performance, on-board systems will have the advantage for the next three-to-five years.

Quality of Guidance

Some off-board navigation systems are better than others. Those that are, in my opinion, the best, deliver vector data to the on-board device, offer supplemental positioning processes to improve road following performance, allow re-routing without needing to return to the server, and provide a visual display with turn manoeuvres and/or a full colour map. These systems offer the user a guidance experience that is as good as or better than the first generation CD-based full-colour map systems. I have had one of these early CD-based

[21] ADAS stands for Advanced Driver Assistance Systems, which include functions like curve warning, braking assistance, steering of headlights around curves, lane departure warning and other active safety features.

[22] For a good catalogue of the systems that were available in 2002, see a report by Secured By Design Ltd, European Telematics: The European market and trends for on-board and off-board navigation systems. While I do not believe that the report relates very much to its title, nor does it have much to say about telematics, it provides a very good description of the various systems and is worth the price for that purpose.

systems in my own car for the past seven years (It was returned to service by an able technician, and has been supplied with updated software and data by its maker, Mitsubishi Electric Corporation), and I find it totally acceptable. It does the job it was built to do. It is good enough. And the best of the off-board systems are also good enough—with the caveat "When all of the external systems are functioning".

I have driven extensively with some of the best off-board systems in Germany, the UK, the US and France. They provide the instructions I need to get me to my destination. The manoeuvre icons are equal to those on my on-board system, and the map functions are much better. I have driven problem free on trips of over one hundred kilometres, with start and end points in cities with complicated street patterns. I have also tried to start a journey where neither GPS nor GSM/GPRS would cooperate. Whatever the reason for the problems, they are tiresome, and tiresome problems cause users to grow tired and abandon the innovation. Consumers do not usually use things that they must depend upon, but only work sometimes.

The overall quality of off-board systems would be improved significantly by building them into vehicles, giving them larger screens, providing steering wheel buttons and voice user interfaces, integrating them into the car's speaker system and co-ordinating the voice instructions with audio output, providing sensor input for map matching, and giving them proper antennae placed outside the vehicle in a well-designed fashion. In other words, making them more like on-board systems.

The trade-offs with on-board

The main advantage that some off-board systems have today is their total portability. If I had a completely portable system, rather than my integrated system, I could loan my system to my wife when she has to find a place in Göteborg where she has not been before, or we could take it with us on a vacation and put it into a rental car wherever we land. I could plan my journey before I get into the car, and I could take the system out of the car to complete the last leg of the journey on foot. This advantage alone is a compelling one for some people, and they will buy it on that basis.

Does this advantage outweigh the current difficulties with off-board systems? For a person who can choose between the two—that means someone who is buying a new car that offers an on-board system, or a used car with an integrated navigation system—and who can afford the one-time cost of the on-board system, I believe that if the person could actually test the two for a few days, the on-board system would still win today. I stress TODAY.

Will the disruptive technology succeed?

The established **value network**[23] for in-vehicle navigation systems has seen a progression of sustaining developments over the past decade. Replacing CD drives with DVDs was a sustaining development, as will be the move from DVDs to hard disk drives. These technologies are being introduced by the established players in the navigation system market to increase the performance of their systems to meet the demands of the high end of the market.

Disruptive Technology, as Clayton Christensen and his team of researchers has shown, gets its commercial start in emerging value networks before invading established value networks.

> *"Disruptive technologies emerge and progress on their own, uniquely defined trajectories, in a home value network, separate from the established one. If and when they progress to the point that they can satisfy the level and nature of performance demanded in another value network, the disruptive technology can invade it, knocking out the established technology and its established practitioners with stunning speed."*[24]

The "home" value network for off-board navigation is wireless location-based services. Network operators Sprint, Cingular, Orange, T-mobile, Vodafone, DoCoMo and Three among many others are the principal drivers of this value network. Handset makers, like Nokia, Siemens, SonyEricsson and Motorola, are also part of this network. They are developing server and client solutions in combination with a number of companies that have had no part of the established on-board navigation market. These include ALK, Webraska, TeleInfo, PTV, Telmap, Telcontar and a growing number of others.Together, these companies are developing a navigation system model that they believe can work equally well inside a moving vehicle and in the hands of a pedestrian user.

As I have said, some of the established players are trying to adapt the technology of off-board navigation, but they appear to have missed the fact that they are a target of the competitive value network, not a valued potential partner. And the disruptive players possess the key ingredient for success: the infrastructure for delivering the applications to the in-vehicle user. What they lack is permission from the vehicle OEM's to integrate this infrastructure with the vehicles' systems.

If there were standards for in-vehicle information systems—and there are not—the competitors would not need permissions. If the established networks could build the infrastructure on their own—and they cannot or will not—they would be able to fight off the competitors by making off-board navigation a sustaining, rather than a disruptive, development.

[23] Value Network refers to the group of companies working with and profiting from a given technology or service.
[24] Clayton M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston, MA: Harvard Business School Press, 1997)

Appendix A: Examples of Off-board Navigation Systems

Telmap Ltd

Product Name: Polaris

Contact: Telmap Ltd.

Retail Price:

Continuation Price:

- The second year is €A region is defined as follows:
  - Scandinavia, Denmark, Norway and Finland
  - Germany, Belgium, Luxembourg and The Netherlands
  - Germany, Austria, Switzerland and the Czech Republic
  - Italy, Austria and Switzerland
  - France, Luxembourg, Belgium and The Netherlands
  - Spain and Portugal
  - United Kingdom (Great Britain and N. Ireland)

Included in Price:

-

Available Markets: North America, Western Europe, Australia

Description: *General*

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Telephone Purchase

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Phone Set-up

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Polaris Set-up

Wayfinder

Product Name: Wayfinder Euronavigator

Contact: Wayfinder

Lund

Retail Price: €199 including Wayfinder software, Bluetooth GPS and one year of unlimited routing for Western Europe

€149 including Wayfinder software and one year of unlimited routing for Western Europe.

Continuation Price: The second year is €99 (including VAT) all of Western Europe

Included in Price:

- See above

Available Markets: Western Europe, including the following countries:

Denmark, Norway, Sweden, Finland, Germany, Belgium, Luxembourg, The Netherlands, Austria, Switzerland, Italy, France, Spain, Portugal, United Kingdom (Great Britain and N. Ireland), Ireland

Description:

General

Wayfinder is sold in Sweden through a mail order centre based in Stockholm. (Dustin AB). I found this information on the Wayfinder web site. It is not available through retail outlets. I phoned Dustin and ordered Wayfinder. It arrived in one week by express mail delivery. A box consisting of a Bluetooth GPS device with a carrying case, car outlet adaptor, wall socket battery loading cable, two socket adaptors, user manual, quick guide manual, and customer number were in the box. In addition, I received a one-year subscription to a single country for routing purposes. The total cost was 5100SEK (3985 for the software; 95 for freight; 1020 for VAT). The price in Euros is around 550.

Telephone Purchase

Wayfinder works on Nokia phones 7650 and 3650 and SonyEricsson P800. I bought the Nokia 3650. A two-year binding agreement with Vodafone brought the cost of the phone down from 4600SEK

to 1800SEK. I already had my subscription with Vodafone for the phone I would be retiring, so it was no problem to continue with Vodafone for the new phone.

Phone Set-up

There was no problem getting the phone set up to communicate with Wayfinder. It uses an Internet, not WAP, connection. I downloaded all the connections from the Vodafone site, and then selected Vodafone Internet when connecting with Wayfinder.

Wayfinder Set-up

Once the phone was ready, I entered the special Wayfinder site for new customers and registered my phone. I keyed in the number that came in the box (16 characters), and a set-up file was automatically sent to my phone via SMS and an icon set up on my menu grid, GetWayfinder. I clicked on this icon and it started the set-up program. The biggest problem was selecting the correct Vodafone connection. It took me a while to figure out that it had to be Vodafone Internet, and could not be Vodafone GPRS, which is WAP. But after getting over that hurdle, it functioned smoothly. The program was downloaded to my phone and another icon appeared on my menu grid, Wayfinder.

PTV/3SOFT

Product Name: ?

Contact: PTV

Retail Price: DaimlerChrysler A-Class - €1,600

DaimlerChrysler Smart - €1,400

Continuation Price:

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Included in Price:

- iPaq
- Mobile Phone
- GPS
- Unlimited Routing

Available Markets:

Description: *General*

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Telephone Purchase

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Phone Set-up

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Set-up

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Trafficmaster and Motorola

Product Name: Smartnav

Contact: Trafficmaster

Cranfield, UK

Retail Price: £499 excluding installation (installation approx. 2 hours cost £100)

Continuation Price:

- Subsequent years £49 (Euro 75) per year. (If customer requested 200 routes per year, cost to customer would be £0.24 (Euro 0.38) per route)

Included in Price:

- First year subscription for services

Available Markets: UK only

Description:

General

How Smartnav works: There is a button in the car with a telephone microphone, speaker and speech synthesizer. The user pushes the button and gets connected to the Trafficmaster call centre. When the call is made, the position of the vehicle is passed to the call centre using GSM/SMS. The call taker asks the user where he wants to go. The call taker calculates the route on their workstation (I do not know what system they are using. It is either Motorola's or their own). The route instructions plus some form of road representation are packaged and sent back to the vehicle, and the voice connection is closed down. The instructions and the data are stored on board the vehicle. There is some form of spatial filter (map matching) on board so the system knows where the vehicle is on the road network. As the user drives, the instructions are given by voice synthesis. There is no display, no icons, no maps, just voice. I have used the system, and it is extremely difficult to follow a route. You never know if you have made the correct manoeuvre until the system tells you that you are off course. It tries to re-route you back to the original route--so there is probably a corridor of data--but most often it fails. Then you need to push the button again and start all over.

Optional Services

- Stolen Vehicle Tracking - £8 per

month

- Location of Speed Enforcement Cameras - £6 per month

Smartnav for OEM's - System sold in the UK

- Mitsubishi Motors - Retail Price: £524
- Chrysler and Jeep – Retail Price: £749

The best available comparison between on-board and off-board systems for pricing purposes is with Smartnav. Even though this system is voice only, we have both hardware and service as separate costs. The retail price for an on-board system is between one-and-a-half to five times greater than for Smartnav. Assuming that the Smartnav database is updated at least once per year, and an on-board system user purchased an updated CD once per year, an on-board system user would pay at least double the price annually for up-to-date data of a single geographic area as for the annual Smartnav subscription.

The question is whether the pricing for the Smartnav system is sustainable. With the on-board systems, the map data suppliers have never lost money. They charged their $50 per CD delivered to their OEM or system developer customer. The system developers and automotive OEM's had very large sunk costs for development. However, ignoring the sunk costs, the automotive OEM's report that they are earning money on the sale of navigation systems. Tier 1 suppliers have very low margins, no matter what they are selling, so they may not be earning significant profits. They will continue to develop and supply these systems because they offer them the chance to sell additional systems.

Telephone Purchase

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Phone Set-up

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Smartnavr Set-up

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Name

Product Name:

Contact:

Retail Price:

Continuation Price:

- The second year is €A region is defined as follows:
  - Scandinavia, Denmark, Norway and Finland
  - Germany, Belgium, Luxembourg and The Netherlands
  - Germany, Austria, Switzerland and the Czech Republic
  - Italy, Austria and Switzerland
  - France, Luxembourg, Belgium and The Netherlands
  - Spain and Portugal
  - United Kingdom (Great Britain and N. Ireland)

Included in Price:

-

Available Markets:

Description:

General

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Telephone Purchase

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Phone Set-up

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Polaris Set-up

Name

Product Name:

Contact:

Retail Price:

Continuation Price:

- The second year is €A region is defined as follows:
  - Scandinavia, Denmark, Norway and Finland
  - Germany, Belgium, Luxembourg and The Netherlands
  - Germany, Austria, Switzerland and the Czech Republic
  - Italy, Austria and Switzerland
  - France, Luxembourg, Belgium and The Netherlands
  - Spain and Portugal
  - United Kingdom (Great Britain and N. Ireland)

Included in Price:

-

Available Markets:

Description:

General

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Telephone Purchase

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Phone Set-up

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Polaris Set-up

Name

Product Name:

Contact:

Retail Price:

Continuation Price:

- The second year is €A region is defined as follows:
  - Scandinavia, Denmark, Norway and Finland
  - Germany, Belgium, Luxembourg and The Netherlands
  - Germany, Austria, Switzerland and the Czech Republic
  - Italy, Austria and Switzerland
  - France, Luxembourg, Belgium and The Netherlands
  - Spain and Portugal
  - United Kingdom (Great Britain and N. Ireland)

Included in Price:

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Available Markets:

Description:

General

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Telephone Purchase

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Phone Set-up

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Polaris Set-up

Product Name: Yeoman

Company: Yeoman Ltd, Cambridge, UK

Price: Retail Price: £200 excluding installation (app. 2 hours costs £100) ; includes:

- Have sold service with Benefon GPS-enabled GSM handset. Also works without positioning in handset on normal GSM handset.

  Description

  How the Yeoman system works: Customer calls Yeoman routing centre and speaks to an operator. Operator calculates route and sends voice and text manoeuvre instructions to the driver. No graphics.

Product Name: ViaMoto

Company: Motorola

Price: Retail Price:NA ; includes:

- Motorola handset with integrated GPS receiver

  Description

  This is a mobile phone-based service that Motorola has introduced first in the US on AVIS rental cars. As reported in the April 1 2003 issue of *The Intelligent Highway*, AVIS customers receive a Motorola handset containing an integrated GPS receiver, speakerphone and the ViaMoto software. The user contacts the AVIS Assist call centre and asks for directions to an address or point of interest. Turn-by-turn directions are sent as a data packet and announced sequentially when cued by the location of the user. This appears to be a variant of Smartnav. The cost of the service to the customer is $10 per day.

Product Name: IbDN offered by O2

Company: Webraska

Price: Retail Price: €400; includes:

- XDA PDA from O2
- First year service included

- After first year, €20 per month plus GPRS fees

  Description

Product Name: T-Mobile Traffic Scout

Company: T-Mobile Traffic

Price: Retail Price: €550; includes:

- Hands-free car kit

- GPS

  Description

  Product Name: WisePilot

  Company: Appello

  Price: Retail Price: €NA; includes:

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  Description

End User Prices

Services	Price
Routing and Traffic Smartnav/Trafficmaster	€ 6.25/vehicle/month
Traffic Only Trafficmaster	€ 13.75/vehicle/month
Telematics Route delivered verbally or by SMS to vehicle T-Mobile Traffic, Volvo On Call	€1.50 - € 3.00 per request
PDA Off-board Navigation	**Price**
DaimlerChrylser A-Class – PTV	€1,600 with PDA, Phone, GPS
DaimlerChrylser Smart – PTV	€1,600 with PDA, Phone, GPS
O2 - Webraska IbDN	€ 400 with XDA from O2, GPS
T-Traffic Scout – T-Mobile Traffic (Deutsche Telekom)	€ 550 without MDA, with GPS
Telephone Off-board Navigation	**Price**
Wayfinder – Wayfinder	€ 550 without phone with GPS
Smartnav – Trafficmaster and Motorola	€ 661 with phone and GPS
Smartnav for Mitsubishi – Trafficmaster and Motorola	€ 695 with phone and GPS
Smartnav for Chrysler and Jeep – Trafficmaster & Motorola	€ 990 with phone and GPS
Yeoman - Yeoman	€ 265 without phone or GPS
MapWay – M-Spatial	€ 0.83 per use, independent of length of route or time taken to arrive to distination
PDA/Phone Autonomous Navigation	**Price**
Compaq – ALK	€ 1235 with PDA/GPS/ small region maps
TOM TOM – TOM TOM	€ 428 without PDA, with GPS and large country maps
TOM TOM - GO	
CMI-GPS Navigator	€ 755 with PDA and one city or metro area map in US.
Navigon Mobile Navigator – Navigon	€ 799 with PDA and large country maps.
Benefon Personal Navigation - Benefon	€ 734 with phone with built-in GPS. Variable map data price
Navman GPS 3450 – Europé	€ 1268 with iPAQ5550, GPS. Car kit
Navman GPS 4400	€ 1345 with iPAQ5550, Bluetooth GPS. Car kit
DigiMax	€ 769 without Palm PDA, with Bluetooth GPS, European data

Appendix B: Navigation System Market Statistics

Since 1997, navigation systems sales have increased significantly, especially in Europe, and have continued their steady penetration in Japan.[25] The total value of navigation systems and data sold worldwide in 2002 was approximately $6 billion.[26] Automated in-vehicle systems come in many forms:

- Autonomous on-board navigation systems that have all the data and applications software inside the vehicle. They are self-sufficient and require no connections to outside information or process sources.
  - Integrated – Systems that are part of the design of the vehicle and are developed with the automotive OEM. They are mostly factory-installed, requiring special connections to audio systems, odometer, and other sensors, and integration into the vehicle's display screen, CD/DVD drive, and user-machine interface. Systems that are automotive OEM options comprise two-thirds of the systems delivered today in all three major markets, Japan, Europe and North America. This trend is expected to continue.
  - Independent – So-called aftermarket systems, they can be installed in a similar way as a hands-free telephone, but require more space for display, disk drive and memory management unit. They can be moved between vehicles, but they depend on connections to vehicle systems (odometer, sensors, audio) for operation.
- Semi-autonomous on-board navigation systems – The systems can be integrated or independent, and combine real time traffic data delivery via radio or cellular network with on-board data storage.
- Off-board navigation – Deliver routing instructions and the necessary associated data via wireless data systems (GSM/SMS, GSM/Data, CDPD, GPRS, UMTS)[27] from

[25] In Europe, 1.3 million navigation systems were sold in 2002, one-third as aftermarket systems, and two-thirds as OEM installed systems. In 2003, total sales increased to 1.6 million units. At the end of 2003, the number of navigation systems in operation in Europe was approximately 5.4 million units. By contrast, in the US the cumulative number of units in operation at the end of 2003 was just 1 million. In Japan, 12.2 million navigation systems were installed by the end of 2003, with 3.15 million sold during 2003.

[26] This is our own estimate double-checked with many industry experts

[27] GSM: Global System of Mobile Communication. GSM is global, operating in over 200 countries (not US and Japan) - 900/1800 Mhz

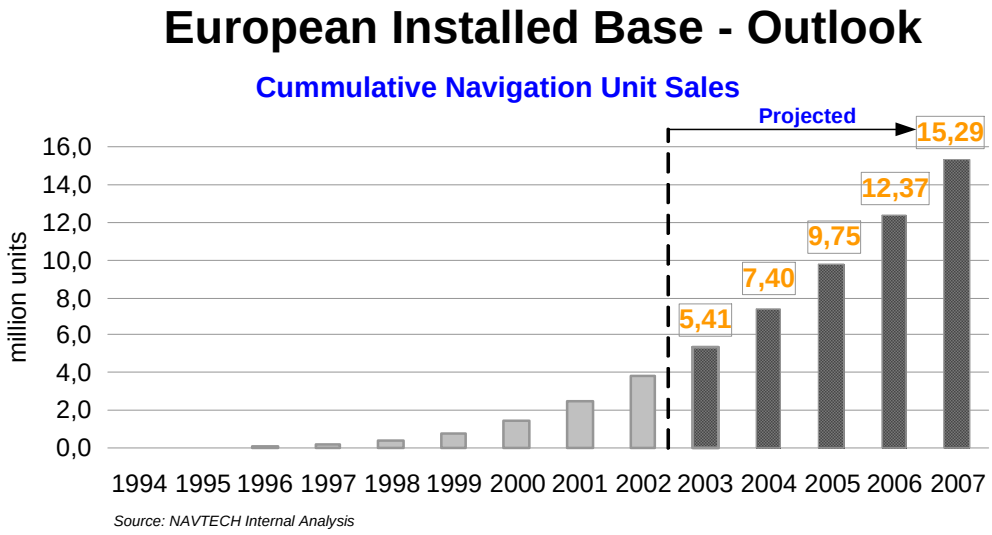
(footnote continued)

remote service providers. The hardware for display, processing and storage can be the same as the on-board systems, or it can consist of portable devices, such as personal digital assistants (PDAs) or wireless handsets. The critical addition to the hardware package is a telecommunications module.

- Hybrid navigation – combines off-board delivery of static and/or dynamic data with some form of on-board data storage and applications support software.

Systems on the market today are of the autonomous and semi-autonomous variety, consisting primarily of integrated, OEM systems and a growing number of portable, independent systems based on PDAs. Navigation systems are still luxury items. Volume sales have not materialised. Larger display screens, better user interfaces, increased map area coverage and on-board storage have contributed to making them better navigation aids, but they are installed on a mere 5% of the cars sold in Europe annually, and by 2007, they are projected to be in less than 8% of all cars on the roads in Europe.

Figure 1.



Market Size and Growth Rates

What is the relative size of each of the business sectors and how are the estimates of market size developed. We use the current

GSM/SMS: Global System of Mobile Communication/Short Message Service. Provides for 160-character messages between GSM handsets or between a GSM handset and an information source. Messages are entered via the handset's keypad, or via add-on keyboards, such as Tegic's T9 or Ericsson's Chatboard.;GSM/Data:
CDPD: Cellular Digital Packet Data. A method for sending packet data over analogue networks. Requires specific network equipment, that now covers 85% of North America to support wireless Internet connections
GPRS: General Packet Radio Service for GSM, enables more efficient use of radio resources leading to increased capacity and higher speed data services
UMTS: •Universal Mobile Telecommunication System - Also known as 3G (for 3rd Generation) - Officially IMT-2000
–WCDMA - Wide-band CDMA. Supported by GSM countries and Japan
–CDMA-One - Developed by Qualcomm

navigation system market as the base. In this market, the automotive OEM's sell over 60% of the systems. DVD-based systems are gradually taking over from CD-based systems. Portable systems will not affect the total number of OEM systems because these systems will be purchased by customers who would not install an integrated navigation system in their car, either because it would be too costly as part of a new car purchase, or because they own a used car and the aftermarket systems are too expensive. We do see off-board systems eventually having an impact on the type of systems factory-installed by the OEM's, with them gradually replacing the autonomous and semi-autonomous variety.

Growth Rates

There are two growth scenarios for navigation systems in North America and Europe:

- Slow, steady growth in the range of 2-5% of total new car sales resulting from fitting navigation systems as an option on the majority of luxury brands by 2005.
- Rapid, accelerated growth resulting from a combination of low-cost standard fit devices in most models, and government legislation requiring or encouraging the installation of systems.

Factors currently influencing the growth rate of navigation systems

New car and truck sales

Worldwide new vehicle sales are predicted by most market forecasters to grow by 5-6% through 2005, from 49 516 million units in 2003 to 53 867 million units in 2005. These increases will be sufficient for most car companies to continue to fund their navigation and infotainment developments.28 It is not sufficient to make them standard fit. Much of this growth will come from developing countries where navigation systems will not be available for many years in the future, partly because of cost, and partly because of the lack of data availability.

Types of vehicles sold

The luxury car segment will share in this growth and support a steady increase in navigation systems. It is more likely that other luxury car makers will incorporate navigation systems in an option package, rather than making them standard. The situation is different in North America, where it is more common for a dealer to order cars for display to attract buyers, rather than to build cars to customer specification. Buyers in the US are used to comparative shopping,

[28] Infotainment is used widely in the automotive industry to describe a combination navigation, audio and video platform.

and buying what they see, rather than ordering a car and waiting for several weeks (or months) for delivery. For the US market, it is more likely that navigation systems will be standard fit in a model range.

Technical capabilities

A major breakthrough for navigation systems in the US and Europe will occur only when these systems are no longer just convenience devices, but are integrated into the driving functions in a way that makes them indispensable driving aids. Drivers in these regions can find their way to destinations without navigation systems, using address directories and maps. The situation is different in Japan where the lack of street addresses makes navigation systems much more of a necessity. This is reflected in purchase statistics. Advanced driver assistance systems (ADAS) that will begin to appear at the end of the decade will incorporate navigation and ADAS data supply in a single module. Route planning will be used to support the calculation of an electronic horizon for ADAS, as well as for producing route guidance for the driver.

Wireless communications

As the usage of GPRS spreads and as network operators finalise their roaming agreements, GPRS will replace GSM/SMS as the message bearer. This will increase the range of services that can be provided. Gradually also, 3G will be introduced. This technology will simply make it easier and faster to download large amounts of data to the vehicle and enable new services that cannot be contemplated with today's 2G and 2.5G technology.

What factors could influence growth rates in the future

The biggest influence on growth rates will be government actions. Government authorities will increasingly view navigation systems as part of a total ITS solution that is an alternative to investing in infrastructure or adding personnel. Automatic speed controls installed on vehicles is a substitute for police speed controls and installation and maintenance of cameras, and it is a cost that is borne by either the consumer or the automotive industry. The vehicle industry will resist any attempts by government authorities to introduce any type of system as standard options because such an action will reduce their revenue opportunities and increase their costs.

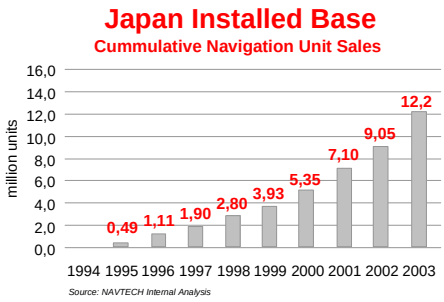
Autonomous and Semi-Autonomous Navigation Systems

In Figure 1 we saw the statistics for the European navigation system market. In Figure 2 we can see that in 2003, Japan reached a level of installed base that Europe is projected to reach only in 2006. Of the 12.2 million navigation systems installed in Japan, 7.2 million are equipped with a form of communications device called VICS.[29] This is not an off-board system, but a method of providing real-time

[29] VICS – Vehicle Information and Communications System

information on traffic congestion and regulations to on-board systems, like using RDS-TMC to communicate with systems in Europe. Off-board applications have been tried in many forms in Japan by the major car manufacturers in cooperation with navigation system developers, but thus far they have not succeeded in interesting consumers. They cannot compete with the large screens and high-quality three dimensional graphics available on most of the new systems being sold in Japan.

Figure 2



Germany is by a large margin the most active market for navigation systems:

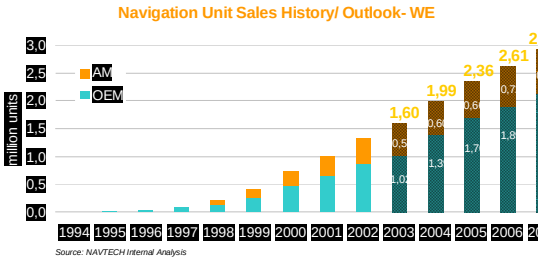
- All of the German OEM's offer one or more navigation systems in their vehicles[30];
- Three of the four primary European navigation system manufacturers have their head offices in Germany[31]; and,
- With the largest population, more cars are sold in Germany than in any other single market in Europe[32].

[30] Audi, BMW, DaimlerChrysler, GM Opel, Volkswagen, Porsche
[31] The three are Siemens VDO, Harman Becker and Blaupunkt. The fourth that is not located in Germany is Magneti Marelli.
[32] 3.524 million cars and trucks, followed by UK with 2.885 million, France with 2.715 million and Italy with 2.559 million

Figure 3

European Navigation Market - Outlook

Market share	2001	2002	2003	2004	2005	2006	20
OEM	65%	65%	64%	70%	72%	72%	73
After Market	35%	35%	36%	30%	28%	28%	27

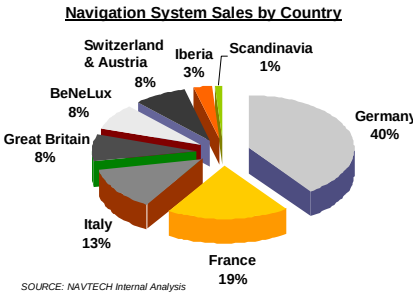


Source: NAVTECH Internal Analysis

Figure 4

Navigation Sales By Country

- Germany still ahead but the market is developing well in all countries



SOURCE: NAVTECH Internal Analysis

Aftermarket systems have remained a steady 35 % of total system sales, but they are projected to fall as more OEMs offer factory-installed options. Aftermarket products provide neither the price advantage over the integrated systems, nor a functional equivalent.

Figure 5

OEM Product Trends - Displays

- Significant growth of monochrome display stabilized around 1/3 of the OEM demand.

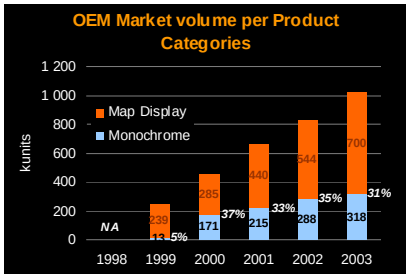


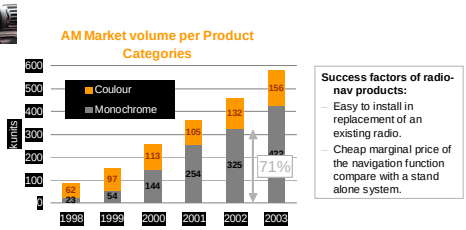
Figure 6

AM Product Trends - Displays

- 1DIN Radio Navigation* with monochrome display and turn-by-turn directions are 70+% of aftermarket volume.

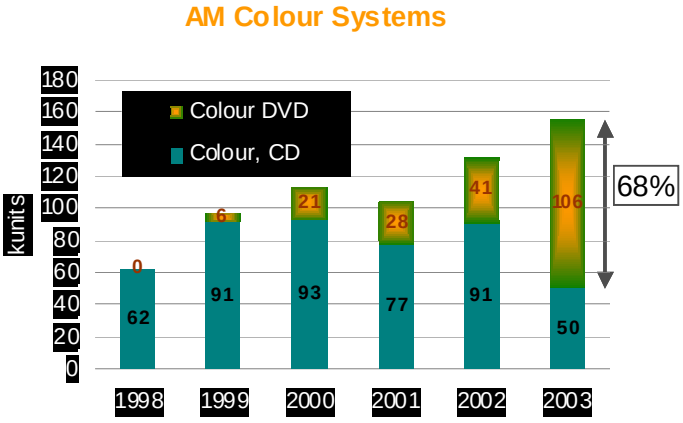
*provide turn by turn guidance with voice and pictogram on a monochrome display.

- Colour map display systems are growing slowly in comparison.



After Market Product Trends - Media

- Radio/Nav monochrome systems: CD is still predominant (close to 100%)
- Colour display systems: most new systems are using DVD.
  Close to 70% of AM system should be with DVD in 2003.



Notes: