Michael L. Sena Consulting AB
Mobility Research Report

Route Guidance Systems

Expanding Options for the Market

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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

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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, in-vehicle 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. Even if one considers the recent surge in sales of personal navigation devices that compete in the aftermarket, penetration rates of in-vehicle route guidance systems are in a small fraction of the vehicles on the world's roads. 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 principal questions that this *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.

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[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.

Route Guidance Systems
Expanding Options for the Market

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

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[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 have 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 signs and route number 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. My wife and I drove from the south of France where we were visiting friends to Lyon. 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 the Japanese navigation system

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[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.

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 hundred 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 1921[7] 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 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 is an unfair characterisation. It is male drivers

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[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.

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 route guidance systems. They come in many forms:

  ■ 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

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

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 (See Appendix B). This trend is expected to continue.

- 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.

- Semi-autonomous, dynamic 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.

- Hybrid navigation – Systems that combine off-board delivery of static and/or dynamic data with some form of on-board data storage and applications support software. Systems can be integrated, with hard disk data storage or rewritable media, or independent.

■ Portable – So-called aftermarket systems

- Dedicated - 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 some of them depend on connections to vehicle systems (odometer, sensors, audio) for operation. Others, like the TomTom *Go* illustrated below, are single-purpose navigation systems that function without any connections to the host vehicle and can even function outside the vehicle.

Independent aftermarket system: TomTom Go

▪ Multi-purpose – These include navigation applications that function on devices that are made for another purpose, such as PDAs and mobile phones. The devices can be equipped with built-in GPS units, or they can be linked to GPS units via a cable or some form or wireless connection, such as Bluetooth. An example of a portable hybrid system is the ALK *CoPilot Live* product that operates on a Smart Phone with a memory card for map data storage and communicates with a central server for dynamic updates and location reporting.

◼ Off-board navigation – These are systems that deliver routing instructions and the necessary associated data via wireless data systems (GSM/SMS, GSM/Data, CDPD, GPRS, UMTS)[10] from remote service providers. The hardware in the vehicle 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. In some cases, such as with Trafficmaster's and Motorola's *Smartnav*, the human-machine interface (HMI) can be totally different from the autonomous or portable systems because the entire paradigm is different: it involves talking to a human operator. In other cases, as with Webraska's *SmartZone*, the HMI is, for better or worse, the same as in on-board.

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[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
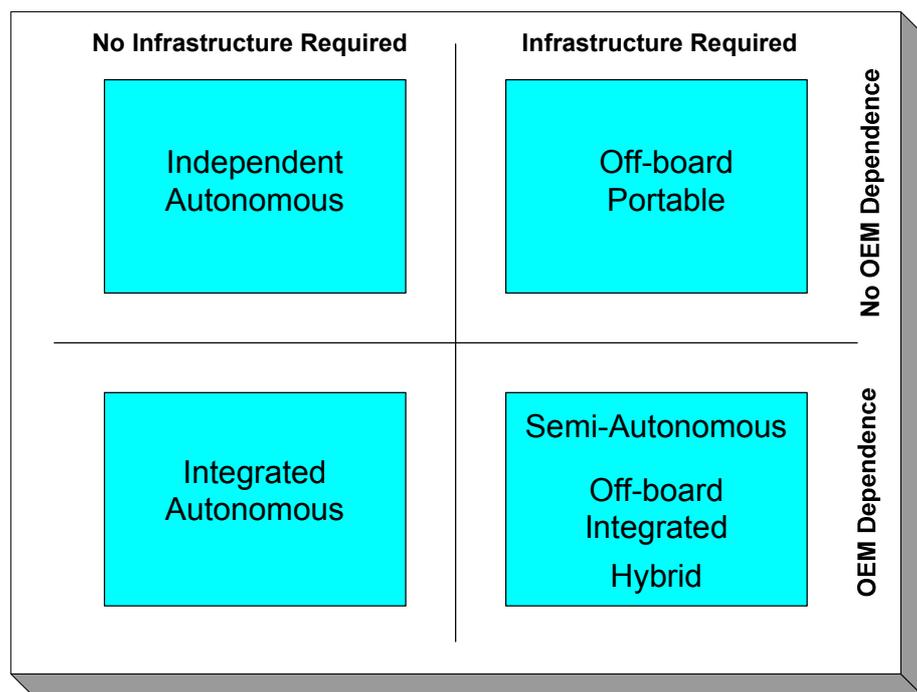
GPRS: General Packet Radio Service for GSM, enables more efficient use of radio resources leading to increased capacity and higher speed data servicesUMTS: •Universal Mobile Telecommunication System - Also known as 3G (for 3rd Generation) - Officially IMT-2000

–WCDMA - Wide-band CDMA. Supported by GSM countries and Japan

–CDMA-One - Developed by Qualcomm

The critical addition to the hardware package for off-board navigation is a telecommunications module for *two-way communications.* This is the component that is used to send address finding and routing requests from the vehicle to an application server, and to send the resulting text, icon and/or voice routing instructions and map data back to the vehicle.

The following diagram shows the different types of systems according to whether they require some form of infrastructure, and whether they require participation by or permission from the automotive OEMs for installing the devices in their vehicles. Infrastructure is one- or two-way communications, such as RDS-TMC or GSM network availability. Independent/Autonomous includes systems like the SiemensVDO **Dayton**, TomTom **Go** or the Magellan **NeverLost**. Integrated/ Autonomous systems are rare today since most navigation system suppliers have modified their systems to be able to accept traffic data transmitted via RDS-TMC. However, not all manufacturers have agreements in place for all markets where traffic data is sold, rather than delivered as a free service. Therefore many high-end systems that are Integrated/Dynamic are functioning in autonomous mode.

	No Infrastructure Required	Infrastructure Required	
	Independent Autonomous	Off-board Portable	No OEM Dependence
	Integrated Autonomous	Semi-Autonomous Off-board Integrated Hybrid	OEM Dependence

Automated in-vehicle system product groups

Off-board systems are most commonly portable devices today, either based on a wireless handset or a PDA. The only off-board integrated system today is Trafficmaster's and Motorola's **Smartnav.** It consists of a single button placed in a convenient location on the instrument panel, and the communications, GPS and software black box hidden somewhere in the vehicle. In theory, no permission is required by the vehicle OEM to install this system, but a fairly large number of OEMs offer the system in the UK as a dealer fit option. Most of the

integrated, factory fit systems on the market are semi-autonomous. Some OEMs, such as BMW and Fiat, and their system suppliers have taken a step toward off-board navigation by connecting their on-board systems to service providers who can talk to the driver and send a destination directly to the on-board unit. This saves the driver the time and effort of stopping the vehicle, searching for the address of a location, and entering it manually into the unit. The operator sends the coordinates of the destination to the on-board system, and the system uses the geocoded location as the destination and calculates the route.

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 their customers to choose whichever system they feel meets their particular requirements and their pocketbook?

Automobile manufacturers like BMW, along with their system vendors, have gone to great lengths to create a special look and feel for their particular versions of route guidance systems, and to integrate these in their vehicles.

Route guidance systems have been costly to develop, both for the OEM and the system supplier, and they are troublesome to integrate. No one will release official figures, but internal development to prepare their vehicles for integration of navigation systems has cost each OEM in the many tens of millions of dollars. On top of this, the OEMs have paid their system supplier(s) for improvements and modifications to the systems so that they meet 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. Why?

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.[11] 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 account 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-autonomous category. Adding traffic information to autonomous systems should have taken them from useful to essential driver aids.

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[11] For a period of time, the cost of integrated navigation systems was rebated in The Netherlands because the transportation minister convinced the parliament that they improved safety and reduced traffic congestion.

[12] 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).

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 Navteq (formerly Navigation Technologies) and Tele Atlas have been coded using the special tables produced by the traffic information providers.

This enables 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.

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 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

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[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.

customers. The average cost of a CD for a geographic region of coverage, say Germany or the UK, is around $150 retail. 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. The newest navigation systems are now being delivered with data on a DVD rather than on a CD. A DVD holds a few gigabytes, and can be loaded with all of Europe or North America. A DVD covering all of Europe costs approximately $310-$400 retail. 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.

> An informal survey I made of automotive OEMs confirms that the aftersale market for DVD-based navigation media has collapsed. Instead of being a positive development for customers, system developers, OEMs and data suppliers, DVDs have turned out to be a major problem for everyone. Users are not updating their maps.

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.

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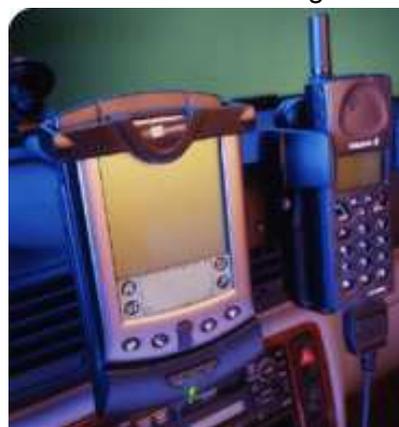
The ***Polaris*** system by Telmap (Herzlia, Israel) takes off-board navigation one step closer to its on-board predecessor. In addition to turning manoeuvres and voice instructions, Polaris offers full-colour maps that are tailored to the device being used. On an iPAQ, for example, with a high resolution colour screen, the maps are rich and detailed, similar to the best high-end autonomous systems. On a Java-enabled mobile phone, 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.

Illustration of car kit with phone holder and Bluetooth GPS device on top of instrument panel

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 can rent the handset and use it to speed-dial a special number. They use the speakerphone to request a destination address or place. The call is taken by an operator at Unity Call Centre Group, who has access to Motorola's off-board navigation server. The operator inputs the route request and the results are 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, 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, nor 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 **TargaInfomobility** 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.

Hybrid Systems

Thus far, no OEM has shown or announced a hybrid system, as illustrated below. Such a system would be capable of combining the benefits of off-board route guidance with the advantages of local data and data processing. In addition, hybrid systems offer full connectivity with embedded systems for emergency and security services. There are a few critical ingredients still under development that are necessary for a truly functional hybrid system. These include

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[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.

incremental update methods and standards for map data, location referencing methods and standards, wider and more reliable coverage for high-speed, high bandwidth telecommunications networks, and more robust and reliable hard disk drives.[17]

Next Generation In-vehicle Driver Information and Assistance System

© M.L. Sena
29 March 2000
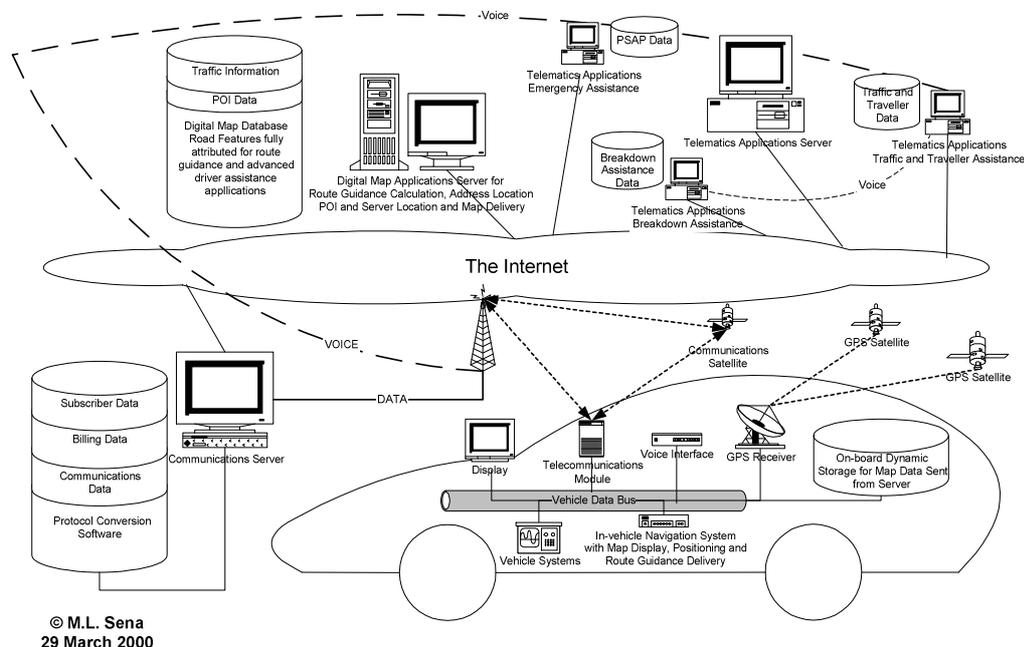
Off-board Advantages

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

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[17] I will address each of these issues in an upcoming Mobility Research Report.

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 OEMs, and this is an ideal place to look for savings. When these costs are passed on to the customer they result in map media retail prices that are up to four times higher than the wholesale 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.

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 selling data is also an income opportunity, compared to selling other parts, the volumes are exceedingly low. The administrative costs, however, 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 Tier1s by the OEMs. 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 OEMs. 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.[18] 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.[19]

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.

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[18] 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.

[19] 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.

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 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 is a handicap. Reception of GPS signals is disrupted by tall buildings or heavy tree cover, and blocked completely in tunnels and parking garages.[20] 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.[21] 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 data during the progress of the route. This leads to a second major problem.

- Off-board solutions were not viable when they relied on a constant GSM (or another second generation technique) network connection. Staying connected to the GSM network is extremely expensive. To avoid the expense, some systems made a connection, downloaded as much data as required to start the route guidance instructions, and then closed the connection. When more data was needed, a new connection was made. This happened via a modem. At 9.6 or 14.6 kilobits per second (kbps), transfer times are slow and data amounts severely limited. So companies competed 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 competed on their speed in preparing the data for sending on the server side. Packet switched data (e.g. GPRS or I-mode, so-called 2.5G) changes the need for a constant network connection.

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

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[20] 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.

[21] 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.

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 OEMs 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.[22]

- 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 its 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.

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[22] OnStar Europe, General Motor's telematics service offered in Germany, initiated an off-board navigation service in the spring of 2004 with their new system offering. GM cancelled OnStar Europe operations on 1 January 2005. OnStar North America operations continue to expand, but off-board navigation is not one of the services offered.

▪ Totally off-board solutions are not realistic for supplying mission-critical information, such as for ADAS[23] 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. Most OEMs have initiated ADAS research programs, and a few companies, like Audi and BMW, have already introduced ADAS systems in their vehicles.

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.

What's the Verdict?

Price Performance Proposition

Less expensive on-board systems are already available[24]. These are the turn-by-turn devices (no maps) usually built into car radios (Blaupunkt, Melco, etc.), and the portable and semi-integrated

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[23] 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.
[24] Prices for portable navigation devices are below €1000, while integrated, full colour systems cost in excess of €2000.

systems from ALK, TomTom and others.[25]   The dual function of the radio-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. The customer does not have to pay for an entire continent or even a whole country, just the part of the world that he or she needs on a regular basis. When more geography is required, the customer can pay for a limited use license.

Performance of off-board systems today is very good, but it is still hampered by dependence on the communications networks. I do not mean that network bandwidth is the problem. Systems like Telmap's **Polaris** have proved that plenty of data can be transferred across simple GSM connections, and GPRS is capable of supporting data transfer rates that are more than adequate for route guidance. 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, and fast-moving vehicles passing between cells increases the difficulty of holding on to a connection.

So, today, off-board systems have a similar price to the low-end on-board systems with a slightly lower level of performance due to the reliance on the telecommunications network. Networks are constantly improving, and in time 3G will be ubiquitous and reliable. 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 systems in my own car for the past nine 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 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

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[25] For a good catalogue of the systems that were available in 2003, see a report by Strategy Analytics, Navigation Product Status 2004; April 2004.

problem free on trips of over one hundred kilometres, with start and end points in cities with complicated street patterns. However, I have also tried to start a journey where neither GPS nor GSM/GPRS would cooperate, and then, my on-board system has the advantage.

The area in which on on-board systems are clearly better is address input. Unless names are stored locally, it is difficult to respond immediately to typed letter input with a list of all possible places or street names matching the letters as they are typed. A name must be typed and then sent to the server for matching, and a list of possible alternatives is then sent back to the client.

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 would be the biggest improvement.

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[26] 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.

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[26] Value Network refers to the particular group of companies working with and profiting from a given technology or service.

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."*[27]

The "home" value network referred to by Christensen above 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, Samsung, 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 Appello, 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 as well inside a moving vehicle as 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 OEMs 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.

Off-board, on-board and hybrid navigation and route guidance systems will continue to develop in parallel for several more years, and eventually merge into a single application with a combination of on-board and off-board data storage, on-board and off-board application programs, and autonomous and dynamic operation modes. How quickly this happens depends on how quickly a critical mass of vehicle OEMs place a functioning telecommunications module into their vehicles.

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[27] 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 Route Guidance Systems

Information is provided in this appendix on some of the off-board route guidance solutions available today. Descriptions are provided for those systems about which I have personal knowledge or for which companies have provided information. For the remainder, I have included a contact name and address. This appendix is not intended to be comprehensive nor complete. I will update it periodically, and add new information as it is received. It is also not intended to be a qualitative review of the applications since any review would be out of date within minutes of its writing by virtue of the constant updating of the applications by their developers.

Telmap Ltd

Product Name:	**Polaris**
Contact:	**Telmap Ltd.** 11 Bareket Street P.O. Box 12888 Herzlia 46733 Israel Phone: +972 (0) 9 9582 844 Fax: +972 (0) 9 9518 188 Web Site: www.telmap.com
Retail Price:	Telmap is a Business-to-Business company, and their products are licensed to companies that are in the Business-to-Consumer market. Prices are set by their customers.
Continuation Price:	NA
Included in Price:	NA
Available Markets:	North America, Western Europe, Australia, New Zealand, South Africa, Israel
Description:	**Telmap Polaris 2.0** is the latest version of the company's wireless navigation product. The software can be delivered on a CD-ROM or via a web site. It is loaded to the phone using Bluetooth, infrared or a cable connection. Any type of GPS interface is supported, including cable, Bluetooth and integrated GPS units. I have driven extensively with Polaris in Europe and in North

America. The application comes close in look and feel to a full-function autonomous system. This is because Telmap transfers vector data to the handset or PDA, and installs a map rendering program on the client device. As a result, certain functions, like off-route detection and recalculation, can be done locally, rather than requiring a return trip to the server. In addition to the vector map data, Polaris supplies map images for reference purposes at various scales. The number of maps that can be downloaded depends on the length of the route and the storage capacity of the client device. In Follow Me mode, a vehicle icon is clearly shown moving on a map, with current street and next turn street visible in large test, as well as distance to next manoeuvre and manoeuvre icon.

In Polaris 2.0, Telmap has added traffic information display and usage in re-routing. Another addition is a pedestrian application that can be used outside a vehicle and without a GPS connection. This can be useful for getting from a parking location to an office entrance.

Telephone Purchase

Polaris runs on Java-enabled handsets as well as the iPAQ and XCA PDAs. The company is constantly adding new phones to its list of compatible devices.

Wayfinder

Product Name:	**Wayfinder Euronavigator**
Contact:	**Wayfinder Systems AB** Baravägen 1 P.O. Box 1154 SE-221 05 Lund Sweden Phone: +46 46 288 22 00 Fax: + 46 46 288 22 01 E-mail: sales@wayfinder.com Web Site: www.wayfinder.com
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: 	*Telephone Purchase* Wayfinder then worked on Nokia 7650 and 3650 and SonyEricsson P800. Today, Wayfinder works on a wide range of phones from Motorola, Nokia, Siemens, among others. See their web site for full details. *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), a set-up file was automatically sent to my phone via SMS, and a GetWayfinder icon was set up on my menu grid. I clicked on this icon and it started the set-up program. The biggest problem was selecting the correct Vodafone connection. It took me awhile 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.

Operation

I used Wayfinder in my car for one year, mostly testing it at the same time and with the same routes as my prototype Volvo RTI System. The instructions and their timing provided by Wayfinder matched very well with the RTI, even though Wayfinder was using only a GPS device for positioning and RTI had the benefit of dead reckoning as well as GPS. In most cases, the manoeuvre icon was sufficient, but I missed the map for verifying that I had made the correct turn.

Wayfinder's mapping functions have improved significantly since the early version that I tested.

PTV/3SOFT

Product Name:	**PTV navi service** and **PTV naviguide**

Contact:	**PTV AG**
	76131 Karlsruhe
	Germany
	Phone: +49 721 9651 0
	Fax: +49 721 9651 696
	E-mail mobility@ptv.de (General)
	            navi-service@ptv.de (Product)
	            thilo.schmalkoke@ptv.de (Sales)
	Web Site: www.english.ptv.de

Retail Price:	**Sample End User Applications**
DaimlerChrysler A-Class	• €1,600
DaimlerChrysler Smart	• €1,400
	Der PDA auf Räd ist jetzt verfü
Falk active pilot	
Initial Price	€59 - €189
Flat Tariff	€16.00 per month
Per Use Fee	€0.89 per route that is less than 50 kilometres @1.49 per route that is longer than 50 kilometres
Remarks	One year of free navigation is included in the Flat Package; 25 free routes are included in the Per Use Package.
Geographic Coverage	Western Europe (Navteq data)
Cullmann variocom VC4	
Initial Price	€499
Flat Tariff	€99 for one year €149 for two years
Per Use Fee	None
Remarks	Mounting in the car is required. Three months of free navigation are included in the Package Price
Geographic Coverage	Western Europe (Navteq data)

Continuation Price:	PTV navi service – Annual Service Fee per End Device

	• 10 – 50 end devices €135
	• 51 – 100 end devices € 120
	• 101 – 250 end devices €110
	• Over 251 end devices on request
	• All prices are exclusive of VAT. There is a unique activation fee of €500 per fleet. The minimum contract period per end device is 12 months
Included in Price:	• Ptv navi service software • Access to data of Western Europe (Navteq) with unlimited routings
Available Markets:	Germany, France, UK for Professional Market only (starting with 10 units per customer minimum)
Description:	PTV is not acting as a commercial service provider for off-board navigation in the <u>consumer market</u>. PTV serves the consumer markets through their customers, such as Falk, Cullmann and DaimlerChrysler. Their customers have the contract relationship with private consumers and represent the product with their brands. PTV provides its ptv Naviguide software for these applications. For the <u>professional market</u> PTV performs a different role. The company provides an off-board navigation services with their own brand: **ptv navi service**. The main difference between the ptv navi service and the consumer solutions is that the professional service can be integrated with various other business critical applications for mobile workers and field forces. Such applications are tour/trip planning, order management or fleet management. *Telephone Purchase* PTV naviguide client software has been developed in cooperation with 3SOFT GmbH (www.3SOFT.de) runs on Windows CE on a Compaq iPaq, T-Mobile mda or 02 xda. PTV is working with Jentro Technologies GmbH (www.jentro.com) to develop client software for java-based mobile phones, smart phones and PDAs.

Trafficmaster and Motorola

Product Name:	Smartnav
Contact:	**Trafficmaster Plc** University Way Cranfield Bedfordshire MK43 0TR, UK Phone: +44 8 705 561 712 Web Site: www.trafficmaster.co.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:	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

<u>Smartnav for OEMs</u> - 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 OEMs had very large sunk costs for development. However, ignoring the sunk costs, the automotive OEMs 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.

Smartnav Set-up

Provided by installer.

ViaMoto is a mobile phone-based service that Motorola has introduced first in the US on AVIS rental cars. 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

Webraska

Product Name:	**IbDN** (Internet-based Distributed Navigation®) **SmartZone Navigation**
Contact:	**Webraska Mobile Technologies** 22, rue Guynemer BP 107 78602 Maisons-Laffitte cedex France Phone: +33 1 39 12 88 00 Fax: +33 1 39 12 88 88 Web Site: www.webraska.com
Retail Price: **Orange France**	**Sample End User Applications** • €299 – purchased through the Orange Accessories store.
Continuation Price:	After first year, €10 per month plus GPRS fees based on whether the customer has a subscription for Orange World, or whether the uses are paid for individually. With an Orange World GPRS subscription costing €6-10, the fee for a 20 km route would be €0.02. Without the subscription, the GPRS fee for the same route would be €0.20.
Included in Price:	• Wireless GPS receiver • GPS charger • Software on CD-ROM along with user manual • Customer support
Available Markets:	With Orange France subscription, data is available for Western Europe, excluding Norway and Finland. Webraska also has operations in Australia.
Description:	 Webraska products are sold through consumer service companies, such as network operators.

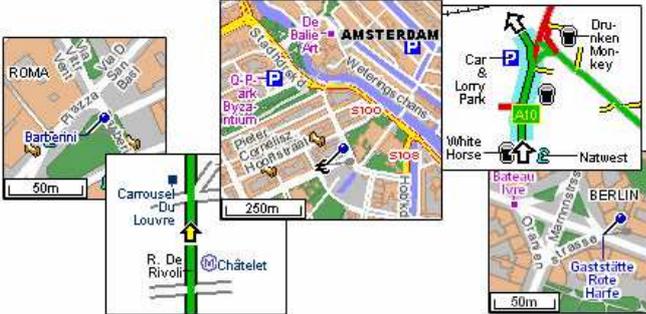|	Webraska released their latest version, 2.1, in December, 2004. In addition to support for additional devices and general human machine interface improvements, they added radar warnings and improvements to address input. For example, the interface allows input of the French address format (number first followed by comma) as well as the German/Swedish format with name first and then house number. Another addition is manoeuvre maps produced using actual street geometry. Telmap was first among the off-board system developers to use actual street geometry instead of idealised intersection icons, but most of the companies have now followed suit. *Telephone Purchase* • SmartZone Navigation runs on all four major wireless operating system platforms: • Symbian Series 60 (e.g. Nokia 7610) • Symbian UIQ (SonyEricsson P800/P900) • Microsoft Windows Mobile for Smartphones (SPV C500) • Microsoft Windows Mobile for Pocket PC Phone Edition (Qtek 9090)

Appello

Product Name:	**WisePilot**
Contact:	**Appello** Mölndalsvägen 30 A SE412 63 Göteborg Sweden Phone: +46 31 405020 Web Site: www.appello.se
Retail Price:	Appello is a Business-to-Business company, and their products are licensed to companies that are in the Business-to-Consumer market. Prices are set by their customers.
Continuation Price:	NA
Included in Price:	NA
Available Markets:	Europe, North America
Description:	 *Telephone Purchase* WISEPILOT supports Symbian and Pocket PC devices, and currently works on the following models: • Nokia (6600/6620, 7610, 3660, 3650, 6630) • SonyEricsson (P800, P900, P910) • Siemens (SX1) • Qtek (HTC) (1010, 2020, 9090 (xda & mda) • HP iPAQ (6315/6340)

T-Mobile Traffic

Product Name:	T-D1 NaviGate
Contact:	**T-Mobile Traffic** Am Propsthof 74 D-531 21 Bonn Germany Phone: +49 228 5201-0 Fax: +49 228 5201 909
Retail Price:	NA
Continuation Price:	NA
Included in Price:	NA
Available Markets:	NA
Description:	**T-D1 MDA**

M-Spatial

Product Name:	**Spatial Platform** **MapWay**
Contact:	**m-spatial ltd.** St John's Innovation Centre Cowley Road Cambridge, UK Phone: +44 1223 421 537 Fax: +44 1223 421 531 Web Site: www.m-spatial.com
Retail Price:	NA
Continuation Price:	NA
Included in Price:	NA
Available Markets:	NA
Description:	**MapWay** is a suite of pre-built WAP and Java applications.

ALK

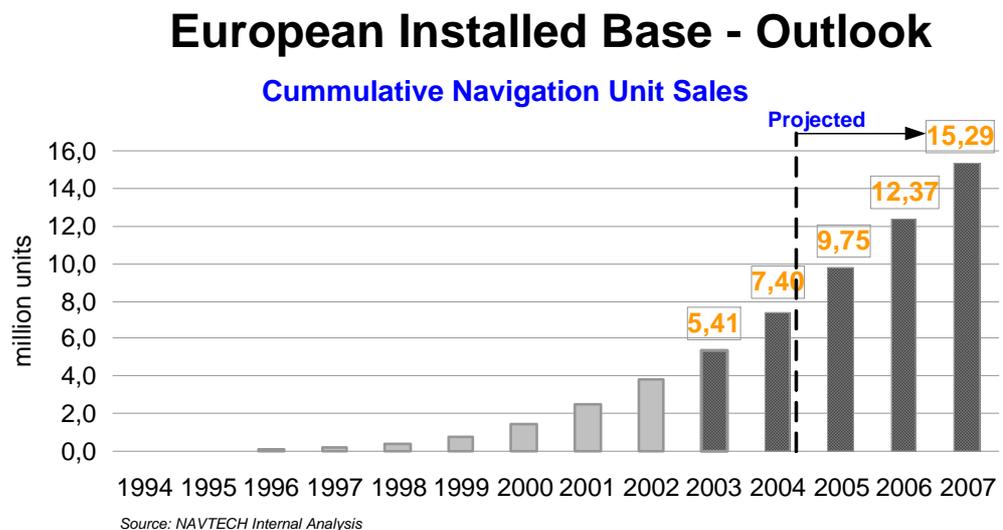|	
Product Name:	**CoPilot Live – Windows SmartPhone Edition**
Contact:	**ALK Technologies, Inc.** 1000 Herrontown Road Princeton, NJ 08540 USA Phone: 1 609 683 0220 Web Site: www.alk.com
Retail Price:	CoPilot Live Smartphone – Software Only - $249 CoPilot Live Smartphone – Software with CoPilot's Bluetooth GPS - $349
Continuation Price:	NA
Included in Price:	CoPilot Live Smartphone with GPS • Install Disk • Data Disk with Street-level data for the entire continental US, or Europe • CoPilot Bluetooth GPS receiver • In-vehicle mounting hardware • 12-volt in-vehicle power adapter • User's guide available as a PDF in software • Quick Start Guide • GPS Receiver Guide
Available Markets:	North America, Europe
Description:	**CoPilot Live Smartphone** is not an off-board navigation system. It runs on a telephone for a combination of reasons, primarily because the phone is multi-purpose and customers need not purchase either a single-purpose device, like the TomTom GO device, or a PDA that they may use only for route guidance sessions. Another reason for CoPilot Live Smartphone running on a telephone is that ALK uses the phone for communicating both from and to the device in commercial applications. Data and software are downloaded to the phone's Flash memory during set-up, so, like autonomous devices, all data is locally accessible on the device, and all software is running locally. This means that CoPilot Live has the same standard features as CoPilot running on a PDA without connectivity, such as 3D map display, multi-stop trips, instant re-route.

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.[28] The total value of navigation systems and data sold worldwide in 2002 was approximately $6 billion.[29]

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.

European Installed Base - Outlook

Cummulative Navigation Unit Sales

Source: NAVTECH Internal Analysis

Market Size and Growth Rates

2004 was a great year for in-vehicle route guidance system sales in all three major markets: Europe, Japan and North America. In

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[28] 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.

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

Europe, total sales were up a full 20%, from 1.6 million units to 1.92 million. Three-quarters of the total were OEM line fitted, and the remainder were aftermarket systems. Penetration rate (total number of systems delivered divided by the total number of cars sold) was 8.6% (6.7% in 2003) in Europe of the total 16.3 million cars sold. Adoption rate (number of vehicles offered divided by the number of vehicles sold) was 86% (81% in 2003). in the high-end luxury market (e.g. BMW 7, Mercedes S), the take rate (number of systems delivered divided by the number of models offered with the option) was 100%, and in the lower-end luxury category it was 57%.

This is all good news. But at the low-end sectors of the market, where the volume of car sales is the highest, in-vehicle route guidance system sales are still in the single digits. _Filling this hole--and doing it surprisingly quickly--are portable navigation devices_, like the increasingly popular TomTom Go, Navman, Garmin and Magellan systems. Sales of these systems have grown from a few hundred in 2002, to 800,000 in 2003, to a whopping 1.8 million!!! in 2004. Projections for 2005 are 3.1 million for this category, compared to 2.3 for the OEM systems.

Smart phone systems from Telmap, Webraska, Wayfinder, Appello and others have not yet gained much traction. This is due to change in late 2005, when they begin to gain major momentum.

What is interesting about developments to-date is that _buyers are not abandoning one category to purchase another_. Total sales are growing. So neither in-vehicle system nor personal navigation device sales are expected to decline when smart phone sales start to take off.

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.[30]   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, 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

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

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.[31] This is not an off-board system, but a method of providing real-time 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
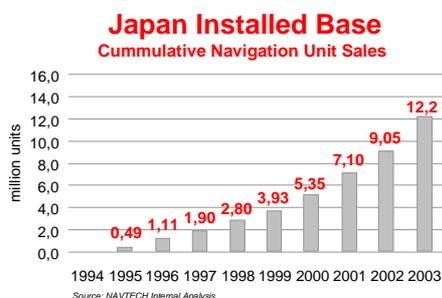
Germany is by a large margin the most active market for navigation systems:

- All of the German OEMs offer one or more navigation systems in their vehicles[32];

- Three of the four primary European navigation system manufacturers have their head offices in Germany[33]; and,

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[31] VICS – Vehicle Information and Communications System

[32] Audi, BMW, DaimlerChrysler, GM Opel, Volkswagen, Porsche

[33] The three are Siemens VDO, Harman Becker and Blaupunkt. The fourth that is not located in Germany is Magneti Marelli.

▪ With the largest population, more cars are sold in Germany than in any other single market in Europe[34].

Figure 3

European Navigation Market - Outlook

Market share	2001	2002	2003	2004	2005	2006	2007
OEM	65%	65%	64%	70%	72%	72%	73%
After Market	35%	35%	36%	30%	28%	28%	27%

Navigation Unit Sales History/ Outlook- WE
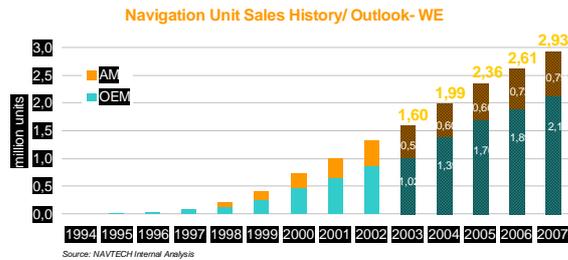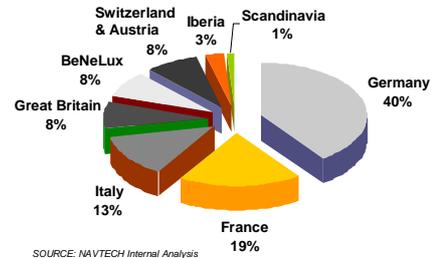
Source: NAVTECH Internal Analysis

Figure 4

Navigation Sales By Country

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

Navigation System Sales by Country

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.
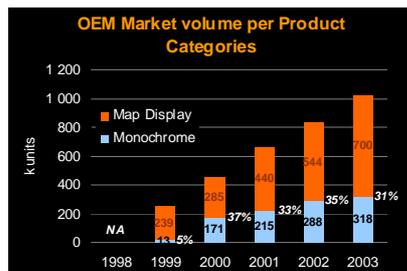

OEM Market volume per Product Categories

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.

AM Market volume per Product Categories
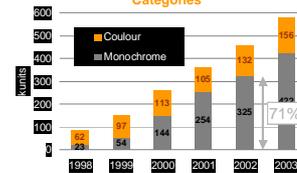
Success factors of radio-nav products:
- Easy to install in replacement of an existing radio.
- Cheap marginal price of the navigation function compare with a stand alone system.

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[34] 3.524 million cars and trucks, followed by UK with 2.885 million, France with 2.715 million and Italy with 2.559 million

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.

AM Colour Systems

Notes:

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