**Michael L. Sena Consulting AB**

**Position Paper**

# Interoperable Map Data Media for Navigation Systems

## Rethinking the problem, and exploring possible solutions

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## Preface

The Position Papers 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 a 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 design 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.

Traffic congestion in and around our cities is a symptom of ill-considered decisions about the placement of origins and destinations for the people who live, work, shop and recreate in city regions. The increased number of vehicles on our roads is the result of people moving between dispersed origins and destinations in a way that can no longer be accommodated by point-to-point collective transportation systems. Whether it was the automobile that enabled the dispersion, or the desire of families and businesses to move out of cities that created the need for more private travel, is a subject of debate. There is no debate on the simple fact that traffic congestion and its side effects are a problem in almost every corner of the world.

Unless an holistic view is taken to the problem of personal mobility, a view which accepts that where people begin and end their journeys must be addressed simultaneously with how they will move between these locations, ITS solutions will not be able to deliver their full potential benefits.

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Position Paper

# Interoperable Map Data Media for Navigation Systems

## Rethinking the problem, and exploring possible solutions

The majority of navigation systems sold today are delivered in new vehicles at the time of purchase, as opposed to being bought on the aftermarket.[1] These systems are ordered from the system developers by the vehicle OEMs for factory or dealer installation. In some cases, the OEM has a contract for the map data directly with the map data supplier(s), in other cases the map data contract is with the system manufacturer. In almost all cases, the map data media can be used on systems developed by one and only one manufacturer, that is, there is no interoperability of the map data media between systems produced by different manufacturers. The exception to this rule is when different system manufacturers use the same software, physical storage format and applications tools, but such sharing is not widespread.[2] Some system developers provide for compatibility of the map data media between older and newer versions of their systems, while others do not.

Why is this so? The answer is simply that the format of the map data stored on the media, be it a CD-ROM, DVD, Flash memory or hard disk, is part and parcel of the total system design. The way the data is packaged and stored on the media determines how large a geographic area can be included on the media with a complete set of physical features and related attributes; how accurately the position of the vehicle can be matched to the actual road on which the vehicle is travelling; how quickly and accurately a route request can be processed; and, how quickly map images, route descriptions in the form of graphics and voice instructions can be delivered to the driver interface. System developers protect their media data formats like master brewers protect their beer recipes. Each navigation system manufacturer uses basically the same hardware components and similar software approaches to produce a product that looks almost identical to its competitors', but like the taste of beer, there can be vast differences in the final result. In the case of these systems, the result is measured in its performance.

There is one major problem with this approach and several undesirable consequences that follow the problem. Converting the raw ingredients of

[1] According to a report by Strategy Analytics, in 2001 a total of 3.4 million navigation systems were sold worldwide. Of this number 2.6 systems were OEM installed and 800,000 were aftermarket installed, or approximately a 70% OEM share. The same report projects worldwide sales of navigation systems to be 10.6 million in 2007, with a similar split between OEM-installed and aftermarket systems.

[2] Currently, a few vendors use identical software called SDAL developed and licensed by Navigation Technologies. Map data media can be interchanged between these vendors since the physical storage format of the map data on the media is an integral part of the system design.

a map database to the special format required by each system takes a significant amount of time. Data is delivered from one of only a few map data suppliers in either their own transfer format or in one of several standard formats, like GDF or ARC Shape Files.[3] A file for an area the size of Germany can contain 2-3 Gbytes of data, and all of Europe up to 50 Gbytes. This data must go through a number of steps before a master disk can be produced and the final CD, DVD or other media copies made and distributed. Most of these steps are automated, but a substantial amount of manual intervention is required to fine-tune the data and add special features. By the time the conversion and manufacturing process is completed for an area the size of Europe or North America, between three and six months could have passed. This is the minimum amount of time for a customer to receive the most recent version of data. If a car manufacturer or system developer re-issues updates twice a year, and a customer purchases a vehicle or a system at the end of an update cycle, the data can be up to one year old.

Assuming that the information delivered from the map data suppliers was absolutely up-to-date at the time it was delivered to the system developer, some of that information will have changed the day after delivery. The most important navigation attributes, such as one way designations, turn restrictions, time-of-day prohibitions, are the ones that change most often. The longer it takes to get the final media into the hands of the user, the more the accuracy and completeness of the contents will degrade. No matter how well the system performs, inaccuracies in the data will result in disappointment on the part of the user of the system. This disappointment will reflect on the system manufacturer, the data supplier, and on the company that actually sold the system, most often the vehicle OEM.

Time also costs money. Several months of computers churning, with staff monitoring the process, adds up to a large sum. To make matters worse, this time-consuming process with its associated costs needs to be repeated by every system vendor each and every time an update of the data stored on the media needs to be performed, ideally at least twice per year. Since it is a fixed cost for each conversion, it can be added to the price of each system, or to each map data media delivered with the system or sold separately. If the system vendor sells a large number of systems or map data media, the distributed cost per unit is lower. However, since the conversion cost is fixed, it is the same whether one unit is sold or millions of units are sold. This means that each system vendor, or whoever is bearing the costs for the conversions, requires a minimum number of units sold to amortise these costs. One more issue: When the new version is ready, the old, unsold media, should be destroyed. If the minimum number is not reached for each conversion, one or more of the following will result:

- The cost of the system and/or the media will be uncompetitively high.

[3] GDF stands for Geographic Data Files. It is a navigation data transfer format originally developed in cooperation between European navigation system manufacturers and map data suppliers. The current version in use is GDF 3.0. A new version has been developed inside the international standards body, ISO/TC204 Working Group 3. It is scheduled for release after final voting in mid-2002. ARC Shape Files is a format developed by Environmental Systems Research Institute for transfer of geographic data from its internal proprietary format to other systems, and has become a de facto industry standard.

- There will be fewer conversions made by the system vendor in order to increase the time available to reach the minimum number of units sold. This results in more out-of-date data.

- The system vendors or the system sellers (i.e. the vehicle OEMs) will have a lower profit or a loss on each unit sold.

While this conversion process to proprietary formats may not be a problem for all system vendors and their OEM clients, it is shared by most of them. Navigation systems remain luxury purchases, rather than mass market products, even though they continue to be ranked high on consumer preference surveys.[4] With high fixed costs, the only way to reduce unit costs is by increasing volumes. One way to do so is to make them standard fits, rather than factory or dealer options. This would please system vendors and map data suppliers, but it would only increase the total financial burden on the OEMs since they would have to purchase more systems. Margins on standard fitted equipment are lower than if they are sold as options, so the OEMs would be earning less on each system. In the worst case, systems would require further mark-downs at the point of sale when prospective purchasers bargain them away as an unwanted option. A rule of thumb in the automotive industry is that an option should become a standard only after the take-up rate exceeds 75%.[5] Currently, the take-up rate for navigation systems is approximately 5% worldwide.

The fixed cost of conversion needs to be spread over the largest possible number of units or it must be eliminated altogether. There are two ways to reduce the unit costs of conversion, and one way to eliminate these costs. They are:

- Reduce the number of system developers from the current few dozen to a few. Market forces usually determine how many companies can profitably compete in an industry. Unless worldwide sales increase, the number of system developers will be reduced by attrition. Consolidation through mergers is not a realistic option to trim the number of proprietary formats and conversions since there are no economies of scale in combining system vendors who produce completely different systems, and few redundant operations if the merged companies retain their respective systems.

- Reduce by choice the number of formats used by system developers. This is what has been done in Japan (see Figure 1), where all OEMs and their respective system developers have grouped themselves into spheres. All system developers use basically the same physical storage format, called KIWI, but each sphere creates a modified version of KIWI that works within the sphere, but not between systems in different spheres.

[4] A J.D. Power and Associates Survey, *2001 Automotive Emerging Technologies Study – Wave I*, found that 61% of respondents were either definitely or probably interested in purchasing a navigation system, significantly ahead of in-vehicle Internet and e-mail (26%) and satellite radio (41%).

[5] Attributed to Bob Lutz, auto industry veteran and current GM executive

- By agreeing to a single standardised physical storage format for map data, the cost of conversion can be eliminated altogether. Map data suppliers could deliver their data in an application-ready format. It has been argued that this approach would effectively rule out any significant differentiation by system vendors and their OEM customers. Those against a standard PSF have proposed a standard API[6] which can be used by every system vendor to access other vendors' data. This approach provides for interoperability, but it does not eliminate, or reduce, the number of conversions required since each system will still be optimised to run with its own data format.

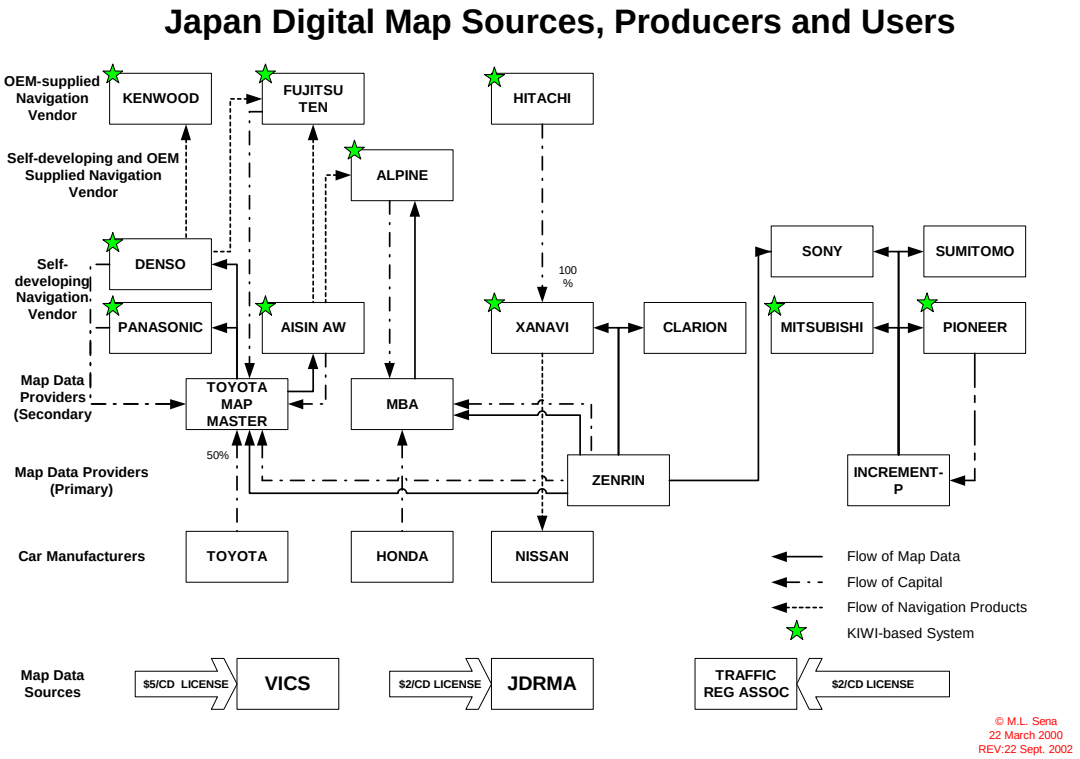



**Figure 1: Navigation System Spheres in Japan**

The first option would be preferred by the strongest system vendors. However, a monopoly would not necessarily be in the OEMs' or the consumers' best interests. Consumers have indeed benefited from Microsoft's dominant position in most PC software categories because everyone can exchange word, spreadsheet, graphic, database and project management files since they are using identical programs. Before Microsoft created a de facto set of standards in each of these categories, by either purchasing its competitors or competing them out of business, file interchange was a major problem. Nevertheless, consider whether it would be beneficial or even legally allowable, if Microsoft also produced and sold the only hardware configuration on which its software operated.

Interoperability by minimising the number of physical storage formats is preferable to dominance by a single system developer. Can

[6] Application Programming Interface is an interface that enables a user written program to communicate with the operating system, or access method/device drivers.

interoperability be achieved? The answer is yes—it exists to a limited degree in the Japanese market—but everyone is going to have to give something up. Thus far, none of the parties to the debate have proved willing to do so. Standardising the PSF and creating a standard API have both been tried through the ISO standardisation route, to-date without concrete results. System vendors have no incentive to adapt a PSF developed by committee, or by one of their competitors, and coordinating the implementation of a multi-vendor, multi-format API approach defies the imagination. Yet, as more time passes, the cost and quality issues related to single-vendor map media grows, and more versions of map media formats proliferate, further exacerbating the unit cost problem. Neither the car manufacturers, the map data vendors nor the eventual system users benefit from the current situation.

As already stated, system vendors are reluctant to relinquish control of their data format because more than any other single factor, it defines the performance of their systems. However, their proprietary formats were originally designed for write-once read-only optical media and for hardware platforms with limited amounts of memory. They were designed for single-function navigation systems, with direct access between the map data media and the principal components of their systems, such as positioning devices, display and application software. They were also designed in close cooperation with their major OEM customers who demanded performance above all else. There may have been thoughts about map media interoperability, but these thoughts were not expressed in either design specifications or purchasing requirements.

The original preconditions for navigation are disappearing. The OEMs have taken over the HMI[7] function, giving it to specialists so that other functions using the driver interfaces (e.g. display, voice) can have a similar look and feel. In-vehicle networks such as MOST[8] will make it possible to separate components from individual systems and share them across many systems. For example, most cars with telematics and navigation systems have separate GPS devices, rather than one device shared by both systems. New uses for map data, particularly advanced driver assistance systems (ADAS), make access to a centralised map database a certain necessity. This database will need to be constantly updated to ensure total reliability of ADAS functions, and will need to be in a standardised map format so that it can be updated from a variety of sources.

## Off-board No Magic Solution

Those who believe that an off-board alternative to autonomous systems is the answer to 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. Data transfer speeds that are much lower than are possible with totally on-board media, and the necessity of using

[7] Human Machine Interface

[8] MOST: Media Oriented Systems Transport. An initiative with similar aims as AMI-C (Automotive Multimedia Interface Collaboration). Founded by German car makers Audi, BMW and DaimlerChrysler, it has over 60 company members developing a set of common specifications for a multimedia interface to vehicle electronic systems in order to allow a variety of computer-based electronic devices in the vehicle. Has approximately a dozen members.

smaller data packets than the high bandwidth can support because of the possibility that contact will be lost in the high-bandwidth areas, 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, totally off-board solutions are not realistic for supplying mission-critical information, such as for ADAS 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.

Then there is the issue of what will be done with all of the legacy CD/DVD or the other on-board media systems when the industry does move to off-board data delivery. As the off-board data supply model begins to attract users, the economics of the on-board media model worsens. The danger is that media updates will become more and more infrequent or stop altogether. The same can happen when one of the suppliers closes down operations. There are no guarantees that this won't happen to any of the current system suppliers, even the largest. An embedded system with no possibility of obtaining updated data quickly becomes a worthless accessory and a liability when an owner tries to resell his or her car.

## Inappropriate Role Models

The navigation system industry is not functioning properly today because of a mismatch between the business model adopted by the manufacturing side with the business model desired by consumers and the vehicle OEMs, the systems' main sales channel to consumers. The system developers have applied a model similar to the video games industry, in which a video game is designed for a specific console, and consumers purchase the games with the full knowledge that the games can be played on one and only one console.

The OEMs and consumers would like to apply the DVD/Video and music CD model, in which the choice of navigation system is separate from the choice of media, and a variety of media can be played on any system—maximum choice, total interoperability, and presumably the best way to spread the cost of conversion over the maximum number of units.

Applying the video games model is flawed from the outset for several reasons:

- In the video games model, hundreds of developers compete with each other to be chosen by one or more of the three major console suppliers, Sony (PlayStation), Nintendo (GameCube) and Microsoft (Xbox), to develop their next blockbuster game. Producing a high quality game costs upwards of $5 million, but a winner can generate sales of $200-$500 million.[9] With navigation systems, there is one development team for each of the several dozen system

[9] The Economist. *Console Wars* (June 22nd 2002); pages 61-62.

manufacturers. Since the system developers are working with proprietary formats, and since there is basically only one set of applications (address finding, route planning, map display, route directions, POI location), there is no obvious necessity to develop multiple titles.

- Each video game is unique, and it's a game, not reality. It is the result of a combination of the developers' creativity applied to the then-current capabilities of the console. There is no limit to the number of titles that can be created for a console, except the money the console manufacturer wishes to invest. The result is broad choice for the consumer even within the single console-to-game restriction. Conversely, each navigation CD/DVD contains the same information, a representation of the real world. The information is not unique, but because of the time and cost required to gather it there are only a few suppliers of this information. Creativity is applied to how the data is formatted and the software for applying this format to the problem of navigation. It's not a game, it's reality.

- Any customer can purchase any video games console or all three. With an embedded navigation system, the customer gets the system chosen by the OEM. There may be instances when a customer chooses one OEM's model over another's just to get a particular brand of navigation system, but it's probably a rarity.

- A game contains no information that goes out of date. It can be played as long as the media is not damaged and the console for which it was designed continues to function. Consumers don't need to replace the same title, they purchase new games. When new systems with greater functionality appear, they do not have to scrap their old systems, nor do they expect that their old games will play on the new systems. The information on map data media for navigation systems is out of date before it is released. It needs to be constantly replaced in order for the system to function at its peek of performance.

- Video game system manufacturers compete on the performance of their consoles (i.e. speed and the degree of realism in graphic quality and sound), and on the quality of the games designed for their consoles. Navigation system manufacturers compete on the performance of their systems as well, but there is no room for creativity in the basic map information. It's either right or wrong.

## The Video Games Model

**Games Developers**

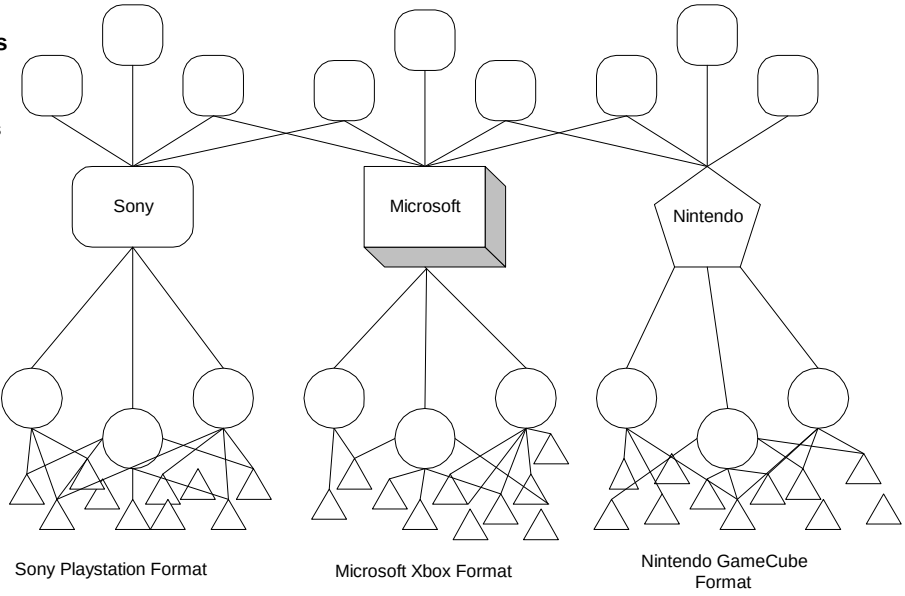
Games developers work for one or more system manufacturers

**Games System Manufacturers**

**Games Titles**

**Games System and Games Titles Customers**

Customers purchase one or more titles for each games system they buy
A customer can own one or more games systems




## The Music CD Model

**Music Artists**

Music artists produce their own titles, or work for one publisher.

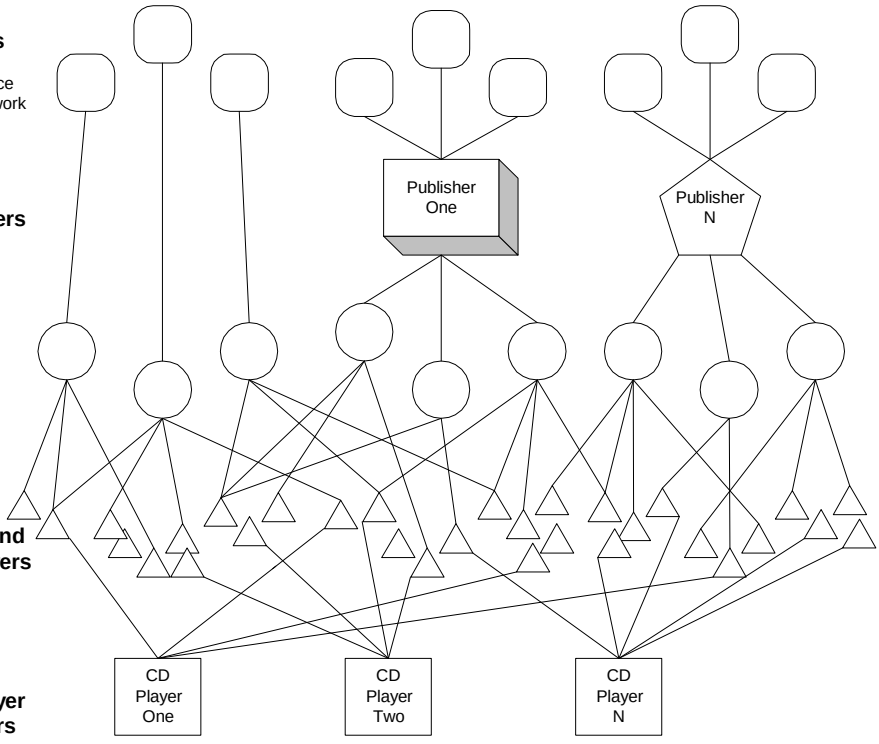
**Music Publishers**

**Music Titles**

**Music Titles and Music CD Players Customers**

**Music CD Player Manufacturers**

Customers purchase any music title for any player



## The Current Navigation Systems Developers Model

**Navigation System Map Data Suppliers**

Data suppliers combine themes from sub-suppliers and deliver data to software developers in a transfer format

**Navigation System Software Developers**

Each system manufacturer has its own team of software developers

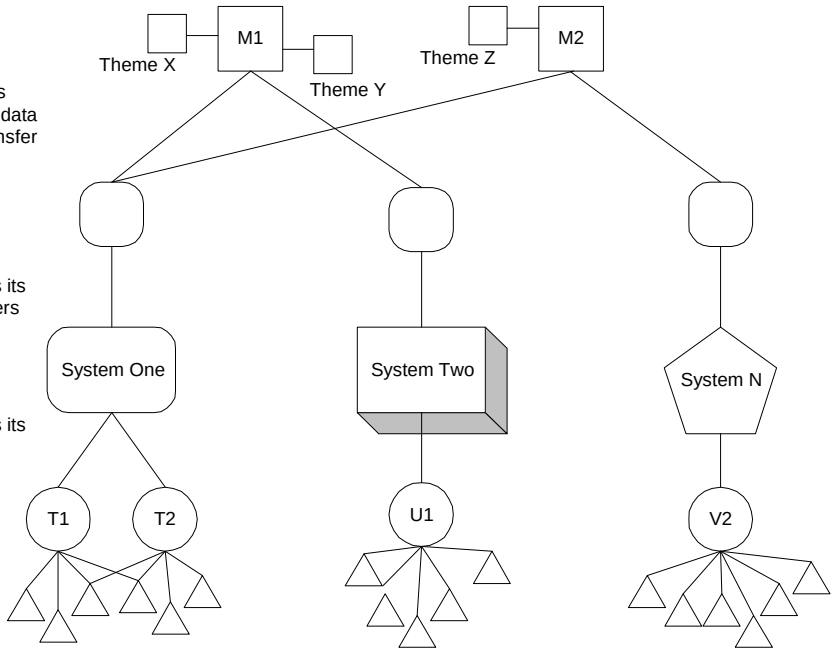
**Navigation System Manufacturers**

Each system manufacturer has its own proprietary data format

**Navigation System Map Data Media Titles**

**Navigation System and Map Data Title Customers**

Customers purchase one or more titles for their specific system




Nav System One Format with M1 on one title and M2 Data on another title

Nav System Two Format with M1 Data

Nav System N Format with M2 Data

## A Model for Interoperable Navigation System Map Media

**Navigation System Map Data Suppliers**

Map data supplliers or other data suppliers provide customer-ready data in one standard format

**Navigation System Software Developers**

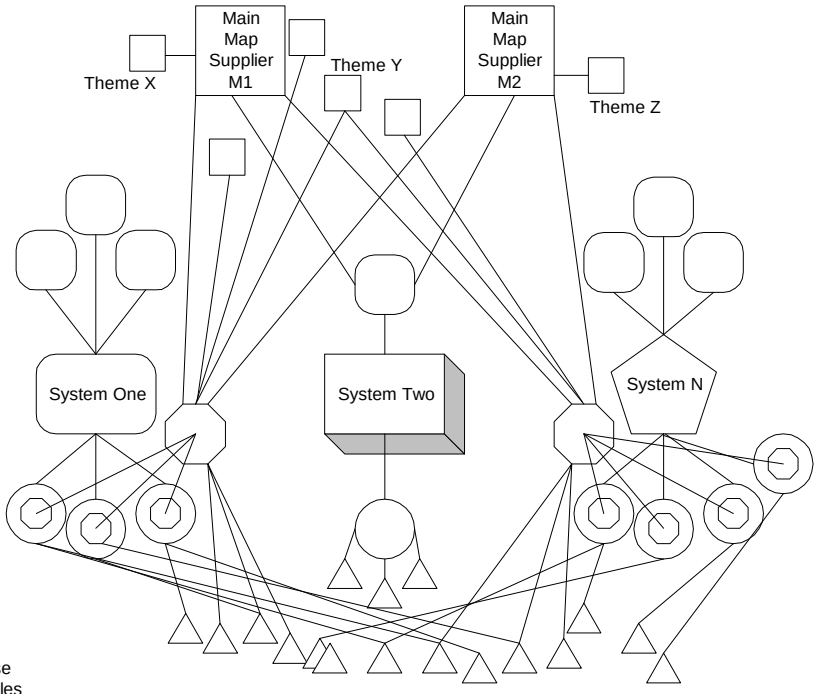
**Navigation System Manufacturers**

System vendors can either work with the standard format, or use their proprietary format

**Navigation System Map Data Media Titles**

**Navigation System and Map Data Title Customers**

Customers who buy systems that use the standard format can purchase titles from the system manufacturers or other data publishers, including the map suppliers.




Nav System One with Standard Format

Nav System Two Format

Nav System N with Standard Format

Applying the music CD or DVD/Video model is also flawed.

- With music CDs, millions of artists create material that can be converted to a single format. Anyone can produce a music CD, although music publishers sign the big-name artists. With film, there are fewer artists and higher costs of production, but the format of sound and images is the same within the TV standards in each of the three major markets, North America, Asia and Europe. Navigation data is not sound tones that can be converted to standard bits readable by any music CD player. In order for every navigation system to be able to read data stored on the disk, there must be a one-to-one match between what the software in each system expects to receive via a data access library (DAL), and what the data stored on the media is able to return to requests from the DAL. With navigation data, the ideal situation is to have one very accurate and up-to-date representation of reality. Having many hundreds or millions of contributors to this single representation would be a great advantage, especially if they have access to specialised information. But this data should be delivered in a way that does not further increase the cost of the storage and transmission process.

- Each music or movie title is unique and differentiation is based on the voice of the artist or the ability of the instrumentalist. The success of the title is based on the judgment of consumers and awards juries (e.g. Cannes, Academy Awards, etc.). There is no reason why there cannot be different titles for each geographic area produced by different publishers. The titles can contain a unique theme, such as tours of North American diners or covered bridges.

- Music or movie titles can be played forever, with the same caveats as with video games. Consumers purchase new titles in order to be entertained. Map data media can also be played forever, but only to the detriment of the user. Users don't want entertainment, they want accurate information and logical routes.

- Dozens of music CD systems and DVD/video systems manufacturers compete on how well they deliver the standard sound and images. With navigation systems, dozens of system manufacturers—many of whom also manufacturer music CD and DVD/video systems—compete on how well they deliver the results of a complex computer process using stored factual data.

## Time for a Change

What is the real problem we are trying to solve? It is the excessive amount of time required for map data conversion and its associated costs, not in the first instance providing for greater choice of titles for customers. If greater customer choice is a goal, then allow customers to choose the navigation system, just as they would with music CD or video games players, rather than making the choice for them by installing a pre-fitted system. If data can be converted quickly and inexpensively for all system developers, and this data can be passed on quickly and

inexpensively to their navigation system customers, one of the major obstacles to mass market navigation system appeal would be eliminated.

No matter how improbable it may sound, or how difficult it may be to accomplish, it seems that map content must be freed from the job of supporting navigation system performance. There should be only one universal and totally accurate version of reality, but if there must be more than one because different companies are competing to represent this reality, then at least it should be in a format that everyone can read. The appropriate model for delivering navigation systems, and the information that needs to accompany these systems, is somewhere in between the music CD model and the video games model. The navigation system can be likened to one of the video games boxes, a self-contained operation that needs only the map data to bring It to life. The map data can be viewed as one or a few songs that every navigation system can play.

This does not mean that there need be only one or a few CDs or DVDs for all systems. There is still plenty of room for innovation and differentiation around the basic map data content. Titles can be developed around special themes, either as supplements to the basic geometry or as additional, non-navigation content. A supplement might be scenic route designations and information related to such routes, such as the aforementioned covered bridges of North America. An addition might be realistic 3D images of buildings or landmarks, both man-made and natural. Navigation system vendors, like the video games suppliers, can commission such special themes to take advantage of their particular hardware offerings, like higher resolution displays and faster graphics processors.

With a standardised and open map content format specification, anyone could produce navigation media, just as anyone can produce a movie or make a recording. Media produced directly by map content providers would not be able to take advantage of a system's particular hardware and software, but it would allow for interoperability of the media with all systems that have adopted the specification.

Specifying format does not necessarily guarantee the quality of the content. The current practice of system vendors having sole responsibility for the media places quality assurance in their hands, and the burden of errors with the OEMs who sell the system.[10] Data suppliers are now two steps removed from the navigation system customers. If data content is standardised and delivered in a navigation-ready format, it will be the data suppliers who will be responsible for its quality. However, there will need to be some form or authorisation body who will ensure that only qualified data suppliers can market their products.

Not all system vendors may choose to adopt the standardised data format. Outside of the automotive OEMs making the format a pre-condition for installing a navigation system in their vehicles, there is nothing to prevent a system developer from continuing the industry's current practice of developing proprietary formats. Customers still buy

[10] A few years ago around the Christmas holidays a driver in Germany drove into a river. He said that his navigation system told him there was a bridge at the end of the road. The model of the car he was driving was reported, but there was no mention of the navigation system manufacturer nor the map data supplier.

Apple computers long after Wintel became the dominant de facto PC standard. But Apple's trifling market share bears witness to the fact that cost, convenience and, most of all, interchangeability of files, carries greater weight than engineering excellence.

How can we move to the standardised map content model, and do it quickly? The standards committee approach has run its course. Reconciling the seemingly irreconcilable business models of the major players by putting their representatives together in different world venues every few months has proven to be too slow. Since the auto industry comprises the primary client base for navigation systems, one solution might be that the auto industry organises a competition, select a winner, and begin to change their purchasing requirements to enforce its adoption. The competition would pit different map content format producers against one another, and their solutions would be judged on the basis of their ability to be stored on different media, to deliver data to all navigation applications—including voice, text, graphic and map display—to have a competitive price, and on other major factors that determine performance. One of the most important factors is the ability to support the transition to off-board data delivery. No system should be purchased unless the map data content conforms to the specified format.

There are several ready candidates for such a competition. The Japanese KIWI Consortium has a format which most Japanese companies are currently using. The way this format is applied does not fulfil the conditions of a single format because extensions are made by each of the spheres to the basic map content. However, it is as close to a standards approach that the industry has at present, with more system vendors using the base KIWI format than any other single format. NavTech's SDAL, particularly its recently announced successor to SDAL, code named Zebra, would also be a candidate. Zebra is designed to be updated from NavTech's also new Real Time Map Service, which is built for delivering data directly to off-board application service providers and to on-board map servers.

Another possible solution is to select a small group of system vendors, perhaps two or three, who together will develop a standard. In this way, no single vendor will have an advantage, and those developing the standard will have the most detailed information and experience in the requirements.

What if the automotive OEMs cannot agree to cooperate on such an undertaking? What if system vendors simply refuse to adapt their systems to the format? And what if no one wins the competition?

The industry will probably not disappear. In-vehicle navigation is too good an idea. It may just limp along until a new and better solution is found to delivering map content in an accurate, accessible and affordable format. In-vehicle navigation, especially when supplemented with up-to-date traffic and road conditions, is too logical a driver's aid to be relegated to the scrap heap of technological solutions that can't find an economically sustainable business model. When this solution is found, people will look back to the time when their predecessors navigated with street signs and maps and received periodic traffic alerts on the radio, and they will wonder why it took so long to find a safer and more obvious way of

moving around on wheels. If the industry does not succeed in finding a solution to the current format issue, the move from the current generation of autonomous navigation systems to the new navigation methods—with map content delivered to the vehicle from off-board sources—will probably take the form of a "big bang", rather than a smooth transition, and many of the current systems are likely to be left unsupported with map data in a few years. New system technology[11] which is "good enough", but not nearly as functional or as robust as the current integrated systems, will develop for the mass market. In time, these newer systems will be upgraded in performance and eventually—in five or so years—integrated in the vehicle environment. Perhaps, one day they will deliver on the real promise of navigation systems. That will be a good thing, but the public and the industry will have lost what could have been several good years of navigation system utility.

[11] Technology is already appearing, like PDAs with map data stored locally, or mobile devices with built-in GPS and data downloaded from the Internet using GPRS or 3G networks

**Notes:**