The inclusion of landmarks within navigation systems: industry requirements

Route guidance systems: optimal navigation via the use of landmarks

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Deliverable no: 2
Authors: Ross, T., May, A.J. and Burnett, G.E.
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ABSTRACT

Research has shown that the usability, safety and acceptability of navigation systems can be enhanced by the use of landmarks within guidance instructions. 'Landmarks', refer to buildings, street furniture and built aspects of the environment. The REGIONAL project aims to enable the inclusion of landmarks within future navigation systems by gaining a thorough understanding of the driver requirements for this information and the commercial enablers and barriers to their inclusion within databases, navigation software and end products. This deliverable tackles the latter issue of the requirements of industry.

Two requirements elicitation methods were used: (1) a literature survey of user-centred and technological issues; and (2) semi-structured interviews with the industrial stakeholders involved in the process of providing vehicle navigation information to the driver. A total of 12 personnel were interviewed from the following types of companies:

- Map database providers, including navigable and 'points of interest' data.
- Vehicle navigation systems providers (OEM and after-market solutions).
- Vehicle manufacturers who include vehicle navigation systems as optional equipment.
- Motoring organisations who have business-related navigation requirements and aim to provide navigation services to the public.

The main findings are:

For database development

- For landmarks to be included, there must be a strong business case.
- Landmark information should have multiple potential uses, in addition to incorporation within a vehicle navigation system.
- The source data must be available, accessible, accurate and easily maintainable.
- Selection of landmarks should, as far as possible, not rely on field visits to verify there existence and location.
- Once obtained, landmark data should be easily maintained (to keep the information up-to-date), by (a) selecting landmarks which are unchanging or (b) selecting those where updates will be automatically notified.

For navigation system software

- Guidance must be given on the 'rules' for use of landmarks, whether these be generic (e.g. 'where a landmark exists on the database, use it') or specific (e.g. 'if there are more than 3 turnings within 100m, and the landmark is on the same side as the turnings and within 10m of the target turning, present the landmark').
- For each potential use scenario, the 'proof' is needed that any particular approach (set of rules) is the optimum.
- Landmarks must be considered within the context of a wider set of information that can be used by the driver, ie landmarks should be considered within the 'big picture'.

For the HMI

- The use and design of landmark information must enhance not reduce current customer perception of reliability, value and trust in the system.
- Guidance must be given on the implementation of landmarks within the HMI, e.g: Should the information add to or replace that currently provided? Should it be verbal, visual or both? Should icons/words be generic or specific? How can consistency of the HMI be maintained if different information is appropriate in different navigation scenarios?
- The use and design of landmark information should not constrain the internationalisation of products.

1 INTRODUCTION

1.1 Vehicle navigation systems

The task of navigating in unfamiliar road environments is a common and demanding cognitive activity for drivers (Burnett, 2000). Research has long demonstrated the problems that drivers have in planning and following efficient routes to destinations (King, 1986, Streeter, 1986, Wierwille et al., 1989). If efficient routes cannot be planned and followed, the consequences are stress, frustration and delays for the driver, potentially unsafe road behaviour (e.g. late lane changes) and inappropriate traffic management (e.g. traffic diversions through small villages).

Vehicle navigation systems offer a technological solution to enable drivers to navigate unfamiliar routes and arrive at a predefined destination. Due to their cost, vehicle navigation systems were once found only on executive and luxury cars. However, they are now commonly offered as options on medium 'family sized' cars and are even appearing at the compact end of the market. It is predicted that the use of first generation vehicle navigation systems will be increasingly common in the developed world (Rowell, 1999, Zhao, 1997); the greatest current uptake has occurred in Japan where in excess of 3.5 million vehicles have route guidance systems installed (Rowell, 1999).

Whilst business use has predominated, the reductions in cost and the availability of systems in cheaper cars has resulted in increased leisure use and a diversification of the user base. This trend is expected to continue.

Vehicle navigation systems may be offered as standard equipment, a purchase option, or as an after-market system. They will all, however, function in a similar fashion. The initial driver task is to enter a required destination. This is usually achieved using a joystick/keyboard combination to enter a street name, number and region. Systems will usually allow a driver to enter specific destinations such as football grounds or historic monuments. Once a destination is entered, the navigation system will calculate a route based on pre-set criteria such as shortest time, shortest distance, maximum use of motorways, or even avoiding motorways altogether.

Most systems will then provide 'turn by turn' instructions to the driver: for each turn or manoeuvre the driver is required to make, the navigation system will present a symbol to indicate the type and direction of turn that is required. A visual indication of the distance to the next manoeuvre may be given via a count down bar. Turn information is usually provided in several stages: a preparatory instruction may be given several hundred meters preceding a manoeuvre, and a final turn instruction given just before the driver needs to take a particular turning. Navigation systems may also provide a stylised 2D or 3D 'map view' of the route and/or particular manoeuvres. The system may switch between turn-by-turn and map overview modes, depending on the proximity to a manoeuvre.

As well as visual instruction, most navigation systems will provide simultaneous auditory (voice) output to the driver that emphasises some form of distance representation, e.g. 'turn left in 200m' or 'turn left soon'. Auditory output consists of either pre-recorded voice instructions, or text-to-speech translations. If a driver makes a navigational error (e.g. does not turn off when required, or takes an incorrect turning), the system will dynamically recalculate the route and the driver may not even be aware that this has occurred.

There are five major challenges for a navigation system, it must:

1. have access to a complete and accurate electronic navigable map database covering the intended route;
2. be able to accurately locate the present location of the vehicle;
3. enable the entry of one or more destination points;
4. contain the software algorithms to calculate the route;
5. be able to present the navigation instructions to the driver in an effective and efficient manner.

Map databases are usually held on a CD-ROM in the vehicle. This navigable database holds geographical data on the road layout and junctions, as well as additional information such as road names, traffic priorities and geographical regions. The database may also contain other information that is not directly used for navigation, such as the names and locations of selected Points of Interest (POI), (e.g. historical monuments, petrol stations and hotels). To maintain the

accuracy and completeness of data, updated CDs are issued at regular intervals by the navigable map database company. A driver can decide how frequently they wish to purchase these updated map databases.

In order to determine the current position of the vehicle, navigation systems typically use GPS, an onboard compass and wheel sensors; data from these sources are 'map-matched' with the database to locate the vehicle with a typical accuracy of a few metres.

1.2 Driver-centred design of navigation systems

Although the technological design challenges are many and considerable, the driver-centred design of navigation systems is of paramount importance. Systems must provide navigation information that maximises the driver benefits and minimises any potential costs (in the widest definition of the term) to the driver and other road users. This has major implications for what information is presented to the driver and when, and in what format. The main driver-centred requirements for a navigation system are to:

- Present unambiguous turn information to enable correct manoeuvres to be made.
- Minimise cognitive effort required to assimilate this information.
- Minimise navigational uncertainty throughout the journey.
- Enable quick and effective data input (e.g. destination entry).
- Provide confidence and trust in the system.
- Minimise distraction from the primary task of driving.
- Enable a hedonic response (i.e. rather than being relieved to reach a destination, a driver should find using a navigation system a pleasurable experience).
- Ensure integration, and interoperability with other in-vehicle systems.

In essence, a navigation system must be designed from a usability perspective. The usability of a system refers to the “quality of interaction between a user and other parts of the system overall” (ISO-9241, 1997). This is acknowledged as one of the most important aspects of design for a vehicle navigation system (Barrow, 1991, Dewar, 1988, French, 1997).

Several authors have argued that navigation systems should be more naturalistic, i.e. their behaviour should approximate a passenger with detailed route knowledge providing navigation instructions to the driver as required e.g. (Burnett, 2000).

A key characteristic of more naturalistic navigation instructions is the inclusion of landmarks as navigation aids. When a passenger or informed local provides navigation instructions to a driver, they will invariably include landmarks to either help identify a manoeuvre or confirm to the driver that they are on the correct route, e.g.:

"Turn left after the *petrol station* on the left."

"Go straight over *two sets of traffic lights*.”

"Keep going past the *station*…. "

There are compelling research arguments that the inclusion of landmarks would aid the task of navigating with a navigation system:

1. Landmarks are used within basic human navigation strategies. They form key elements within cognitive maps of the environment, aid the learning of the environment (Golledge, 1993, Evans, 1984), and are used in way-finding strategies (Alm, 1990).
2. Landmarks are valued as information items by drivers. They were rated the second most popular information type (after left-right directions) requested by a driver from a passenger for aiding navigation (Burns, 1997). This finding is confirmed by other studies (Burnett, 1998, Wochinger and Boehm-Davis, 1997, Streeter, 1986).
3. Landmarks can enhance the usability (defined as a function of effectiveness, efficiency and satisfaction, (ISO-9241, 1998) of navigation systems. They can improve the proportion of correct navigation decisions (Bengler et al., 1994). They can (in comparison to a display that emphasised distance rather than landmarks to locate a manoeuvre) reduce the mean number of glances to a display and result in lower perceived workload (Burnett, 1998), and can increase confidence of the location of turnings and satisfaction with the information presentation (Alm, 1992). Simulator trial participants have shown strong preferences for vehicle navigation

interfaces that included landmarks (Green, 1993), and this impacted on driver preference to an even greater extent than the modality (auditory vs. visual) of the interface.

Therefore, the inclusion of landmarks within navigation instructions has the potential to: (1) enable navigation systems to more effectively aid navigation decisions; (2) reduce the cognitive effort and distraction imposed by these systems, and (3) result in systems which are more accepted by the driver.

Whilst the human factors arguments for including landmarks within navigation systems are compelling, and there exists the technological feasibility, there are considerable pragmatic barriers to their introduction by the automotive industry. The benefits of landmarks will not be realised unless a means of overcoming these barriers to introduction is developed. In particular the requirements, and current constraints of the automotive supply chain and the navigation market must be understood and addressed. This is one of the challenges of the REGIONAL project, and the focus of the remainder of this deliverable.

1.3 Aims of the project

The two main aims of the REGIONAL project are to:

(1) understand drivers' requirements for landmark information to enhance navigation instructions;

(2) provide human factors design guidance to the stakeholders involved in the development of navigation systems.

There are four basic requirements that must be satisfied in order for landmarks to enhance navigation systems:

They must:

(1) be useful within a navigation context (add value to the activity);

(2) not compromise other aspects of the driving task such as safety and driver acceptance;

(3) have technical and resource feasibility from an industrial perspective;

(4) make sound business sense.

The REGIONAL project aims to address aspects of at least the first three above. The focus of this deliverable is point (3) above. Points (1) and (2) are being addressed by empirical studies within the project, and will be reported at a later date.

Specifically, this deliverable aims to describe the key barriers and enablers for actually including landmarks in navigation systems, both in the short term and the long term, and to discuss the implications for system design.

2 REQUIREMENTS ELICITATION METHOD

Two requirements elicitation methods were used: (1) a literature survey of user-centred and technological issues; and (2) semi-structured interviews with the industrial stakeholders involved in the process of providing vehicle navigation information to the driver

A total of 12 personnel were interviewed from the following types of companies:

- Map database providers, including navigable and 'points of interest' data.
- Vehicle navigation systems providers (OEM and after-market solutions).
- Vehicle manufacturers who include vehicle navigation systems as optional equipment.
- Motoring organisations who have business-related navigation requirements and aim to provide navigation services to the public.

Interviews were tailored according to the individual company involved; in general, the following topics were covered:

- Overview of the company, its business activities and objectives
- Company and individual stakeholder involvement in the vehicle navigation process
- Technical details which are relevant to presenting landmarks (eg. relationship between database paths and nodes, database anchoring of POI information, onboard or offboard data storage methods, speech output conversion, visual display limitations).
- Key motivators for enhanced vehicle navigation systems.
- Criteria for enhanced navigation systems.
- Market trends from a technical and user perspective.
- Current and future enablers and barriers to enhanced navigation via the provision of landmark information.

All interviews were recorded and transcribed. Since some discussions covered commercially sensitive issues, results are reported in general industry (rather than company-specific) terms, and comments are not attributed to specific personnel or organisations.

3 RESULTS

3.1 Overview of navigation systems development responsibilities

The main aims of the REGIONAL project have been stated as that of (1) understanding drivers' requirements for landmark information to enhance navigation instructions; and (2) providing human factors design guidance to the stakeholders involved in the development of navigation systems.

Key to providing effective design guidance to the stakeholders involved in navigation system design, is an understanding of the constraints that exist, the current barriers to incorporating landmarks within navigation systems, and the future opportunities that are likely to arise.

The navigation systems development encompasses a wide range of responsibilities that enables information within the environment to be presented to the driver. The main activities are shown below in Figure 1 below:

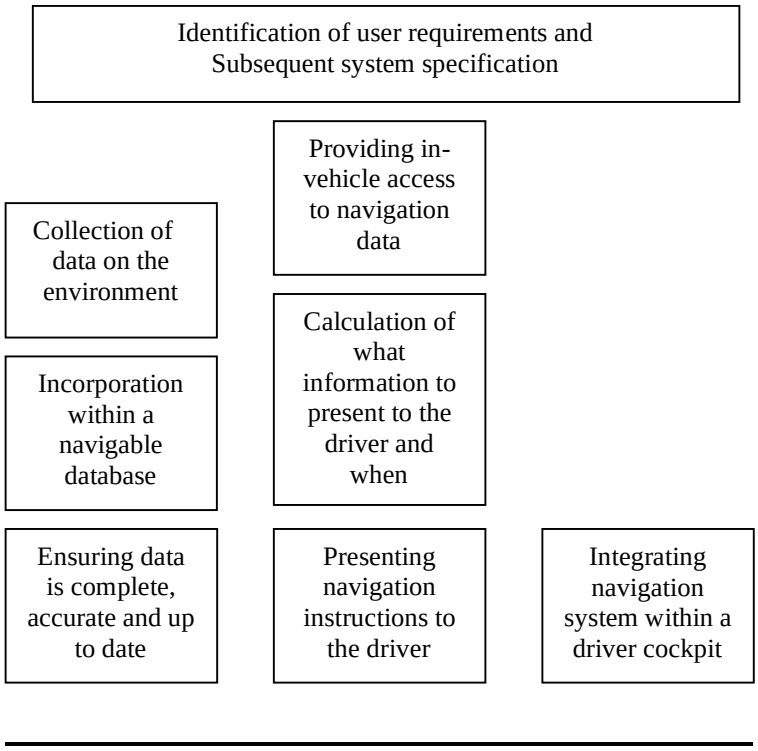

Figure 1. Responsibilities within the navigation systems development process.

Although Figure 1 outlines the responsibilities for each of the major stakeholders, there is considerable discussion between the different parties, in terms of functional requirements and system design. The design and development of a navigation system is driven by two main forces: (1) the availability and format of the data on the navigable database, and (2) the customer and market requirements as perceived by the automotive manufacturer. In other words, if the data is not there, it can't be presented by a navigation system, and if the customer requirements or market forces don't justify the collation and maintenance of data, this will not be included in a navigable database.

The key to the navigation systems working correctly is the ability to access current and complete data digitised on the navigable map. The map databases are comprised of links and nodes that describe the road geometry, and all data on the database is linked to this 'link-node' structure. A 'link' is the database representation of a linear part of the road netwrok. A node has a particular longitude and latitude. All database attributes (eg POIs) are located on a 'link'; no attributes are

associated with nodes. A POI at a junction would be located at the end of a 'link' rather than at a 'node'. Coordinates are not used to locate items on the database.

The navigable maps are initially developed from aerial photographs and OS geometry. Where possible, additional data is collected from third parties and then coded onto the database. For example, local authorities provide details of changes to the road infrastructure, and other information such as details of changes in traffic priorities. However, the extent of this data varies considerably: some local authorities are very cooperative, others less so. More detailed data (eg exact details of hotels and restaurants) are obtained or verified by contacting the establishments directly.

Typical data that is included on the navigable databases includes: all road geometry, traffic rules, road curvatures, bridges, tunnels, motorway signs, large out of town or town centre shopping areas, pubs if they have restaurants attached to them, most petrol stations (including supermarkets with associated petrol stations), POIs such as historic monuments, hotels and sporting venues and cartography,.

Data that is *currently* absent from the database includes: all gradient information ('world appears as flat') all road signs other than those on motorways, traffic lights, pubs (with no restaurant), other buildings such as post offices, and street furniture such as post boxes, bus stops and telephone boxes.

Field visits are undertaken by the navigable map database developers in order to verify the data. These field visits focus primarily on checking and updating the navigable aspects of the database, eg junction layouts, traffic systems, and are completed on a regular basis. Particular emphasis is placed on verifying and updating data on town centre routes. It is impracticable to regularly manually check every detail of every database item via a field visits.

The navigation system is developed on the basis of intense negotiation between the vehicle manufacturer, the systems supplier and the map database company. The functionality of the navigation system is a compromise between the ideal requirements of the vehicle manufacturer and the possibilities offered by the content and format of the data held on the map database. For specific items (eg vehicle dealerships), it is possible (but rare) for navigation system developers to include POIs that are not held on the map database. If this is done, the information needs to be collected separately and then coded as an addition to the underlying database structure.

The systems development process is a continuous one of trade-offs, based on a cost-benefit assessment. This is ultimately centred on the business case for offering enhanced functionality, or accessing additional information. It is a huge task by the map database company to collect, verify, code and maintain additional categories of information (eg to add all post boxes to the map database). New categories of information will not be included on the database unless there is a sound business case for doing so; this will take into account the other potential users of the map database information (eg commercial users of the information, and internet and mobile information access methods). Therefore the navigation system will be designed based on both its desired characteristics (from a marketing and competitive analysis perspective), and the constraints that are in place.

There are considerable barriers associated with the responsibilities shown in Figure 1. In particular, these problems relate to (1) data collation and maintenance, and (2) information presentation to the driver. These problems are described in more detail in the sections that follow.

3.2 Market Trends

In Europe, the first navigation systems (from the mid 1990s) were mainly the preserve of the company executive or the wealthy technophile, much as mobile telephones were in the late 1980's. Increasingly, they are offered as options on many new cars and as standard on the higher end vehicles but are still not a true mass market product. Other markets are more saturated, such as Japan with in excess of 3.5 million vehicles which already have route guidance systems installed (Rowell, 1999). It has been estimated that by the year 2005, more than 10 million navigation systems will be sold per year throughout Europe and North America (Rowell, 1999).

The current navigation market has the following features:

- Primarily road vehicles
- Primarily navigation data, some POI information (coverage depends on region), some integration of travel information (e.g. Volvo Dynaguide system).

- A pressure on database manufacturers to achieve 100% coverage with accurate and up-to-date data

Future trends for navigation systems are:

- a more diverse market, associated with cheaper systems in lower spec. vehicles
- increased commercial use
- commercial alliances to incorporate and supply 3rd party data (e.g. traffic information, specific POI categories)

The maturing navigation market will become increasingly demanding and successful companies will be those who can design in high quality (robustness, accuracy, completeness), improved functionality plus key features that will discriminate their products from others.

Current and near future technology can enable all these things. By and large, it is not technology that limits what navigation systems can do. The limiting factor is the resources that need to be expended for the desired enhancements to be achieved. Fundamentally, the business case must be proven for any major investment by the database companies. This is an important aspect for researchers to consider when defining any process for the inclusion of landmarks, hence the close industry consultation taking place in the REGIONAL project.

3.3 Technology Trends

Current navigation system technology

- is on-board (as opposed to off-board), CD-based and, generally, stand alone
- requires frequent software and database revisions which, due to current technology need to be done off-line (e.g. purchase of an updated CD)
- results in a disparity of data quality between countries
- is implemented with an HMI (Human-Machine Interface) which is limited to a colour LCD display (typically 5”), recorded speech output and manual input using dedicated keys (integral to the display or on a remote control)
- has (for some systems) limited integration with dynamic traffic information

Developments are in progress to change the current situation. Trends for the future are:

- use of DVDs for greater onboard storage capability
- incorporation of off-board data, allowing constant up-dating, close integration of static and dynamic information, and the possibility of pay-per-use.
- more standardisation of data formats
- an increasingly pan-European approach to data to ensure consistent high quality
- increased content and quality for databases
- increased positioning accuracy, with less reliance on map-matching and dead-reckoning
- the investigation of enhanced HMIs, e.g. HUDs, speech input, quality text-to-speech output
- more integration with external data, e.g. traffic information for dynamic re-routing
- integration with other on-board systems e.g. engine management, trip computer, hazard warnings
- non-automotive applications (e.g. hand-held devices for tourism information or navigation)

3.4 Customer feedback

To date, surveys of navigation system users, either after market or OEM, have been limited. Some companies have commissioned market research in the area, others have provided on-line feedback via websites or helpdesks. Of the feedback received from users, the majority relate to the coverage and accuracy of the database. Some database manufacturers provide a feedback form for reports of specific errors but these are not often returned. Very few comments are made on the HMI design and, of those, most are at a level too general to influence future products.

Currently, the European navigation market is in its infancy (with Germany being the most established). It is therefore not surprising that customer feedback is fairly limited and at a general

level. As the market becomes more mature and includes second, and third, generation users, customers are likely to become more demanding. Near 100% coverage and accuracy will be an expectation (which is likely to be achieved by the leading database providers) and it is the HMI that is likely to then come under scrutiny. Manufacturers (of databases, systems and vehicles) are therefore already looking at ways to improve the provision of information to the driver and develop discriminators that will sell their product.

3.5 Potential challenges to improved navigation systems

The barriers to making the improvements outlined above fall into two categories: those effected by the characteristics of the end users and those caused by the design and development process.

The challenge in designing navigation systems is that they are used by a diverse range of end-users (drivers are by definition a heterogeneous group). The functionality and HMI must allow for variations in age, experience with technology generally, experience with that specific system, and frequency of use. If functionality is to be increased, this shouldn't be accompanied by a decrease in system usability. A major challenge is ensuring that the core features of a navigation system are easily accessible, while the overall functionality increases. Additionally, the inclusion of more sophisticated data should not result in decreased reliability - user trust is very important to achieve in navigation systems. As more data is coded on the database, and used by the navigation system, the maintenance requirements for this data increase proportionately.

In relation to the design and development process, the technology per se is not normally a limiting factor in achieving a step-change in navigation system utility. It is the resources and procedures to source and maintain the data used by the technology that does have an influence. For example, adding more POIs and integrating real-time traffic information are two of the current challenges facing database providers. For the latter, the integration of the TMC codes is a challenge that has already been partly met. What remains is the bigger challenge of using the real-time traffic information within the navigation system software to enable dynamic re-routing. Having the resources to service existing clients whilst in parallel developing new initiatives can be problematic. As a result there has to be a very strong business case for the addition of new categories of data to the database. The push therefore has to come from customers, i.e. navigation system suppliers and/or vehicle manufacturers. Consequently the customers must first be convinced of the added value of the new data.

3.6 Potential challenges to landmark inclusion

The inclusion of landmarks is not a trivial addition to the development process for navigation systems. It would impact on database development, navigation system software and the HMI to the driver. Thus, the decision-based tool(s) developed by research in REGIONAL must be operationalised to allow any constraints to be taken into account and to minimise the effect of any potential barriers. In the discussion section below, ways of achieving this will be discussed.

Prior to the decision to spend resources on the inclusion of landmarks, it will be necessary to identify those which will have maximum 'benefit' in terms of the usability, safety and marketability of the final product. Identifying impact on usability and safety is the aim of the REGIONAL project under which these industry requirements were elicited. 'Marketability' can only be determined by each vendor, based on knowledge of their customers and direct competitors. Once the potential benefits have been confirmed and the decision can be made, from a human factors perspective, that certain categories of landmark should be included, the process of adding these to existing systems begins.

It is at the implementation stage that barriers to landmark inclusion may appear. These barriers may result in the decision not to include any landmarks (the likelihood of this is low once the benefits have been proven), or to include only certain categories. Another factor in the decision making is the time period over which landmarks will be incorporated (in database, navigation software and HMI).

3.6.1 Source data

The first potential barriers are related to the source data used by database providers. Often, centralised data does not exist and, if it does it is frequently paper-based. The coding required to transform the source data into a form that is compatible with the rest of the database can also vary. One of the main measures of database quality is the accuracy of the information held. Many

potential landmarks are not held in the source data in a form which ensures accuracy. In these cases often the only way to ensure the database is a true representation of the actual environment is to visit the site. This is obviously a time-consuming activity and is avoided wherever possible. Landmarks are more likely to be used if they can be described and located without the need to individually verify each one.

A related issue is the increased precision of information required for an object to be used as a landmark (cf. a POI). For example, railway stations are already included on POI databases and associated with a particular link. As a place to *go to*, current data on such POIs is of sufficient accuracy. For use as a landmark to navigate by (especially for pin-pointing a manoeuvre) the database would need to 'know' how visible the station was from each direction of travel and pinpoint the place along the link that drivers would perceive to be its actual location.

Once the data is digitised and contained within map databases, the next challenge is to keep it up-to-date (another measure of quality). Certain landmark categories, by their nature, change frequently (e.g. named shops), others are more permanent (e.g. bridges). Inevitably, database manufacturers will prefer the more stable landmarks, unless there is a reliable way of being informed of changes. Such situations may occur if someone has a vested interest in keeping the information up to date. One example will be where a company (fast food chain, petrol stations) pays to be included in the database for marketing reasons. Part of their in-house procedure is likely to be to inform the database manufacturers of any new closures, openings or other changes. Although this is an attractive option from the logistical point of view, it must always be balanced against the benefits (usability, safety, marketability) of including such landmarks. If currency of landmark information is difficult to guarantee then there can be implications for perceived quality of the database (from industry customers) and of the navigation product as a whole (from end users).

3.6.2 Navigation system software

The presence of landmark information on a database is only the first step to its use in the navigation task. The information must then be interpreted by the navigation software and subsequently presented to the driver. The extent of additional 'intelligence' required from the software will depend on how the landmarks will be used. Presenting landmarks on a map (in a similar way to POIs in many current systems) will require little additional programming (but would also add less value to the customer). Using the landmarks in a more sophisticated way is likely to require major upgrades. For example, if a landmark is to be used to maximum benefit when identifying a manoeuvre, it will be necessary for the software to identify the direction of travel of the vehicle, the next manoeuvre to be taken, the presence of a landmark, the appropriateness of the landmark for that manoeuvre, its position in relation to the junction and (if included in voice guidance) the preposition to be used (e.g. turn right *after* the petrol station). The REGIONAL tool aims to support some of these decision making steps but, nonetheless, maximising use of landmarks is not a trivial task. Also, it is important that any additional processing required does not result in slower route calculation and information presentation (timeliness being of the essence for the navigation task).

3.6.3 Human-Machine Interface (HMI)

Once the storing and processing of landmark information is complete, a crucial final step is to present the information to the driver in such a way as to enhance the navigation task. Further research in REGIONAL will provide guidelines for visual and/or auditory presentation so it is not yet possible to define the most appropriate HMI. However, results from industry suggest some potential problems that the guidelines should take into account. The provision of landmarks within the HMI can either be in addition, or as a replacement, to current information**.**

The majority of market systems provide voice instructions that include direction (left/right turn) and distance. Some also give information on type of junction (e.g. roundabout) and/or sign information (M69 to Leicester). Visual information varies widely from a simple direction arrow to detailed layout of the manoeuvre and surrounding roads. Often distance countdown is provided (by a reducing bar or digital countdown) plus current/next street name. Adding to this information could result in long voice messages and cluttered screens which would be detrimental to both usability and safety of the system. Replacing this information is likely to avoid the presentation of too much information but, from a marketing perspective, eliminating information which was on a previous model (or is present in a competitor product) may infer a reduction in system capability.

The HMI must also cope with inconsistent presentation of information e.g. where an appropriate landmark does or does not exist.

4 DISCUSSION

The results of the literature review and industry interviews generated useful data to help guide the output of the REGIONAL project. The most important issues are discussed in this section and it is these that will influence the final output of the project. In the concluding section of this deliverable, the plans for generating a REGIONAL tool(s) are discussed. In brief the intention is to first develop a theoretically-based tool, based on the optimum choice and presentation of landmarks to satisfy drivers' requirements for information. This will enable (from a theoretical perspective) the identification of the most appropriate landmarks. This tool will then be operationalised to fit within the product development process undertaken by the industry stakeholders. It is this second stage that will need to take account of the constraints within which the industry works and the enablers that will encourage the inclusion of landmarks.

In this section, these issues are presented according to the stage of development to which they relate: database production, programming of navigation system software or design of the HMI.

4.1 Implications for databases

The over-riding issue in database development is the balance of resources need against the benefit achieved, i.e. the business case. The decision whether or not to include landmarks will therefore be influenced by:

- the market for particular landmark information
- the format and accessibility of source data to populate the database
- the ease of maintenance once the data is obtained.

4.1.1 Market requirements

It is rare that demands from one particular customer (navigation supplier or vehicle manufacturer) will be enough for resources to be spent on inclusion of a specific category of data (e.g. the location of their dealerships). Database providers tend to produce one product for a particular market (e.g. Europe) which is then tailored to particular regions and is used by a wide range of customers. Any more specific tailoring will then need to be done by the customers themselves - not an easy task and one that is avoided. The obvious implication for the inclusion of landmarks is therefore that the more customers requiring that landmark information, and the more regions it is relevant to, the more likelihood of it being included. For example, landmark is more likely to be included if that object is also used as a POI.

In addition to providing software for vehicle navigation systems, database companies have other target technologies, e.g. tourist information software (PC-based, portable, kiosk or in-vehicle) and other in-vehicle applications. The latter includes advanced driver assistance systems (ADAS) such as adaptive cruise control, collision warning, lane recognition, adaptive headlight control, optimised engine control and fuel consumption. These systems can potentially use information held on a database (road curvature, bridges etc.) to predict the approaching road conditions to enhance the performance of the system. The IN-ARTE project (Wevers et al, 2000) has identified information that could be added to databases to support these systems in rural areas.

The work is being exploited further within the NextMAP project (Pandazis, 2000), which aims to 'define, prototype, and evaluate the content of digital map databases required for future in-vehicle ITS applications, in particular Advanced Driver Assistance Systems (ADAS)'. Using the same 'object' (e.g. a bridge) within a database for both navigational landmarks and ADAS will improve the business case for their inclusion.

4.1.2 Availability of source data

Once the decision has been made to include particular landmarks, the next task is to secure access to the raw data. Database manufacturers have established links with many data suppliers such as conventional mapping companies, local authorities, tourist guides, etc. The new landmark data may come from these existing suppliers but it is likely that new business relationships will also have to be set up. It is also possible that there will be no centralised data source for particular landmarks (e.g. monuments). The presence of usable sources will be a defining factor in landmark inclusion.

In addition, the attributes required to be associated with landmarks may differ from those currently used for similar data (e.g. POIs). For example, it is not necessary to know how close to the road edge a particular POI (e.g. hotel) is in order to provide directions *to it*. However, to use landmarks to *pinpoint* a particular manoeuvre, precision of location is important - in order that it may be related to a particular corner of a junction for example. As a further example, buildings used as POIs are currently located according to the building number. The method assumes equal spacing of buildings and allocates a location based on proportion along the link. This will be sufficient for landmarks used as 'progress' information (e.g. continue past the petrol station on the left) but not for pinpointing a manoeuvre (e.g. take the right turn directly opposite the petrol station).

The availability of data, and the specific attributes required for landmarks, are a challenge to the inclusion of landmarks and, although not insurmountable, it is likely to influence the types of landmarks to be included. If the source data doesn't exist or field visits are necessary to determine certain attributes then the effort required is likely to outweigh the business advantages for that particular landmark.

Features of objects that will *encourage* landmark inclusion are the following:

- they already exist on the road network database, although they may not currently be used (e.g. sharp bends)
- they already exist in the POIs on the database (e.g. petrol stations)
- they are easily accessible form a third party data provider (e.g. hotels)
- they are useful for several different functions (e.g. landmark, POI, tourist information, ADAS)
- the attributes necessary for their use as landmarks already exists in centralised information
- surrogate measures (i.e. not a field visit) can be used to determine the relevant measures. For example, traffic lights are, by their function, always located next to the road and always visible from some distance (if not, then a warning sign will alert drivers to their presence).

Satisfying only one of these features is not, however, likely to be sufficient. The landmark may exist as a POI but if the relevant attributes are not easily accessible then they cannot be used as landmarks.

A final issue associated with source data is the accuracy of that information. Accuracy is one of the priority goals of database providers and the inclusion of additional data always increases the risk of inaccuracies. The database provider will need to be sure that the initial data is as correct as possible with errors of *commission* likely to be more problematic than errors of *omission*.

4.1.3 Database maintenance

Obtaining source data is the first step to the inclusion of landmarks but, with currency being one of the main quality aims for database providers, *maintaining* the data is also a significant task. Adding more data increases the risk that information will not be current. This risk is heightened if there is not an identified 'owner' of the information. For example, the Highways Agency are responsible for changes to Motorways and trunk roads and this provides a route for updates to be provided. Some landmarks will have no centralised data or owner (e.g. public houses in the UK).

Therefore to encourage landmark inclusion, and reduce the difficulty of updating information, the following features will be important:

- the chosen landmarks will, by nature, have permanence (e.g. bridges, traffic lights) rather than undergo frequent changes (e.g. named shops). A related point on the use of generic or specific labels (e.g. 'petrol station' or 'BP petrol station') is discussed under the heading of 'HMI' later.
- the chosen landmarks, if subject to frequent change (acceptable frequency will need to be determined by the database provider), will have an owner that has a vested interest in making the database providers aware of changes.

The latter point suggests potential benefits from commercial alliances, e.g. a fast-food chain ensuring that the locations of their restaurants are always up-to-date as a marketing activity. The benefits of this currency must be balanced against the effectiveness of the particular class of landmark for the navigation task (and hence the benefit to the driver).

4.2 Implications for system software

The main implications for navigation system suppliers are the software changes needed to access the landmark data and the additional 'intelligence' needed to use the information appropriately. The information will then need to be displayed appropriately, the HMI issues are covered in the next section.

The development costs associated with software upgrades will need to be balanced against the likely benefit to the driver and the increase in marketability of the product to end users (i.e. vehicle manufacturers for OEM products, drivers themselves for after-market products). If these aspects could be quantified it would aid the decision making process.

The specific software requirements will vary depending on the landmarks available on the database and the level of intelligence the supplier wishes to incorporate. Some examples are:

- The system may need to employ a series of 'if - then' decisions to display landmarks in appropriate situations only. For example 'if the manoeuvre is a left turn, if it is from a major to minor road, if there is at least one other left turn within x metres, if there is a landmark available on either corner of the road or exactly opposite the turn, then use that landmark'.
- The system may need to take account of links that are not part of the current route if they have associated landmarks that are useful to a manoeuvre. For example, when turning right at a cross-roads, only two links are on the current route but there may be a landmark on the opposite corner (i.e. one of the other two links) which would be useful for identification.
- Similarly, 'off-board' systems (a possible future technology) which download 'strip maps' of the route may need to increase the envelope around the route to incorporate potentially useful landmarks.

Increasing the database information to be accessed and the intelligence to use it effectively may also have implications for the memory capacity and processing speed required. As these aspects of the technology can change rapidly, suppliers have to work with these constantly changing capabilities. This means not being constrained by today's technology when designing software to be used in systems in 5 – 10 years time. Similarly, customer requirements also change quickly, are often unpredictable and changes in system intelligence have to keep pace.

One trend for the future is for systems to be tailored to individual users. The significance of this for the software will vary according to the nature of the personalisation. Turning all landmark presentation on or off will be easier than choosing different landmarks depending on, for example, whether you want all pubs to be shown, or all supermarkets, or churches.

There are some situations where the benefit of landmarks will be reduced:

- If there is a *significant* increase in the accuracy of vehicle positioning then this will reduce the number of situations where landmarks are *essential* to help pinpoint a manoeuvre (i.e. because the system will be able to give an instruction such as 'take the *next* left' at an accurate point). However, landmarks are still likely to increase the confidence and trust in a system. It is also important to note that such a high level of accuracy is unlikely to exist in the near future because there are several components that influence accuracy (presence or absence of the GPS error coefficient, the quality of reception data, the precision of the map data and the map-matching capabilities of the system).
- Under certain circumstances, a landmark may be difficult to see, e.g. if it is unlit at night. Navigation system algorithms will need to take these kinds of factors into account when presenting landmarks to the driver.
- Instances where manoeuvres are currently problematic for navigation systems, e.g. identifying the correct roundabout exit, may be improved, but are unlikely to be resolved completely by the use of landmarks.

As with incorporating the landmark information on the database, providing a landmark feature poorly in the system may be worse than not doing it at all. The REGIONAL project output will therefore need to support the navigation system supplier in making appropriate decisions to ensure maximum benefit for the driver.

4.3 Implications for the HMI / the driver

The implications for HMI design affect two stakeholders: the manufacturer and the end user – the driver. The main issues relate to the presentation of landmark information and will be investigated in REGIONAL empirical work. They are important issues to tackle as they have implications for customer's perception of the product as well as for usability and safety.

Should the information be presented verbally, visually or both?

One of the main aims for those involved in navigation system design is to make the system information as naturalistic as possible. This would suggest the use of verbal messages as a priority. This mode is recommended in human factors guidelines as the main source of navigation information but it is usually advisable to support this with visual information which is more appropriate to the 'spatial' nature of the task, particularly for complex manoeuvres. It is also likely that displays will be present in the vehicle cockpit for the foreseeable future, as a result of the increase in driver information systems. For marketing reasons, any existing screen needs to be seen to be utilised and thus it is likely that navigation information will continue to be presented via this medium.

There are pros and cons to each method for presentation of landmarks. The human factors implications will be studied later in REGIONAL, but there are certain other issues that will need consideration. Currently, most navigation systems use recorded messages for voice instructions. The addition of landmarks in voice messages will necessitate further recording and increased data storage. This is particularly the case where specific (rather than generic) labels are used (eg Public Houses are referred to by name, rather than generically as 'Public House'). Text to speech conversions currently do not provide the accuracy that individually recorded labels do (see also below).

Visual presentation is likely to require the use of icons as opposed to text (due to restricted screen space and visual matching, and the need for the HMI to be language independent). To ensure clarity, a high screen resolution would be required. Also the icons must be intuitive, i.e. should not require learning. Ideally, internationally standardised icons should be used. For navigation systems, few conventions currently exist, although for some potential landmarks (e.g. petrol stations) ISO standards *do* exist. Although these could be used, care must be taken if they are used to display other information related to the vehicle (e.g. petrol low warning).

Should landmark information add to, or replace, that provided in current systems?

If landmark information *replaces* other information (e.g. distance to manoeuvre), there is a concern that second generation users (of own or competitor products) may see this as a reduction in quality (i.e. some information is now unavailable). Another issue is that, if landmark information is not available (or appropriate) at every manoeuvre, then the information may be perceived as inconsistent by users. If information is not presented because the navigation system decides it is not appropriate (eg a petrol station is present, but the system decides not to use it as a landmark because it is ambiguously sited), the driver may perceive this as a failure of the system (does not know about the petrol station).

If landmark information is *added* to the voice instruction there is the potential for long messages. If added to the visual display, it should not compromise the clarity of information (i.e. by adding clutter).

Should the information content vary according to the situation?

It is likely that the value of landmarks will be greater in some situations than others. For example, in a residential setting where there are several turnings close together on the left, a landmark will be the best method of identifying the particular manoeuvre to take. On well signposted trunk roads, it may be appropriate to use road sign information (e.g. road number and direction) as the primary source of information, with landmarks providing a secondary information source. Experimental work within REGIONAL should provide information to identify these different situations. The challenge is then for the HMI to provide appropriate information in varying scenarios whilst maintaining users' perception of a consistent interface.

Should a generic icon be used for each category of landmark or should each individual landmark have a specific representation?

This is likely to be very dependent on the landmark in question and the scenario in which it is located. For example all drivers will understand the ISO symbol used to indicate a fuel station.

Equally, many well-known companies, e.g. Shell in the UK, will have a logo that is easily recognisable. Newer or more obscure brands of fuel station are more likely to be recognised by drivers by their overall visual appearance (pumps, brightly coloured canopy, shop) than their logo. In a situation where two fuel stations are close together, use of specific logos would be of value. Where the fuel station is the only one for many miles, a generic icon would suffice. Other factors also affect the decision: brand name changes (quite frequent in the fuel industry) would cause reliability problems for specific logos; some systems already use brand logos, the use of a generic fuel icon (even if more appropriate for the driver) would be seen as a backward step and would not be looked on favourably by the marketing department.

Should generic terms be used in the voice instructions (e.g. 'petrol station') or do more specific terms have an advantage (e.g. 'Shell petrol station')?

Many of the issues are the same as those covered in the previous paragraph. An addition factor with voice instructions is the fact that the majority of navigation systems currently use recorded messages. Using specific terms would significantly increase the resources for this aspect of system development. The value added by such an investment would need to be seen to be very significant for it to occur. Text-to-speech systems are another alternative but currently they cannot cope satisfactorily with wide variations in pronunciation.

How reliable does the information need to be before it is acceptable to the driver?

Various types of information reliability are an issue here. Some examples are:

(1) the system presents a fuel station, but none are visible;

(2) the system has presented all previous fuel stations correctly but then omits to present one that actually exists;

(3) the system presents a Shell station which has recently changed to Texaco;

(4) the system presents a fuel station opposite a turning but in reality it is several metres away.

Future work in REGIONAL will help identify the types of unreliability that will have the most detrimental effect on the driver. Many of the potentially problematic effects could be overcome by careful design of the interface, e.g. to ensure that the driver is not solely dependent on the landmark information or to design the landmark information in such a way that errors will be minimised. From a driver's perspective, errors of commission (information which is presented incorrectly) are likely to be worse than errors of omission (information which is omitted). This is supported by the industrial stakeholders in the navigation system development process: if a feature cannot be incorporated with an expectation of near 100% reliability, it will be omitted.

4.4 The marketing perspective

As the main aim of most manufacturers is produce a product that equals or improves on that of competitors, the design of the HMI is a balance between human factors advice, the requirements of marketing and the constraints from engineering.

As well as the more specific questions above, manufacturers must consider the following:

- Can landmarks be presented by a universal method, reducing the need for systems to be adapted to each market?
- Is there sufficient drive from marketing – is it seen as a tangible enhancement?
- Does the particular HMI implementation of landmarks increase utility without making system use too complex?
- Does the addition of landmarks support the overall aim of making the navigation system more naturalistic, less stressful and does it increase drivers' trust and confidence in use?

5 CONCLUSIONS

5.1 Industry requirements for the inclusion of landmarks

The proven safety and acceptability benefits of incorporating landmarks in navigation systems are the motivation behind the work of the REGIONAL project. For the ideas and results of the work to be implemented in future systems the project output must recognise the motivations of industry and the information that will enable inclusion of landmarks. The most salient points are:

For database development

- For landmarks to be included, there must be a strong business case.
- Landmark information should have multiple potential uses, in addition to incorporation within a vehicle navigation system.
- The source data must be available, accessible, accurate and easily maintainable.
- Selection of landmarks should, as far as possible, not rely on field visits to verify there existence and location.
- Once obtained, landmark data should be easily maintained (to keep the information up-to-date), by (a) selecting landmarks which are unchanging or (b) selecting those where updates will be automatically notified.

For navigation system software

- Guidance must be given on the 'rules' for use of landmarks, whether these be generic (e.g. 'where a landmark exists on the database, use it') or specific (e.g. 'if there are more than 3 turnings within 100m, and the landmark is on the same side as the turnings and within 10m of the target turning, present the landmark').
- For each potential use scenario, the 'proof' is needed that any particular approach (set of rules) is the optimum.
- Landmarks must be considered within the context of a wider set of information that can be used by the driver, ie landmarks should be considered within the 'big picture'.

For the HMI

- The use and design of landmark information must enhance not reduce current customer perception of reliability, value and trust in the system.
- Guidance must be given on the implementation of landmarks within the HMI, e.g: Should the information add to or replace that currently provided? Should it be verbal, visual or both? Should icons/words be generic or specific? How can consistency of the HMI be maintained if different information is appropriate in different navigation scenarios?
- The use and design of landmark information should not constrain the internationalisation of products.

5.2 Desired output of the project

In order for landmarks to be successfully integrated within navigation systems, two main project outputs are required:

(1) A detailed theoretical understanding must be developed of a driver's requirements for landmarks to aid their vehicular navigation.

(2) Specific guidance (including tools and recommendations) are needed to provide the industrial stakeholders with the knowledge and processes to incorporate landmarks successfully within navigation systems.

From a theoretical perspective (addressing (1) above), the REGIONAL projects aims to understand:

- The role landmarks can play within the task of navigation.
- The role landmarks play as an information source (eg the extent to which they are primary or secondary items of information).

- The relationship between landmarks and the characteristics of the route (eg extent to which landmarks are used at or between manoeuvres).
- The generic characteristics (of landmarks and their use scenarios) which enable them to facilitate the navigation task.

From an industrial perspective (addressing (2) above), the project aims to produce:

- A regression equation to enable the selection of appropriate landmarks according to pre-defined attributes (i.e. **WHAT** to use)
- Rules for the situations in which landmarks should be used (i.e. **WHEN** to use it)
- Guidelines for appropriate HMI design (i.e. **HOW** to use it)

5.3 Future work

To achieve the aims of the project, the following combination of empirical work and industry consultation will be used:

- Direction giving studies will identify the landmarks valued by drivers for navigation.
- These landmarks will be studied to identify the attributes that led to them being chosen (e.g. visible, predictable form, located close to a turning).
- A regression equation will be developed based on (i) quantifying the value of each landmark to the drivers in the study and (ii) rating each landmark on the attributes identified.
- This regression equation will enable any *individual* object in the road scene to be assessed according to its value for navigation. *Categories* of landmark can also be assessed by estimating the likely rating for an object in that category (for example, the intrinsic design and use of fuel stations means that they will be visible day and night, have a recognisable form and be close to the side of the road to be visible to drivers).
- The regression equation will be validated by on-road studies to determine whether the landmarks rated as having high value actually improve driver safety, navigation performance and system acceptability.
- The theoretical model (regression equation) will be operationalised in consultation with industrial partners to take account of particular requirements and constraints.
- Ongoing empirical studies will investigate: the situations in which landmarks are most valuable; the rules (scenarios) that should apply to their use within a navigation systems; the reliability of information that must be achieved and the HMI design (visual/verbal) that will ensure maximum value is obtained from use of landmarks.

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