Using landmarks to enhance navigation systems: driver requirements and industrial constraints

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Additional Information:

- This is a conference paper presented at the 8th World Congress on Intelligent Transport Systems, 2001.

Metadata Record: [https://dspace.lboro.ac.uk/2134/850](https://dspace.lboro.ac.uk/2134/850)

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INTRODUCTION

The task of navigating in unfamiliar road environments is a common and demanding cognitive activity for drivers. Research has long demonstrated the problems that drivers have in planning and following efficient routes to destinations. 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).

The usability of navigation systems is of paramount importance: they must be designed from a driver-centred perspective. The usability of a system refers to the “quality of interaction between a user and other parts of the system overall”. Usability has been acknowledged as one of the most important aspects of navigation system design by several authors and has major implications for what information is presented to the driver by navigation systems, when, and in what format.

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. A key characteristic of more naturalistic navigation instructions is the inclusion of landmarks as navigation aids. When a passenger or someone with local knowledge 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 right after the petrol station, go straight over the traffic lights and keep going past the train station….’

As well as anecdotal evidence, there are compelling research arguments that the inclusion of landmarks would aid the task of navigating in an unfamiliar area with a navigation system:

1. Basic human navigation strategies employ landmarks:
   - They form key elements within cognitive maps of the environment, aid the learning of the environment, and are used in way-finding strategies.
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. This finding is confirmed by other studies.

3. The usability of navigation systems (defined as a function of effectiveness, efficiency and satisfaction, ISO 9241 - part 11, 1998) can be enhanced by including landmarks: They can improve the proportion of correct navigation decisions. They can (in comparison to a display that emphasises distance rather than landmarks to locate a manoeuvre) reduce the mean number of glances to a display and result in lower perceived workload, and can increase confidence of the location of turnings and satisfaction with the information presentation. Strong preferences have been shown in simulator trials for vehicle navigation interfaces that included landmarks, and this impacted on driver preference to an even greater extent than the modality (auditory vs. visual) of the HMI.

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. See for a review.

This paper addresses both the driver and industrial issues that must be tackled to enable inclusion of landmarks within navigation systems. Driver-centred issues are presented first, including the results of an empirical study to help identify the driver requirements for landmarks as a source of navigation information. The paper then discusses the industrial constraints and key barriers to the inclusion of landmarks within navigation systems. In conclusion, the implications for future navigation system development are discussed.

DRIVER REQUIREMENTS FOR LANDMARK INFORMATION

If landmarks have the potential for enhancing navigation systems, it is necessary to understand what constitutes a ‘good’ landmark, and the factors that determine this.

There are recommendations in the human factors literature regarding good ‘classes’ of landmark: traffic lights, petrol stations and bridges have been found by several studies to have potential for navigation (see ). However, such guidance is not, in itself, sufficient to enable landmarks to be incorporated successfully within navigation systems, as these results are very specific to the study carried out, in terms of subjects, country, driving environment etc. What is needed is a more predictive method that takes into account all of the factors that determine the ‘quality’ of the landmark. For example, although traffic lights may be a good generic class of landmark, in particular instances, where several sets occur close together, they may actually be very poor.

There are multiple factors that contribute to a landmark either being ‘good’ or ‘poor’ from a human factors perspective. These include the following:

(A) The landmark itself (eg. its visibility; whether it can be easily and unambiguously described). (B) The general siting of the landmark (eg. the extent of visual clutter of the background). (C) The exact location of the landmark (eg. proximity to a turning). (D) The existence of other objects (eg. whether other similar objects are nearby that may be confused
with the intended landmark). (E) The existence of other information sources (eg. whether there is any other information source that can be used in preference to the landmark). (F) The driver characteristics (eg. the familiarity that a driver has with that particular landmark). (G) The environment (eg. whether it is night or day; foggy or clear).

The actual driver’s information requirements at that point in time are also important, and the presentation of landmarks must take this into account. A driver may require information to preview a manoeuvre, or help identify the exact position of a manoeuvre, or to confirm that they have just completed the correct manoeuvre, or to provide confidence that the navigation system is working correctly.

The use of other information sources for navigation purposes also needs to be taken into account, in particular whether the landmark is being used as a primary or secondary (redundant) source of information.

CHARACTERISTICS OF ‘GOOD’ LANDMARKS

A study was undertaken to investigate the use of landmarks within an urban driving and navigating scenario. The main aims of the study were to determine:

1. The set of landmarks actually used within a particular navigation scenario.
2. The means by which each landmark was actually described.
3. The extent to which they were used as the main or as a secondary information source.
4. The role the landmarks (as information sources) had within the task of navigating.
5. Whether they were used at manoeuvres or between manoeuvres.
6. The generic characteristics of landmarks which determine (within particular contexts) whether they are good or poor.

Space precludes a detailed description of the methodology; instead a summary, plus the most interesting results are presented here. In addition, the study is being replicated in a different driving environment and a statistical model developed of the attributes that determine the ‘quality’ of a landmark in a given context; the results will be reported at a later date.

The study reported here involved 32 experienced drivers (male and female, ages 22-60) providing written directions based on either (1) studying a video of a predefined route, or (2) their long term memory (cognitive map) of the route plus minimalistic schematics that provided just enough road layout information to indicate the desired route. The former group had no prior experience of the routes; the latter group had all lived in and/or worked in the test area for at least five years and had detailed local knowledge.

Care was taken not to bias the participants towards using landmarks: the study was described in terms of a ‘direction giving’ study, and no mention of landmarks was made until after the direction-giving exercise.

Two key assumptions underpinned the methodology: (1) that the landmarks that were actually used by subjects in their directions were those that were valued for navigation; (2) that landmarks that were used by both the cognitive map and the video participants were better than those that were used by only one group. (This second point makes practical sense, since it can be argued that the best landmarks are those that are easily visible and those that are easily remembered).
DATA ANALYSIS

Several aims of the data analysis related to how the landmarks were used within the route scenarios, to identify the implications in terms of navigation system design (ie. points 3-5 above). This is the focus here.

A detailed description of the route was developed, including all potential landmarks and manoeuvres that a driver would be required to make. Each potential landmark and manoeuvre were assigned a unique identifier, for example the route contained 12 traffic lights, and these were identified as TL1 to TL12. There were 25 manoeuvres, these were identified as MA to MY. A manoeuvre was defined as a point where there is a potential navigation manoeuvre, [excluding where there is just one right of way AND the driver is following that right of way]. In practical terms, this relates to where a driver would normally expect some navigation instruction because there would be doubt as to their next action. The issue of what constitutes a landmark is potentially problematic; after much discussion and analysis of the literature, the definition of a landmark included buildings, street furniture and built aspects of the environment (eg. bridges), but excluded geographical features such as hills and bends in the road, and also street signs. Navigation systems already (and increasingly will) make use of some of this information, and the relationship between this and landmarks as defined above will be investigated within the project.

The next step was to identify each instance of a landmark being used by the participants as an information item within the direction-giving study. For each participant, each occurrence of a landmark was coded according to the following 3 criteria:

Factor 1: Route - Whether it was used at a ‘manoeuvre’ OR for ‘progress’ between manoeuvres.

Factor 2: Navigation model - Whether it was used to ‘preview’ a manoeuvre (eg. provide lane positioning guidance) OR ‘identify’ and locate a manoeuvre OR to ‘confirm’ that a manoeuvre has been correctly completed OR to provide the driver with confidence that they are on the correct route (‘trust’).

Factor 3: Information value – Whether it was used to provide ‘primary’ or ‘secondary’ information to the driver.

Primary information was defined as that information essential to the driver to complete the manoeuvre (ie. the driver would be unable to perform the manoeuvre if that information was absent). An example would be:

‘Turn left after Sainsbury Supermarket.’

Secondary information was defined as that which is supporting or redundant information ie. the driver would still be able to complete the required manoeuvre, but would be less confident that it was the correct action. An example would be:

‘Take the next left, opposite the Petrol Station.’

For all three factors above, it was recognised that there was a degree of subjective judgement involved in coding, however the actual coding of the data proved relatively straight forward.

SELECTED RESULTS

Space precludes detailed presentation of results; a summary is provided. The interested reader is welcome to contact the first author for more details.
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<th>Rank</th>
<th>Description</th>
<th>Video (n = 16)</th>
<th>Map (n = 16)</th>
<th>Total (n = 32)</th>
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</thead>
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<td>Traffic Lights</td>
<td>118</td>
<td>112</td>
<td>230</td>
</tr>
<tr>
<td>2</td>
<td>Petrol Stations</td>
<td>52</td>
<td>17</td>
<td>69</td>
</tr>
<tr>
<td>3</td>
<td>Pedestrian Lights</td>
<td>48</td>
<td>19</td>
<td>67</td>
</tr>
<tr>
<td>4</td>
<td>Shops/Supermarkets</td>
<td>27</td>
<td>36</td>
<td>63</td>
</tr>
<tr>
<td>5</td>
<td>Churches</td>
<td>33</td>
<td>15</td>
<td>48</td>
</tr>
</tbody>
</table>

Table 1. The top five landmarks, by frequency of use

**Figure 1.** Actual, and maximum possible, frequency of use

**Figure 2.** The use of landmarks at or between manoeuvres
Differences In The Navigation Model

Figure 3. The use of landmarks within the navigation task

Primary VS Secondary Information

Figure 4. The use of landmarks as primary or secondary information

Note For figures 1 to 4 above (showing the 10 most frequently used landmarks), the landmarks are coded according to:

Bridge (BRI), Church (CH), Car Park (CP), Garage (GAR), MacDonalds (MAC), Pedestrian Lights (PL), Post Office (PO), Petrol Station (PS), Public House (PUB), Sainsburys Supermarket (SA). (MacDonalds and Sainsburys Supermarket were coded as separate items due to the frequency of their use, and the non-use of other similar objects).

DISCUSSION

The results presented above have direct implications for the incorporation of landmarks within navigation systems.

Table 1 and Figure 1 demonstrate the relatively high usage of landmarks within the direction-giving task. All of the top 5 landmark categories were, on average, used at least once by each subject. Traffic lights were far the most frequently used, being used on an
average of 7 occasions by each subject to help describe the route. This suggests that landmarks do indeed have potential for aiding the navigation task, since they are seen as an important source of information for aiding navigation around an unfamiliar route.

Figures 2 and 3 show that landmarks are used both at manoeuvres and between manoeuvres, ie. to identify a potential manoeuvre and also to provide confirmation that the driver is on the right route. To a lesser extent, landmarks are also used to provide preview information (eg. to identify correct lane positioning for a forthcoming manoeuvre) but rarely to confirm to the driver that they have taken the correct route (eg. ‘after you turn left you will pass the Post Office’).

Figure 4 shows that in the vast majority of cases, landmarks were used to provide primary information, ie. that if that landmark information was not presented to the driver, the driver would be unable to complete the turning. This also demonstrates the relative importance of landmarks as information items for navigation, and provides strong evidence for the inclusions of landmarks within navigation systems.

As well as a frequency count of each landmark category in each condition, Figure 1 shows how many of each particular landmark were potentially available ie. the total if all participants in either the video or cognitive map condition had used each occurrence of that landmark. For example, the route contained 20 public houses, so the maximum usage of that landmark by either the video or cognitive map group could have been 320 (16 participants x 20 occurrences). Figure 1 highlights the popularity of traffic lights, but also shows that a high proportion of the traffic lights that were available were actually used as information items. This is in contrast with garages (GAR) and pubs (PUB). Each of these categories had a potentially higher number of instances that could have been used to aid navigation, but the actual use was relatively low. For example with pubs, they were only used a total of 20 times out of a potential of 320. In contrast Sainsburys Supermarket (appearing once only on the route and coded separately as SA) was used by all of the participants.

A high proportion of petrol stations (PS) were used by the participants in the video condition, but much less by the cognitive map (long term memory) group. This is due to the visual characteristics of petrol stations being very strong (large, bright, easily visible), in comparison to the local subjects’ cognitive recall of them (you will often use just one petrol station, are unlikely to recall all occurrences of them within an area and may by unsure of their precise location in relation to manoeuvres). In comparison, a higher proportion of the cognitive map group used Post Offices than did the video group. This indicates that the cognitive recall characteristics of Post Offices are stronger than the visual characteristics: they are buildings you may frequent, but will often not be particularly visible (in particular, Sub Post Offices may appear as newsagents).

A further analysis (not reported here for space reasons) also investigated the use of each landmark within a category (eg. for Traffic Lights (TL1-12), how many times TL1, TL2 etc were used by the video and cognitive map participants). Figure 1, plus this extra analysis demonstrates considerable variability between different landmarks, in terms of:

(1) the proportion of that landmark category used (out of the total number available);
(2) the extent to which the landmark is used by either the video or cognitive participants;
(3) The variability within a class of landmarks (eg. there was consistent use of Traffic Lights (TL) - TL1, TL2, TL3, were all used, but inconsistent use of Post Offices (PO) – PO4 was used frequently, PO1 and PO3 less so, and PO4 and PO5 not used at all).

This variability has important implications for not only deciding which categories of
landmarks are used, but also whether all instances of that landmark should be used, or it be
decided on a case by case basis. For example the results suggest that, in terms of general
categories Traffic Lights would be good landmarks (frequently used and consistent), whereas
Post Offices are less good (some are frequently used, but others not used at all).

These results need to be interpreted with some care, since in many cases the use of the
landmark will depend on the siting of the landmark as well as the type of landmark that it is.
For example, Traffic Lights are necessarily sited at manoeuvres, and hence are used as
information items at these manoeuvres, while pedestrian lights (which in the UK have
identical visual characteristics) are sited between manoeuvres and are used to confirm that the
driver is on the correct route.

SUMMARY OF DESIGN IMPLICATIONS
The above results, although tentative at this stage, do have several implications for actually
incorporating landmark information within navigation systems:

• Landmarks have considerable potential to enhance navigation systems.
• As landmarks are important (and may be primary) information sources, they should be
incorporated within an auditory instruction.
• Landmarks should be used at manoeuvres to help locate that manoeuvre.
• Landmarks should be used between manoeuvres to confirm that the driver is on the correct
route, and to develop trust in the system working correctly (eg. ).
• Landmarks can also be used to provide preview information in certain situations, eg.
indicate where lane changes are needed preceding junctions.
• Some landmarks (eg. traffic lights) may be used as a generic set, others would have to be
used on a case-by-case basis.

INDUSTRY REQUIREMENTS
In addition to determining the driver requirements for landmarks to enhance navigation
systems, it is also necessary to understand the industry perspective in terms of actually
incorporating landmarks within navigation systems. The key processes and barriers must be
understood in order to provide human factors recommendations that can be incorporated
within current and future systems development processes. The detailed results of this exercise
are reported in ; below is a summary.

Detailed interviews were carried out with a range of personnel from vehicle manufacturers,
navigation system suppliers, navigable map database developers, and motoring organisations
(who are third party map database users). Interviews were tailored as necessary, but covered
the following topics:

• 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 incorporating landmarks within navigation
systems.

- 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.

Interviews were recorded and transcribed. A summary of results is presented below, taking into account the fact that some of the information was commercially sensitive.

STAKEHOLDERS
The key industrial stakeholders are threefold:

1. **The navigable map database company** develops, maintains and supplies a map database that includes geographical, topological, navigable and ‘points of interest’ (POI) data. This database is used by a navigation system to help determine the current location of the vehicle, and enable the calculation of the most appropriate route to a destination.

2. **The navigation system supplier** develops and supplies the navigation system, which may be an OEM fit or an aftermarket solution. In its most basic form, the navigation system will require the driver to enter a destination, will determine the current position of the vehicle and will then calculate a navigable route to the destination. Most systems will then provide ‘turn by turn’ instructions to the driver, via the presentation of symbols on a visual display, and simultaneous voice output. Other features are common, for example, multistage information presentation, distance countdown indicators, and map overviews of the journey and/or the manoeuvre.

3. **The vehicle manufacture** will supply a navigation system either as standard equipment or as an option. There will be close cooperation between a vehicle supplier and a system developer: a development team will often comprise engineers from both companies.

MARKET TRENDS
In Europe, navigation systems are increasingly being offered as options on low-cost vehicles, and are increasingly becoming mass-market products. In the Japanese market, in excess of 3.5 million vehicles already have route guidance systems installed. 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.

As a consequence, the following trends are occurring:

1. A more diverse user group; (2) incorporation into a wider range of vehicles; (3) increased commercial use; (4) wider range of commercial alliances to incorporate and supply third party data; and (5) a greater expectation of reliability, accuracy and enhanced functionality.

TECHNOLOGY TRENDS
Systems continue to be more responsive, more accurate, more reliable and also to provide more features. Specifically, systems are likely to:
(1) Use DVDs for greater onboard storage; (2) incorporate off-board and onboard data integration; (3) utilise more standardised data formats; (4) employ a pan-market (eg. one system for the European market) approach; (5) provide increased content and quality for databases, and greater positioning accuracy; (6) have enhanced HMIs, with more naturalistic dialogues; (7) be increasingly integrated, both with other in-vehicle systems, and also with mobile devices.

POTENTIAL BARRIERS

There are many potential barriers to enhancing navigation systems via the use of landmarks. A more detailed discussion of these is contained in . In basic terms, these barriers are due to (1) cost and resource issues, and/or (2) lack of knowledge.

The main cost and resource barriers are encountered by the navigable map database companies. They must identify, collate, code and maintain data on all information which appears on their navigable databases. This will include all landmark information. The data that identifies what landmarks exist and where landmarks are located, exists initially in a wide range of sources and formats. For example, local authorities may or may not hold up-to-date information on the location of street furniture such as traffic lights. Field visits are undertaken by navigable map database companies to verify information, but it is impracticable to check manually every single detail. As the amount of potential information on a navigable database increases, so does the effort to collate this data.

Equally important is the issue of data maintenance. Navigable maps must be kept current; this is a task requiring huge resources. Where information quality is likely to degrade rapidly (eg. restaurants that change name frequently), the inclusion of this type of information on a navigable database requires increasing resources from a map database company. Where landmark information is used for navigation purposes (as opposed to being a POI), it is vital that this information is current.

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 (the part of a road between nodes). 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 specific manoeuvre) the database would need to ‘know’ how visible the station was from each direction of travel and pinpoint, to within a few meters, the place along the link that drivers would perceive to be its actual location.

Although the greatest potential barriers probably lie with the map database providers, potential technological problems are also faced by the navigation system suppliers. For landmarks to actually add value to a navigation system, they must be used ‘intelligently’ ie. presented to the driver when, and only when, they aid the navigation task. The performance of the driver, including driving safety, will be impaired if information is presented to the driver which is inappropriate, ie. inaccurate, misleading or overloading. The navigation system therefore needs to know enough about the context of the situation to prevent this. A navigation system will need access to the relevant factors (road, route, traffic, environment, driver), and then operate on these factors, in order to determine whether a landmark should be presented in a particular instance, and if there are several potential landmarks that could be presented, which one (or more) to actually use.

This access to greater information, and adaptive decision making capability will require navigation systems with greater processing capabilities and an enhanced rule-base to present
information as required. Future work within the REGIONAL project will make a contribution to this rule-base.

A key potential barrier is that of being able to actually present the information to the driver in such a way that it maximises their ability to use it, minimises any additional demands on the driver that may affect safety, and also maintains or creates driver acceptance. In terms of human factors design of the HMI, the main industrial drivers are to try to reduce the reliance on the visual display. In some respects this is contrary to the trends for larger and higher resolution colour displays, however the key point here is whether the driver is reliant on the display for information provision.

In terms of the HMI, there are several unresolved issues:

(1) The extent to which landmarks should supplement or replace distance-to-turn information.
(2) The use of visual or auditory presentation of landmark information (or both).
(3) The requirements for information reliability, and the effect on safety and acceptability.
(4) The need for consistency of information presentation, as opposed to more naturalistic, adaptable dialogues which vary according to the situation.
(5) The integration of landmark information with other system outputs (particularly in the case of auditory output).
(6) The tailoring of landmark information to the driver (eg. the use of different categories of landmarks according to the social characteristics of the driver).
(7) The optimum descriptors for each landmark (eg. whether generic ‘Petrol Station’ or specific ‘Shell Petrol Station’ labels are used for categories of landmarks), and the design of visual icons.

From an industrial perspective, there are therefore resource-related barriers, but also those that arise from a lack of knowledge. In many cases, the research results do not exist, and hence navigation system HMI designers do not know how that aspect of navigation system development should be undertaken. It is hoped that future work will address some of the issues above.

CONCLUSIONS

Landmarks appear to have considerable potential for enhancing navigation systems – they should aid navigation (ie. make it easier to reach a destination), increase confidence in a system, promote system acceptability and even engender a hedonic response (make it fun). From a human factors perspective, there are many requirements that must be satisfied. In particular it is necessary to identify the characteristics that define a ‘good’ landmark, and determine how landmark information should best be presented to the driver, given a range of potential usage scenarios. There is currently insufficient human factors knowledge concerning which landmarks should be presented according to an particular set of circumstances, when these should be presented, and how. There is also a need for more research demonstrating under which circumstances, landmarks actually enhance navigation systems.

From an industry perspective, the over-riding requirement is that there must be a clear business case for including landmarks within navigation systems. Although there are some
considerable technological challenges, the major issue is that of the extra resources (effort, time and cost) that are needed to include landmarks within navigation systems. For the navigable map database company, the greatest potential barrier is the effort required to locate potential landmarks on a navigable database, and maintain this data; for the systems supplier, it is knowing which landmark to present in any given scenario; for the vehicle manufacturer (and system supplier), it is knowing how to present landmark information to the driver, and how to integrate this within the navigation instruction (and other information provided to the driver).

In the short term, the human factors requirements and industrial constraints (together with a lack of detailed HF guidance) will mean that the incorporation of landmarks is likely to consist of the inclusion of categories of landmarks (eg. traffic lights) within generic usage scenarios. In the longer term, it is possible that systems will be more adaptive, and will be able to present landmarks on a case-by case basis in a more naturalistic manner.

A cost-benefit assessment must be undertaken to assess the potential benefits of providing landmarks to drivers and the business benefit, and to weigh this up against the resources needed to develop and maintain this capability. Landmarks must be seen as adding value to a navigation system, ie. increasing their quality and making them easier to use. This will be particularly important as they become used by a larger and more diverse user base, and by second or third generation users who will have higher expectations of functionality and ease of use.

ACKNOWLEDGEMENT

This paper is based, in part, on work undertaken within the REGIONAL project, funded by the EPSRC under the UK LINK Inland Surface Transport Programme and led by the HUSAT Research Institute at Loughborough University. The authors also wish to thank the other members of the project consortium (Jaguar Cars Ltd, Alpine Electronics of UK Ltd, Navigation Technologies, RAC Motoring Services and the Motor Industry Research Association) for their valuable input, and also to acknowledge the contribution of Darren Smith to data collection.

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