Route guidance systems: optimal navigation via the use of landmarks

Design Advice for the Inclusion of Landmarks in Vehicle Navigation Systems

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1 DESIGN ADVICE FOR THE INCLUSION OF LANDMARKS

The following advice has been developed from results of research studies carried out over the course of the REGIONAL project (1999-2002). These results, and the studies that produced them, are described in more detail in section 2 of this document. It also takes into account limited findings in the existing literature relating to the use of landmarks within navigation systems. The aim of REGIONAL was to support the inclusion of landmarks within navigation instructions by generating advice on:

- What landmarks to *choose* and incorporate in databases
- How to *use* them appropriately during the navigation task
- The factors to take into account when *presenting* landmarks within systems

The design advice covers these three areas.

1.1 Selecting valuable landmarks

When comparing the relative benefits of 'good' ($V > 50$), 'poor' ($V \leq 50$) and no landmarks, the following predictions can be made. [NOTE: V = landmark value as calculated by the equation in section 1.1.2). The predictions are based on observed behaviour where the navigation task was to make a correct minor turn off a major road.

Incorporating 'good' landmarks within verbal navigation instructions should (when compared with both 'poor' landmarks or no landmarks):

- Increase driver confidence *at* the manoeuvre (i.e. within 50yds)
- Reduce navigation errors
- Reduce driving errors

Incorporating *any* landmarks within verbal navigation instructions, whether they be 'good' *or* 'poor', should (when compared with no landmarks):

- Reduce the number of glances to and total time looking at the visual display

Good landmarks are unlikely to have a significant impact (when compared with no landmarks) on:

- Total approach confidence
- Confidence at the 2 preview navigation instructions (approximately 500 and 200yds prior to the manoeuvre.

However, both good and no landmarks should produce a more positive response than poor landmarks.

1.1.1 Rules of thumb

A landmark should increase driver confidence when identifying the precise location of a manoeuvre if it meets some or all of the following criteria. The more criteria it meets, the more valuable it is likely to be.

Easy to see, i.e. the object itself and/or the sign associated with it is:

- Brightly coloured or lit
- Attention grabbing (e.g. moving, flashing lights or animated)
- Large
- Have a unique shape, profile or colour (the object can be identified without seeing the detail)

Easy to spot/find, i.e. the object is:

- close to the roadside
- not set back in relation to other buildings
- in a typical location for that object
- central to the driver's vertical (up or down) line of site (taking into account where they would be looking whilst approaching /undertaking a manoeuvre)
- central is to the driver's horizontal (left or right) line of site (taking into account where they would be looking whilst approaching /undertaking a manoeuvre)
- visible from a distance

Has pre-warning of its existence, i.e. there is

- explicit preview information (e.g. for traffic lights, there may be a warning sign indicating traffic lights ahead, for a museum, a tourist sign may indicate its location)
- implicit information is there to suggest that the object might be coming up (e.g. entering a village may suggest a pub or church will be present; the flow of a river may indicate where a bridge is likely to be)

Easy to pick out from its surroundings, i.e. there is:

- Little/no visual clutter next to or behind the object
- Little/no visual clutter in front of the object

Is an object that a driver interacts with as part of driving, i.e. the object (and/or sign):

- Is used for planning (strategic) aspects of a journey (e.g. a driver may use objects such as signs, car parks and petrol stations to help them decide on routes, where they might stop on-route, where to park etc)
- Impacts on the physical driving (control) task (e.g. a driver will physically react to objects such as traffic lights, lane markings, give way signs, bends etc)

Ideally located for the task, i.e. the object is:

- Close, laterally, to the point where the driver would start to make a turn
- Close, longitudinally, to the manoeuvre (note: usefulness of an object decreases rapidly with distance after a manoeuvre, and decreases at a lesser rate with distance before a manoeuvre
- Spread over a large distance (ideal for 'progress') *or* precisely located (ideal for manoeuvres)

Other criteria that may also contribute to landmark value (but have not been shown empirically to do so) are the following:

Familiar to drivers, i.e. the object (and/or sign) is

- Stereotypical and easily identified (by drivers in that country)

Easy to name, i.e. the object (and/or sign):

- Would only be given one (or two) names if all drivers in that country were asked to name it

Different to surrounding objects, i.e. the object (and/or sign) is

- Unlike any others nearby

In practical terms (i.e. to justify inclusion in a navigable database) landmarks must also be as ***permanent*** as possible, however this is an issue of database reliability *over time* rather than navigation value at any *point in time*.

1.1.2 Equation

In addition to the 'rules of thumb' criteria above, the project attempted to *quantify* landmark value by developing an equation that incorporated those criteria that seemed to most influence the potential value of a landmark (and hence would improve driver behaviour). The following equation is the result of this work:

V = (0.134) VISCAR + (0.255) USEOFLOC + (0.340) DEGOFINT

Where:

V	=	Landmark value (minimum 0, maximum 100)
VISCAR	=	Visual Characteristics (0-100) i.e. ease of seeing the object (and/or sign)
USEOFLOC	=	Usefulness of Location (0-100) i.e. how ideally located the object is for the navigation task it supports
DEGOFINT	=	Degree of Interaction (0-100) i.e. to what extent the driver already interacts with the object as part of driving

(See Appendix 1 for the detail of the rating scales)

Incorporating landmarks with a value (V) above 40 should improve ***driver confidence*** in the system. Increasing V should increase confidence in a linear fashion.

1.2 Some potential landmark categories to include in database

The ideal approach (from the perspective of fully supporting the driver) is to use the equation and or the criteria identified above to decide whether a particular landmark at a particular junction is of enough value to justify use. However, this could only be achieved in the long term with truly context aware navigation systems. A more realistic approach in the short term is to use the criteria to identify *generic categories* of landmark that are of *potential* use. From the criteria above and from studies carried out in the U.K., Sweden and the U.S., several categories have proved of value to the navigation task in an urban environment. These are:

- Traffic lights*
- Petrol Stations*
- Well known, large supermarkets/shops
- Well known, large restaurants/fast-food chains
- Bridges

*From the perspective of resources, inclusion of the first three listed categories should be cost effective (2 studies have shown that where they exist near a manoeuvre, they are almost universally used). They may also be of value to other in-car applications (e.g. stop and go, find my nearest).

1.3 Reliability of naming

Landmarks are likely to be presented using both generic (traffic lights) and specific (MacDonald's™) terminology and/or logos (for a discussion of this see 1.8). Where specific names *are* used in landmark representations, the issue of name changes arises. If it is assumed that a database of landmarks will never be 100% accurate, then it is important to consider what features will mitigate any errors in naming of the landmark. For landmark categories that will have an associated name (e.g. a petrol stations, shops or restaurants) errors of naming will always have some effect on driver confidence (both at that instance and for subsequent manoeuvres), but this can be mitigated if the named landmarks meet the following criteria:

- Easy to see
- Easy to spot/find
- Has pre-warning of its existence
- Easy to pick out from its surroundings
- Is an object that a driver interacts with as part of driving
- Is very different in appearance from other objects nearby

1.4 Combining with other navigation information

Across all manoeuvres within a route, landmarks cannot always be used in isolation. They should be used in combination with the following information elements (according to context, see below):

- Junction descriptions (e.g. 'T-junction', 'roundabout')
- Directions signs (e.g. "follow A6 to Leicester")
- Lane information (e.g. "use the right hand lane")
- Street names/numbers

(NOTE: Distance has not been identified as a 'natural' component of direction-giving although it is the information most current systems rely on to indicate the exact location of the manoeuvre.)

It would not be appropriate to include all five elements in the verbal instructions at all manoeuvres. This could make instructions too long and difficult to remember. The exact information elements of relevance will be context dependent, i.e. will depend on the nature of the manoeuvre and the available elements at that point.

Some initial rules for the information types to use at particular manoeuvres can be offered (but further research would be needed to extend this):

1. Turns off the main route (major to minor road):
   use **landmarks** (other information is unlikely to exist here) plus **street names** for confirmation
2. Minor crossroads and roundabouts:
   use **landmarks** and **junction description**
3. Major crossroads and roundabouts
   use **junction description**, **direction** (destination) sign plus, where there are many route choices or many similar junction types close by, use **landmarks** and **lane information**
4. Major roads with on/off ramps:
   use **junction description** and **direction** (destination) sign plus, where there are many choices, use **lane information**

1.5 Relevance of manoeuvre characteristics

Adding valuable landmarks to navigation instructions according to the approach detailed in section 1.1 should improve driver confidence where the location of the next manoeuvre is not obvious (e.g. where it is a minor road off a major road). However there are some manoeuvre characteristics that are likely to remain problematic for drivers, even *with* landmarks. For these manoeuvres additional changes to the navigation information may be necessary if drivers are to be fully supported in their task.

The manoeuvres requiring additional information (to landmarks) have one or more of the following characteristics:

- Have other equally or more likely turns close by (and in view)
- Are in busy traffic
- Require a lane choice
- Are concealed

Performance at these manoeuvres could be enhanced if the *visual* navigation information indicates (i) the location of the landmark and (ii) the relative 'sizes' of the target and surrounding roads. These additions should also enhance the information provided at *all* types of manoeuvre.

1.6 When to present landmarks

Landmarks should be used:

1. At manoeuvres to enable the driver to identify the precise location of the turn and reassure the driver that they are following the route correctly.
2. Between manoeuvres to increase driver trust in the navigation system

When used to identify minor turnings off a major road (quite a challenging navigation task), landmarks have an advantage over distance-only instructions (i.e. they increase driver confidence). This benefit occurs for a different minimum landmark value (as calculated by the equation in section 1.1.2) at each stage of the instructions as follows:

Message point	Distance from manoeuvre (approximately)	Landmark value at which confidence increases above that when using no landmarks
Preview 1	500m	Increase does not occur
Preview 2	200m	77
Final	50m	55
Post-manoeuvre	After	38

This finding is interesting when considering at which point to provide landmarks within the navigation instructions. It seems that there is no benefit to providing any landmarks at Preview 1 (probably because most landmarks would not be visible this far back from a manoeuvre), but by Preview 2 there is an advantage to providing only the best landmarks. Landmarks with a lower value are beneficial at the Final message and even the poorer landmarks seem to increase confidence once the manoeuvre has been completed.

The other useful information elements (identified in section 1.4) should be used as follows:

- **Lane choice** information is useful as 'preview' information
- **Junction description** and **direction sign** are useful to identify the precise location of a manoeuvre.
- **Street name/number** is useful for confirming that the correct turn has been taken.

1.7 Rules for using and presenting traffic lights

- If a potential manoeuvre is located at a set of traffic lights, then those traffic lights are an excellent landmark to help locate that particular turn.
- An instruction that refers to '*sets of* traffic lights' appears to be better than one that just refers to 'traffic lights', especially where manoeuvres are complex. Traffic lights can also be used to provide preview information regarding a forthcoming manoeuvre, by requiring a driver to count occurrences of lights (e.g. an instruction of the form 'turn left at the second set of traffic lights').
- A potential problem arises where there is a sequence of traffic lights and pedestrian lights in close proximity to each other, and the optimum timing of a message is such that there are occurrences of pedestrian lights before the required turning at a traffic light controlled junction. In these cases, if a navigation instruction is given that is of the form 'turn left at the second set of traffic lights', most drivers should include pedestrian lights within any counting strategy, but this will not be universal.
- Counting strategies can be used successfully within navigation instructions in order to provide preview information. However, it is recommended that (until further research identifies otherwise) not more that two (and an absolute maximum of 3) sets of lights are referred to, and where possible, instructions are not used that have to incorporate pedestrian lights.
- If a manoeuvre is located at (or very near to) a set of pedestrian lights, an instruction that refers to these as 'traffic lights' is likely to cause considerable navigation confusion. In contrast to the lack of differentiation between traffic and pedestrian lights within a counting strategy, it should be assumed that in these cases, drivers will explicitly identify these as 'pedestrian lights', and they should be referred to as such within a navigation instruction.
- Traffic lights have been shown to be primary information items when included within navigation instructions, i.e. they are information that, if removed, would result in a driver experiencing considerable navigation uncertainty. Therefore they should, as a minimum, be included in the voice instructions of a navigation system, and if feasible, also within any visual display.

1.8 Selecting landmarks that are easy to present

Once landmark value has been calculated/estimated, these landmarks can only be of use if they can easily be presented.

'Easy to present' landmarks are those that require the fewest 'elements' (ideally 1, maximum 2) to describe them effectively. The possible elements are:

- Form, e.g. "large, white"
- Function, e.g. "church"
- Label, e.g. "St Mary's"
- Location, e.g. "on the left"
- Reference, e.g. "turn left after"

Landmarks that require few elements are likely to meet the following criteria:

- Have a visible label from the direction of approach
  (e.g. a petrol station logo that is designed to be seen by all approaching drivers)
- Conform to a stereotype of a form, function or label
  (e.g. a traditional church with spire, traffic lights)
- Have a familiar brand/label
  (e.g. the 'golden arches' of McDonalds™)
- Have no other similar objects nearby
  (e.g. a single bridge in a long stretch of road)

1.9 Presenting landmarks

1.9.1 Specific vs. generic representations

The naming of landmarks raises the question of whether generic or specific terms are best. Familiarity of the landmark representation has been shown to be the most important factor determining whether drivers considered the specific or generic design to be more useful for navigation. For instance

- Specific presentations that included a well-known logo or name (e.g. MacDonald's™, NatWest™) were preferred to their generic equivalent (e.g. a symbolic representation of a burger, coins and notes).
- In situations where the generic design was familiar (e.g. a church icon), the more detailed specific representation was generally rated less favourably. However, it is likely that visual displays including a more complex landmark design will require longer glances to enable the driver to assimilate the information.

When considering specific or generic representations, the former must take into account information reliability, see section 1.3.

1.9.2 Primary vs. secondary information

When landmarks are valuable to drivers they are, almost universally, used as primary sources of navigation assistance (i.e. if they were taken away, the navigation task would be much more difficult, or even impossible). This implies that landmarks should be presented

- within voice instructions if at all possible (voice instructions should be the driver's primary source for safety reasons)
- supported by a visual indication to support driver's location of the landmark in relation to the manoeuvre (a spatial task best suited to a visual display)

1.9.3 Elements identified as useful

Drivers identify the following as useful information items for navigation in current systems:

- Voice instruction, including landmarks
- Distance countdown bar
- Road layout information
- Road names (for confirmation of correct turn)

1.9.4 Potential enhancements to the display

Drivers identify the following as useful information items to *add* to current systems:

- Lane choice indication
- Relative position of landmark in relation to manoeuvre
- The existence of mini-roundabouts
- Information that counts manoeuvres (e.g. "take the second right turn)

Additional information has also been identified for particular types on manoeuvre (see section 1.5), which could be applied to the whole system.

1.10 Individual differences

Until navigation systems have the capability of automatically adapting to the needs of an individual, identifying individual differences is of limited value. However, it can indicate the need to facilitate *manual* customisation of information output (e.g. through a 'preferences' or 'options' facility). The few individual differences that have been identified are stated below.

1.10.1 Navigation ability

Poor navigators may benefit more than good navigators from the inclusion of landmarks. Landmarks should reduce their navigation errors (when compared with instructions relying on distance information alone) and be perceived as helpful. Good navigators can still gain benefits from landmarks but may be seen as superfluous if used in contexts where they are not necessary, hence the importance of taking context into account.

1.10.2 Age

When using navigation systems, older drivers (55+) are likely to have longer glances to the display (due to slowing visual accommodation with age). Therefore information display concepts need to take this into account by:

1. designing voice instructions that can be used as the primary (ideally sole) source of navigation information
2. simplifying the visual information displayed
3. ensuring the detail of a display (alphanumerics etc.) are large enough for older drivers
4. investigating ways to reduce the need for drivers to re-focus on displays (e.g. head-up displays overlaid on windscreen)

These design changes would not only benefit older drivers but would make systems safer and more usable for all drivers.

Older drivers are receptive to navigation systems and studies have shown that, compared with younger drivers, they tend to be more positive about and confident with their use.

2 BASIS FOR DESIGN ADVICE: REGIONAL RESEARCH RESULTS

2.1 Research prior to REGIONAL – literature review

2.1.1 Usable 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, Antin et al. 1989). If efficient routes cannot be planned and followed, the consequences are stress, frustration, and delays for the driver and potentially unsafe road behaviour (e.g. late lane changes).

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" (ISO-9241 1998). Usability has been acknowledged as one of the most important aspects of navigation system design by several authors (Dewar 1988; Barrow 1991; French 1997) 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 (e.g. Burnett 2000). 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:

5. Basic human navigation strategies employ landmarks:
6. They form key elements within cognitive maps of the environment, aid the learning of the environment (Evans 1984; Golledge 1993), and are used in way-finding strategies (Alm 1990).
7. Landmarks are valued as information items by drivers:
8. 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 (Streeter 1986; Wochinger and Boehm-Davis 1997; Burnett 1998).
9. 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 (Bengler, Haller et al. 1994). 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 (Burnett 1998), and can increase confidence of the location of turnings and satisfaction with the information presentation (Alm 1992). Strong preferences have been shown in simulator trials 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 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 (Burnett 2000) for a comprehensive review.

2.1.2 The need for a predictive tool

Several research studies have been undertaken that aim to identify the landmarks that are useful as a navigation aid, and 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 Burnett 1998). These results are useful, since they indicate the types of objects that are useful as landmarks. 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 participants, country, driving environment etc. It is not clear how well these results will translate to other types of drivers, and particularly, to other driving environments. When comparing different driving environments, either within a country or across national borders, there may be some key differences between aspects of particular objects being used as landmarks. A summary of some of these differences is given in Table 1; this table also summarises the driver-related implications of not taking into account some of those key factors.

Differences based on driving environments	Driver issues	Implications regarding potential as navigation information
The existence and rate of occurrence of objects	Potential for using that object with navigation instruction	Lack of opportunities for employing that object as a navigation aid
Their physical appearance within that particular environment	Driver expectations of what the object will look like	Not recognising the object, uncertainty about identifying it
The typical location for that object	Driver expectations of where that object will be sited	Increased effort in searching for object
The role/nature of that object	Differences in the use of that object	Degree to which drivers will be familiar with the object, the types of association with it

Table 1: Potential cross-market considerations for landmarks

These differences all mean that a landmark (object) that works well as a navigation aid in one driving environment may be very poor in a different driving environment. Some examples are given below:

Traffic lights may be useful in one country, but occur so frequently in a different country (e.g. USA) that they may not be useful to distinguish between junctions.

A post office that is always distinctive in a particular country may not have a distinctive appearance in a different county (e.g. sub-post offices in the UK).

A particular regional brand of petrol station may not be well known to drivers originating from other regions of the same country, or from other countries.

Therefore, specific objects that work well as navigation aids for an individual driver in a certain road environment may be totally inappropriate in other contexts. A navigation system designed to incorporate landmarks must take this potential limitation into account, and as far as possible, select landmarks that are likely to be effective navigation aids within *that specific* driving context. This selection of landmarks could also be extended to take into account individual differences between drivers, with landmarks (as navigation information) tailored to the characteristics of individual users.

2.1.3 *Summary of the literature review*

The review of previous research supported the initial justification for the project, i.e. that the incorporation of landmarks will enhance the navigation task. The benefits found in the research were an increase in driver confidence and satisfaction and a decrease in navigation and driving errors.

Few studies have taken the approach of REGIONAL, which was to develop a generic advice (and ultimately a predictive tool) to support manufacturers in the choice, use and presentation of appropriate landmarks. Most previous studies have simply listed the most frequently used landmarks (invariably traffic lights, traffic signs, shops, petrol stations and bridges). However, these results are of limited use as they are influenced by the conditions of the study from which they result and are only truly valid for that particular set of circumstances (road environment, availability of landmarks, driver characteristics).

The literature review enabled the development of an initial set of factors that influence the navigational effectiveness of landmarks, these were: Permanence, Visibility, Conspicuity, Predictability in location, Openness, Familiarity, Predictability in appearance, Uniqueness, Degree of separation, Usefulness of location, Compactness. The further development of these factors was a major task in the remainder of the project (see section 2.4).

The literature review also identified results of studies on individual differences. The main findings, specific to landmark are that:

- Older drivers are less likely to state a need for landmark information and more likely to want road numbers
- Older drivers are more likely to rate navigation information components as useful
- Older drivers exhibit improved turn accuracy and indicator accuracy (especially in fog) when using landmarks
- In direction-giving, older drivers provide more abstract Euclidian directions
- In direction-giving, males use more distances and compass directions, females more landmarks and relational (left-right) terms
- When identifying navigation information of most use, more females stated landmarks, more males stated road numbers

The review also indicated that few studies have focused on appropriate presentation of landmarks. The one finding that does exist is that specific terms are better for well-known landmarks (e.g. 'McDonalds ™' rather than 'fast food restaurant') but for less 'branded objects (e.g. churches) the generic term if preferable.

2.2 Industry requirements

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 (for example, objects which already exist on navigable databases as Points of Interest would be easier to include than brand new data)

- Selection of landmarks should, as far as possible, not rely on field visits to verify their 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 are 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, i.e. landmarks should be considered as one potential source of information within a wider pool of navigation elements.

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.

REGIONAL aimed to take account of, and support, as many of these requirements as possible in the design advice. Although resource limitations meant that not all requirements could be met to the same level of detail, the project ensured that a range of recommendations could be made.

2.3 Studies quantifying landmark use

Two direction-giving studies were conducted, with a dual purpose:

- To identify the most used landmarks as an input to defining the factors affecting their navigational effectiveness (and hence as an input to the predictive model)
- To identify the context of landmark use (i.e. in relation to other environmental information, stages of the navigation task, as primary or secondary information, at manoeuvres or between manoeuvres and the influence of manoeuvre characteristics)

The studies were conducted in the 2 urban environments of a town (population 60,000) and a city (population 295,000) with 32 and 36 participants respectively. In both studies a dual methodology was used: half of the participants did not know the area and gave directions based on viewing a video tape of the route (Video condition); the other half knew the areas well and gave directions from memory, prompted by a line drawing outline of the route (Cognitive Map condition). The reason for the dual methodology was to enable identification of the optimum landmarks based on both visual characteristics and ease of remembering.

The most frequently selected landmarks were:

- Traffic lights and pedestrian lights, in both town and city environments
- In the town the next most frequently used landmarks were petrol stations, churches, a Sainsbury's™ supermarket and post offices
- In the city the next most frequently used landmarks were bridges/flyovers, garages and direction signs (as objects rather than for the direction information)

From these studies, the intention was not to provide a list of the landmarks that should be incorporated in systems (see comments re. the validity of this in section 2.1.3) but to begin to identify the factors that caused them to be chosen over other objects. This was achieved by comparing the attributes of the landmarks used/not used, both across categories (e.g. petrol stations

vs. public houses) and as individual objects within a category (e.g. petrol station 1 vs. petrol station 2). Information on the generated factors is provided in section 2.4.

Both studies also enabled the following conclusions re. the context of landmark use:

- At manoeuvres, landmarks are primarily used to identify the exact location of that manoeuvre.
- Between manoeuvres (termed 'progress') landmarks are primarily used to confirm that the driver is on the correct route.
- Landmarks are infrequently used for the 'preview' stage of the navigation task (i.e. to prepare the driver for a manoeuvre far ahead)
- When stated in directions landmarks are, in the majority, used as primary rather than secondary information for navigating

The data analysis in the city study was extended to allow the use of landmarks to be considered in relation to other available information categories. The categories were: **Direction sign** used for its navigation information, **Direction sign** used as a navigation object, **Distance**, referred to in qualitative or quantitative terms, **Environment**, describing a geographical region or area, **Junction type**, a driver main decision point, **Junction name or number, Landmark**, an object or building referred to, coded according to category, **Lane positioning** or lane changing instruction, **Geometry of node**, a descriptor applied to a junction or manoeuvre, **Geometry of path**, a descriptor applied to a road, **Road marking**, any information on the road surface, **Type of road**, according to visual appearance, **Street name/number, Time**, referred to in qualitative or quantitative terms.

The findings showed that **landmarks** were the most frequently used item (stated over 900 times by the 38 subjects) followed by **junction description** (650 times), **direction sign** for navigation (350 times) and **lane positioning** (300 times). All other categories were referenced less than 100 times. The four most referenced categories were mainly used to *identify* manoeuvres (lane positioning also used for *previewing* manoeuvres) and as primary information (with the exception of direction signs).

The city study also enabled comparison of the profiles of information use across different manoeuvres. Forty manoeuvres were analysed and preliminary conclusions were:

- For turns off the main route (major to minor road):
  use **landmarks** (other information is unlikely to exist here) plus **street names** for confirmation
- For minor crossroads and roundabouts:
  use **landmarks** and **junction description**
- For major crossroads and roundabouts
  use **junction description**, **direction** (destination) sign plus, where there are many route choices or many similar junction types close by, use **landmarks** and **lane information**
- For major roads with on/off ramps:
  use **junction description** and **direction** (destination) sign plus, where there are many choices, use **lane information**

As these results are based on a single study they should be validated and extended by further research.

2.4 Developing the predictive model

A range of methods was used to generate the final list of landmark characteristics that should describe the effectiveness of the object as a navigation aid. These included:

- Consideration of theoretical information processing models.
- Review of relevant applied research literature.
- Data generated from the requirements study (section 2.3).
- Informal content analysis of videotapes of routes.
- Analysis of participant post-trial protocols.
- 'Expert' human-factors assessment, and card sort process.

The card sort technique involved writing main and sub-factors on individual cards, and creating columns that represented each main factor. Appropriate sub-factors were then allocated to each main factor column, and main and sub-factors redefined as necessary.

Table 2 presents the final factor list for use as the basis of a predictive tool. Many of the factors also had associated sub-factors but, for economy of space, these are not shown here.

Main factors identified as of potential relevance to landmark effectiveness
The **visual characteristics** of the object and any sign or logo attached to it (ease with which you can see it)
The amount of required **visual effort for scanning** for the object
Degree of **pre-warning** that a driver gets of the forthcoming appearance of the object
How **familiar** the object is to a typical driver
Ease of naming of the object
Influence of the surroundings on the ability to see the object
The number of objects nearby that have a **similar appearance**
Usefulness of the location of the object for supporting the navigation task (identifying a manoeuvre / increasing driver confidence)
The **level of task demands** on the driver when using the landmark
Degree of interaction a driver normally has with the object

Table 2: List of main factors

The next step was to derive a predictive model based on these factors of the form:

$V = K + w_1F_1 + w_2F_2 + w_3F_3 + w_4F_4 + w_5F_5 + w_6F_6 + w_7F_7 + w_8F_8 + w_9F_9 + w_{10}F_{10}$

Where:

V is a value representing the navigational effectiveness of the landmark

K is a constant

F_n is the rating or score of the particular landmark on Factor n

w_n is the weighting attached to Factor n

To achieve this, the weightings attached to the factors must be calculated. This requires a set of data relating to a range of different landmarks, where for each landmark, the effectiveness, V is known, and a rating of the landmark against each factor is known. This data was obtained from the frequency counts of landmarks referred to in the town study (see section 2.3) according to a formula to calculate V, where high use by both conditions (Video and Cognitive map) and consensus between conditions gave a higher value.

A bespoke computerised ratings programme (termed GRADA – Graphical Ratings Acquisition and Data Analysis) was developed to enable the playing of each of 40 video clips (a 5s approach to each landmark), and the rating of it on each of the factors (predictor variables).

A multiple linear regression model was run on the ratings data and a stepwise method was used to minimise the set of predictor variables included in the model, i.e. identify the minimum set of factors that help predict the effectiveness of a landmark. Using the stepwise method, a significant model emerged {F (3,196) = 35.615, $p < 0.0005$, adjusted $R^2 = 0.343$}, which incorporated 3 of the factors as follows:

V = (0.134) VISCAR + (0.255) USEOFLOC + (0.340) DEGOFINT

Where:

V = Landmark value (minimum 0, maximum 100)

VISCAR = Visual Characteristics (0-100)
i.e. ease of seeing the object (and/or sign)

USEOFLOC = Usefulness of Location (0-100)
i.e. how ideally located the object is for the navigation task it supports

DEGOFINT = Degree of Interaction (0-100)
i.e. to what extent the driver already interacts with the object as part of driving

(See Appendix 1 for the detail of the rating scales)

The model was tested for validity during the road trials reported in section 2.6.

2.5 Comparing good and poor landmarks (road trial)

The study consisted of a road-based trial involving 48 participants using a navigation system to complete a complex urban route. The participants were divided into three matched groups experiencing one of the following landmark conditions: good, poor or no landmarks, incorporated in verbal instructions. A range of objective and subjective measures were taken to assess driver performance with and attitudes to each of the landmark categories.

Landmark condition and driver behaviour

When comparing good, poor and no landmarks, several of the behavioural measures indicated a clear difference between landmark categories. However this was not always in the direction expected. The assumption was that good landmarks would always result in better performance than poor, with no landmarks being the least advantageous conditions. It is interesting to look at a high level summary of findings. Table 3 shows the landmark condition(s) that produced the best performance (√ √), the second best performance (√) and the worst performance (X). For some measures no difference was found, these are indicated by '-'.

	Good landmarks	Poor landmarks	No landmarks
No. of glances	√	√ √	X
Glance duration	-	-	-
% time looking at display	√	√	X
Workload	-	-	-
Driving errors	√ √	X	√
Navigation errors	√ √	X	X
Approach confidence	√	X	√
Confidence at Preview 1	√	X	√ √
Confidence at Preview 2	√	X	√ √
Confidence at Final	√ √	X	√
Confidence post-manoeuvre	-	-	-

Table 3. High-level summary of findings

From this, the main conclusions are:

- Good and poor landmarks resulted in less glances to the display
- Good landmarks produced less driving errors
- Good landmarks produced the least navigation errors
- Good and no landmarks resulted in higher driver confidence on the approach to a manoeuvre (but not post-manoeuvre where there was no difference)
- Workload was unaffected by landmark condition

The two main, reported age effects were that older drivers had longer average glance durations (expected, due to reduce speed of visual accommodation with age) and generally reported themselves to be more confident.

One unpredicted finding was that, for all conditions, glance duration decreased over time (from manoeuvre 2 to 33) from $\geq$ 0.95sec to $\leq$ 0.9sec, with no apparent plateau occurring within the 50-minute period of the trial.

Driver attitudes

Driver perceptions of the system were generally positive with very few opinion statements showing a difference across conditions. The majority of participants enjoyed using the system, perceived it to be of high quality and liked the information that was presented. Where opinions after the trial differed from those prior to system use, good landmarks generally improved driver attitudes, poor landmarks were detrimental to opinion and no landmarks had a mixed effect.

The main age effects were that older (55+) participants were generally more positive about use of the system.

The information that participants found helpful in all conditions was the voice instructions (including the landmarks), the distance countdown bar and the road layout. Those experiencing poor landmarks also found road names particularly useful.

Suggested improvements were:

- The addition of mini-roundabouts on the display
- Indication of the most appropriate lane for a manoeuvre
- Counting of roads (e.g. Take the second left)
- Identification of distance between landmark and manoeuvre.

Several participants felt that (particularly for the 'poor' condition) landmarks were given too soon (many were not visible when the 1st preview instruction was given at 500m from the manoeuvre).

2.6 Testing the predictive model (road trial)

This part of the research took place concurrently with the road trials comparing good and poor landmarks. The aims were:

- Validate the REGIONAL regression model which was developed to predict the navigational value of individual landmarks
- Identify any other factors (e.g. driver or manoeuvre characteristics) that may affect the value of landmarks

Regression model

It was hoped that increasing landmark value would be associated with an improvement in driver behaviour and confidence (as indicated by the measures in Table 3). The model correlated well with measures of driver confidence. In addition, it was possible to identify the landmark value at which confidence increased above that for the no landmarks condition.

An increase in landmark value was not always associated with an increase in driving performance. All other measures of visual behaviour, driving errors and navigation performance did not correlate with landmark value. This could be due to the behaviour measures used not being sufficiently discriminating to show a correlation. However, it may also be possible that, if the measures were taken as a whole, i.e. combined into some overall 'driver behaviour' measure then a different result may be found (as for the findings summarised in Table 3, considering one measure alone does not provide the whole picture). A combined measure could be created but this would be quite arbitrary and the validity of results would be questionable.

Correlation with landmark factors

When considering correlation with the individual components of the regression model (and other components excluded during the regression) again, there was little relationship between ratings on each factor and measures of driving errors, navigation errors and visual behaviour. However, driver confidence once again seemed to be predictable based on some component factors as shown in Table 4 (an asterisk indicates inclusion in the REGIONAL model)

Correlation with driver confidence?	
Yes	No
Visual Characteristics (*)	Familiarity
Visual Effort for Scanning	Ease of Naming
Pre-Warning	Similarity of Appearance
Influence of Surroundings	Usefulness of Location (*)
Level of Task Demand	
Degree of Interaction (*)	
Visibility Distance	

Table 4. Factors showing a correlation with driver confidence

Manoeuvre effects

Particular manoeuvres caused behaviour outside the norm (namely manoeuvres 2, 4, 7 and 33). These manoeuvres had one or more of the following features: were early in the trial, had other, equally/more likely manoeuvres nearby (e.g. roundabout, more major road), were concealed in some way, were in a busy traffic situation. These results suggest that junction representations could support the driver further by providing some indication of road 'size', showing prior/subsequent junctions that could be confused with that intended and indicating position of the landmark on the display.

2.7 Traffic lights as landmarks (road trial)

This study was an empirical road-based trial, where participants were presented with verbal navigation instructions incorporating traffic light information, and asked to complete manoeuvres based on these instructions. Participants completed two complete circuits of an urban route, on the first circuit navigational errors were determined, on the second circuit of the same route, counting strategies were investigated.

The test route consisted of three straight sections of an approximately triangular route. Each of these three parts of the route contained a series of traffic lights and pedestrian lights, and within the constraints of a real road environment, represented a 'high', 'medium' and 'low' density of lights.

A total of 30 participants took part in the study, these were split equally into age groups comprising 20-34, 35-49 and 50+, and also split equally according to gender. All participants were required to have driven regularly for at least 4 years, and not to have previously used a vehicle navigation system.

Below is a summary of the main results arising from the study.

- Where manoeuvres were at junctions controlled by traffic lights, participants were able easily identify the required turning, even the density of traffic lights/pedestrian lights along a stretch of road was high. Where a manoeuvre was located by a set of pedestrian lights, drivers were less successful, with an overall error rate of up to 50%.
- *Perceived* task performance remained high in all cases and gender and age differences were not apparent.
- Participants generally did not differentiate between pedestrian lights and traffic lights, i.e. when presented with an instruction of the form 'turn right at the second set of traffic lights' they generally included any occurrences of pedestrian lights within their counting strategy.

- Navigation instructions that referred to 'sets of traffic lights' rather than 'traffic lights' resulted in fewer navigation errors, although this effect was only readily apparent for the most complex navigation task where the greatest navigational uncertainty existed.
- There were inconsistent counting strategies (relating in part to the inclusion or exclusion of pedestrian lights) used by up to half the participants, and the inconsistencies were greatest for the most complex navigation scenario.
- Based on the results of a dynamic counting task, participants were able to apply a counting strategy successfully for up to four occurrences of traffic lights. However this result does not take into account additional navigating demands, which are likely to reduce the performance on this kind of task.

There are several implications arising from this study, if traffic lights are to be incorporated successfully into future navigation systems. If a manoeuvre is located at a set of traffic lights, then those traffic lights are an excellent landmark to help locate that particular turn, and an instruction that refers to '*sets of* traffic lights' appears to be better than one the just refers to 'traffic lights', especially where manoeuvres are complex. Traffic lights can also be used to provide preview information regarding a forthcoming manoeuvre, by requiring a driver to count previous traffic lights (e.g. an instruction of the form 'turn left at the second set of traffic lights'). A potential problem arises where there is a sequence of traffic lights and pedestrian lights in close proximity to each other, and the optimum timing of a message is such that there are occurrences of pedestrian lights before the required turning at a traffic light controlled junction. In these cases, if a navigation instruction is given that is of the form 'turn left at the second set of traffic lights', most drivers should include pedestrian lights within any counting strategy, and complete the turning as required.

If a manoeuvre is located at (or very near to) a set of pedestrian lights, an instruction that refers to these as 'traffic lights' is likely to cause considerable navigation confusion. In contrast to the lack of differentiation between traffic and pedestrian lights within a counting strategy, it should be assumed that in these cases, drivers will explicitly identify these as 'pedestrian lights', and they should be referred to as such within a navigation instruction. Counting strategies can be used successfully within navigation instructions. However, it is recommended that not more that two sets of lights are referred to, and where possible, occurrences of pedestrian lights are not included within these instructions.

2.8 Reliability of landmarks (road trial)

If landmarks are incorporated in navigation systems, this necessitates information on them being held on a database. The moment a database is created and marketed (e.g. on a CD-ROM) it is already likely to be out of date. This is an intrinsic problem that database manufacturers can overcome if system developers can mitigate the consequences. Information on several categories of landmark will become inaccurate more rapidly than some other types of information (e.g. road geometry is fairly static as are road names). Equally, some categories of landmark will experience more frequent change than others (e.g. the names of public houses change frequently whereas church names rarely do). One solution to name changes is, of course to only use generic terms for all landmarks, e.g. 'public house', 'petrol station' but this would reduce the potential benefits of landmarks and would be seen by industry as a retrograde step (fuel brand logos are already used to identify petrol stations on maps – as 'Points of Interest' data rather than as landmarks). It was important for REGIONAL to at least begin to understand the effect that such database errors may have on drivers. Very little research exists regarding the (un)reliability of navigation information.

The study conducted within the project considered two categories of landmark: public houses and petrol stations (with traffic lights used as a control condition). Eighteen participants drove three routes, each route using one category of landmark within the navigation instructions (10 traffic lights, 10 pubs or 10 petrol stations). All 'target' manoeuvres (i.e. those using landmarks) were linked by several other manoeuvres without landmarks to ensure a continuous and realistic route. For the control condition, there were no errors. For pubs and petrol stations, the 7th landmark was given an incorrect name (i.e. a 10% error rate). Measures were taken of driver confidence at each manoeuvre (1=low, 2=medium, 3=high) and driver opinions.

The results are shown in Figure 1

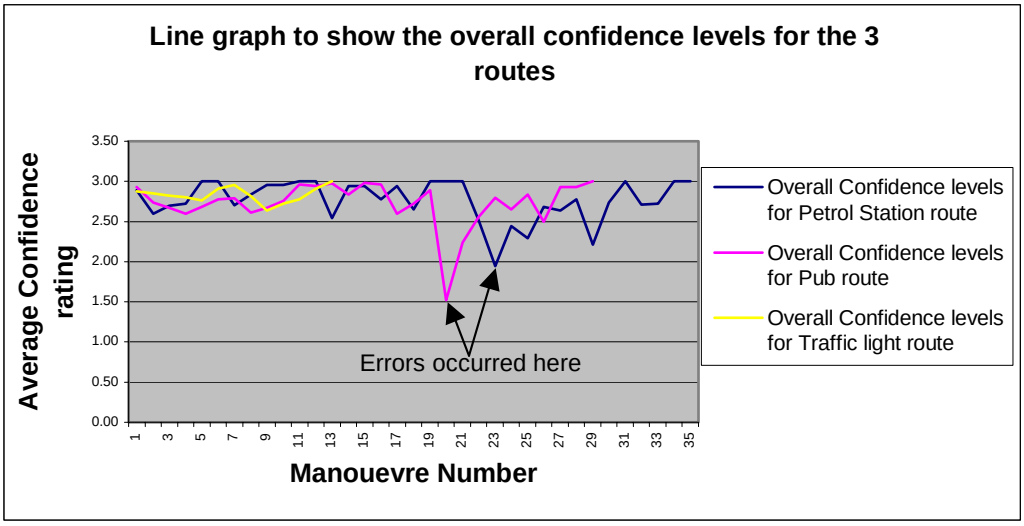

Figure 1. Changes in confidence due to errors in naming of landmarks

The most significant findings were:

- Prior to the error occurring, all categories of landmark induced a similar level of mean driver confidence (traffic lights = 2.83; pubs = 2.79; petrol stations = 2.85).
- Post-error, mean driver confidence dropped to 2.63 for petrol stations and only 2.29 fro pubs)
- The range of mean driver confidence for each manoeuvre prior to the error was 2.5 – 3.0 for all landmark categories.
- Mean driver confidence for the manoeuvre at which the error occurred dropped from this range to 2.0 for petrol stations and 1.5 for pubs (both significant falls in confidence).
- After the error occurred, mean confidence did not return to pre-error levels until 3 manoeuvres later.
- Sixteen of the eighteen participants noticed the error in the pub condition but only 9 (out of 18) noticed the petrol station error.

These results show that the same level of error will not always induce the same reaction from drivers. The effect of an error seems to be dependent on the category of landmark. When considering the factors affecting landmark effectiveness (see Table 2), the scores for petrol stations and pubs would be similar for the following factors:

- High for both on: Familiarity and Ease of Naming
- Low for both on Pre-Warning
- Variable (i.e. context dependent) for Level of Task Demand and Usefulness of Location

However, for the following factors, petrol stations would score much more highly than pubs:

- Visual Characteristics, Visual Effort for Scanning, Influence of Surroundings, Degree of Interaction and Similarity of Appearance.

It is these features of petrol stations (designed to be easily spotted by drivers, very different to surrounding objects, likely to occur singly) that were probably the influential effect in the study. When the petrol station was given the wrong name, half of drivers did not notice, and the remainder probably assumed it must be the right one anyway as there is not likely to be another in close proximity (drivers in the study were also provided with distance information). For pubs, more drivers noticed the error and were more unsure because pubs are often clustered together and can be difficult to pick out from the surroundings.

This very preliminary study resulted in some very interesting findings from which some generic conclusions can be made. However, further studies would be needed before the effects of errors in other categories of landmarks could be identified and the overall impact of driver confidence and performance assessed.

2.9 Good vs. poor navigators (road trial)

The impact of age and gender on reaction to landmarks has been studied by other researchers (albeit to a limited extent). One driver characteristic that had not been studied was navigation ability. A study with 12 participants compared the reaction of good and poor navigators (as defined by the number of navigation errors made when using a paper map) to the use of landmarks. All participants experienced three conditions: paper **map**, verbal **navigation** instructions (distance, junction type where possible and direction of turn) and the same instructions with the addition of **landmarks**.

The study found that, for the good navigators, the number of navigation errors remained similar, regardless of condition (but was always lower than that for poor navigators). However, for the poor navigators, using the **navigation** instructions system reduced the number of errors (compared with the **map**) and this trend was even more significant when **landmarks** were included (the number of errors was half that for the **map** condition). When considering driver preference and the condition that was found to be the least demanding, the good navigators rated the **navigation** instructions most highly and the poor navigators stated a preference for the **landmarks** condition. Driver comments also seemed to suggest that the good navigators found the landmarks 'unnecessary' but the poor navigators found them 'helpful'.

The results of this study would suggest that the addition of landmarks would be particularly useful for poor navigators in reducing navigation errors and improving the driver's opinion of the system. For good navigators, landmarks were not detrimental to performance, but overuse may begin to be perceived as unnecessary by this group and should only be used where necessary (reflecting the importance of context in using landmarks).

2.10 Characteristics influencing effective landmarks presentation

The results from the direction giving study (section 2.3) and the predictive model (section 2.4) focus on how to select a landmark that is likely to aid navigation. This is considered independently of the method by which that landmark may be presented to the driver. Although, there is theoretical value in separating navigation value from presentation method (the latter is dependent on technological possibilities and the former is not), the REGIONAL project also aimed to provide advice to the partners (and the wider navigation industry) on the most appropriate implementation of landmarks with *current* technology. Hence it was useful to identify the features of landmarks that make them easy to present to driver. The combination of a landmark that is both navigationally effective *and* easy to present will provide the best support for a driver.

This part of the work used the data from the direction giving study in the town (described in section 2.3). The written directions from all participants was analysed by categorising the words used to describe landmarks according to the following elements:

- Form, e.g. "large, white"
- Function, e.g. "church"
- Label, e.g. "St Mary's"
- Location, e.g. "on the left"
- Reference, e.g. "turn left after"

Each landmark varied considerably in the number of elements required to describe them effectively. For instance of the 16 participants describing St Mary's Church (which had a Roman-style façade, a small sign indicating its name and a difficult-to-see cross high on the roof) all of the elements were used: Form (n=2), Function (n=3), Label (n=2), Location (n=3) and Reference (n=6). For a set of traffic lights at a cross-roads (used by 28 participants), only 2 elements were needed, and consistently so: Function (n=28) and Reference (n=28). By considering the difference in elements used both for individual landmarks within categories and across categories, it was possible to identify the characteristics that affect the ease of landmark presentation. These are:

- Visibility of label (from direction of approach)
- Conformance to stereotype of form, function, labelFamiliarity of brand/label - elements needed for description
- Proximity of other similar landmarks - detail and location to distinguish landmarkUse as manoeuvre or progress - varying need for accurate location and reference

3 PROJECT DELIVERABLES & PUBLICATIONS

AUTHOR	TITLE	REFERENCE				TYPE
		Journal/Conference	Year	Volume	Page	
Burnett, G.E.	"Turn right at the traffic lights" The requirement for landmarks in vehicle navigation systems"	The Journal of Navigation.	2000	53(3)	499-510	Refereed Journal
Ross, T, & Burnett, G.	Evaluating the human-machine interface to vehicle navigation systems as an example of ubiquitous computing,	International Journal of Human-Computer Studies	2001	55(4)	661-674	Refereed Journal
May, A.J., Ross, T and Bayer, S.H.	Drivers' information requirements when navigating in an urban environment	Journal of Navigation	In press			Refereed Journal
May, A.J., Ross, T. and Grimsley, P.J.	The use of traffic lights as navigation cues	Transportation Research Part F: Traffic Psychology and Behaviour	In press			Refereed Journal
Fowkes, M.	Future Route Guidance	Land Vehicle Navigation, Coventry, UK	1999	-	-	Conference
Burnett, G.E.	Usable vehicle navigation systems – are we there yet?	Vehicle Electronic Systems 2000, Stratford-upon-Avon, UK	2000	-	-	Conference
Burnett, G.E., Ross, T & Wevers, K.	The use of landmarks for enhanced route guidance: The REGIONAL project	7th World Congress on Intelligent Transport Systems, Turin, Italy	2000	-	CD-ROM	Conference
Burnett, G.E., Smith, D., May, A.J.	Supporting the navigation task: Characteristics of 'good' landmarks	Annual Conference of the Ergonomics Society, Cirencester, UK.	2001	-	441-446	Conference
May, A., T. Ross, S. Bayer & G. Burnett	Using landmarks to enhance navigation systems: driver requirements and industrial constraints	8th World Congress on Intelligent Transport Systems, Sydney, Australia.	2001	-	CD-ROM	Conference
Duffield, J, Ross, T & May, A,	Navigation Aids: A predictive tool for information design	Annual Conference of the Ergonomics Society, Cambridge, UK	2002	-	235-240	Conference

AUTHOR	TITLE	REFERENCE				TYPE
		Journal/Conference	Year	Volume	Page	
Bayer, S, May, A & Ross, T,	Information requirements for future navigation systems,	Annual Conference of the Ergonomics Society, Cambridge, UK	2002	-	246-251	Conference
Ross, T.	Using landmarks to enhance navigation systems	Vehicle Communications Technologies, Coventry, UK.	2001	-	-	Conference
Ross, T, Burnett, G.	Evaluation Case Study: In-car Navigation	Human Factors 2000	2000	-	-	Conference
Ross, T.	Putting safety in the driving seat	Safe Highways of the Future, Cologne, Germany. http://www.ukintpress-conferences.com/conf/safe/	2002	-	Web proceedings	Conference
Ross, T.	Safety first	Traffic Technology International	2002	Feb/Mar	50-55	Professional Journal
Ross, T.	REGIONAL as an example of industrial/academic collaboration	Open University TV Programme 'PY Gerbeau's Rules of the Game – Reinventing the Wheel (29 June 2002)	2002	-	-	Television programme
Burnett, G.E., May, A.J. and Ross, T.	The inclusion of landmarks within navigation systems: industry requirements	REGIONAL Deliverable 1	2001	-	47pp	Project Deliverable
Ross, T., May, A.J. and Burnett, G.E.	The inclusion of landmarks within navigation systems: industry requirements	REGIONAL Deliverable 2	2001	-	20pp	Project Deliverable
May, A.J., Ross, T. and Duffield, J.M	Development of a model for predicting the navigational effectiveness of landmarks	REGIONAL Deliverable 3	2002	-	45pp	Project Deliverable
Ross, T., May, A.J. Duffield, J.M. and Paszkowicz, S.	Driver reaction to navigation instructions incorporating good and poor landmarks	REGIONAL Deliverable 4	2002	-	157pp	Project Deliverable
Ross, T. and May, A.J.	Human factors advice for the incorporation of landmarks within vehicle navigation systems	REGIONAL Deliverable 5	2002	-	20pp	Project Deliverable
Ross, T. and May, A.J.	Future research areas	REGIONAL Deliverable 6	2002	-	10pp	Project Deliverable

AUTHOR	TITLE	REFERENCE				TYPE
		Journal/Conference	Year	Volume	Page	
Smith, D.	An investigation into the types of landmarks valued by drivers for turn by turn navigation	BSc Ergonomics Dissertation	2000	-	69pp	BSc Dissertation
Grimsley, P.J.	The use of traffic lights as landmarks, within a vehicle based satellite navigation system	BSc Ergonomics Dissertation	2001	-	70pp	BSc Dissertation
Willingham, D.S.	What is the impact upon the driver if the system information in a navigation device is unreliable	BSc Ergonomics Dissertation	2002	-	45pp	BSc Dissertation
Allerton, J.E.	Tailoring Vehicle Navigation Systems to Individual and Environmental Factors –A Road Based Study (*jointly supervised with the EPSRC Tele-Assess project*)	MSc Ergonomics Dissertation	2000	-	103pp	MSc Dissertation
Bayer, S.	Information requirements for the next generation of navigation systems: methodology & initial results	Diploma in Professional Studies	2001	-	30pp	DPS Dissertation
Williams, D.	Factors affecting the ease with which landmarks can be presented by a vehicle navigation system	Diploma in Professional Studies	2001	-	27pp	DPS Dissertation
Duffield, J.	Development of a model for predicting the navigational effectiveness of landmarks	Diploma in Professional Studies	2002	-	54pp	DPS Dissertation
REGIONAL	REGIONAL (Route guidance systems: optimal navigation via the use of landmarks)	Accenture Human Peformance Masterclass, Loughborough, UK.	2001	-	-	Poster
REGIONAL	REGIONAL (Route guidance systems: optimal navigation via the use of landmarks)	ADVANCE Forum on health and safety, Loughborough, UK.	2001	-	-	Poster
REGIONAL	REGIONAL (Route guidance systems: optimal navigation via the use of landmarks)	Human Factors 2000 Symposium', Loughborough, UK.	2000	-	-	Poster
REGIONAL	REGIONAL (Route guidance systems: optimal navigation via the use of landmarks)	EPSRC Evaluation Day', Crowthorne, UK.	2000	-	-	Poster
REGIONAL	REGIONAL (Route guidance systems: optimal navigation via the use of landmarks)	VS2002, London, UK	2002	-	-	Poster

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APPENDIX 1. RATING SCALES FOR LANDMARK FACTORS

KEY:

MAIN FACTOR LABELS CAPITALISED IN BOLD

1. Sub factors in plain text, numbered

the semantic anchors are shown in italics at each end of the scale

Using the scales to rate landmarks or categories of landmarks

1. Ratings are most valid when made after observation (on road or from a video) of a *specific* landmark as seen when completing a particular manoeuvre (i.e. the manoeuvre for which it is intended to use the landmark).
2. When rating *categories* of landmark, the rating should be based on the likelihood of an object in that category meeting that criterion. For example petrol stations and their signs are highly likely to be located close to the roadside, churches are not.
3. Ratings should be made by placing a vertical line through the appropriate place on the scale.
4. All scales are 100mm long, enabling a value to be measured once the line is drawn.
5. The purpose of the sub-factors is to ensure the 'rater' takes into account all characteristics that are relevant for the main factor rating. It is not intended that the mark on these scales is measured to provide a rating although these scales can be used in this way if desired.
6. Ideally, when making the main factor rating, the rater should not have the sub-factor ratings visible, i.e. the main factor rating should be made independently, using only the memory of the sub-factor ratings.
7. The main factor should be measured to give a value between 0 and 100 for that landmark (or category of landmark)
8. The ratings on the main factors can be considered together to provide a guide as to the 'navigational value' of that landmark (or category).
9. The ratings on 'Visual Characteristics', 'Usefulness of Location' and 'Degree of Interaction' can be used in the equation below to determine overall landmark value (V). This value has been shown to correlate well with driver confidence (i.e. a higher value will result in higher confidence at that manoeuvre). The minimum value (V) to produce a positive effect on confidence is 40.

V = (0.134) VISCAR + (0.255) USEOFLOC + (0.340) DEGOFINT

Where:

V	=	Landmark value (minimum 0, maximum 100)
VISCAR	=	Visual Characteristics (0-100) i.e. ease of seeing the object (and/or sign)
USEOFLOC	=	Usefulness of Location (0-100) i.e. how ideally located the object is for the navigation task it supports
DEGOFINT	=	Degree of Interaction (0-100) i.e. to what extent the driver already interacts with the object as part of driving

VISUAL CHARACTERISTICS

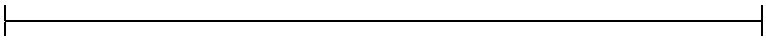
Rate the object (including any sign/logo attached to it or associated with it) on the factor of Visual Characteristics. By visual characteristics, we mean the aspects relating to the object itself, and disregarding its surroundings or location. Visual Characteristics will take into account 8 sub-factors, 4 of which will relate to the object itself and 4 to any physical sign attached to it or associated with it.

SUB-FACTORS

Mark on the scale your rating for the object against each sub-factor.

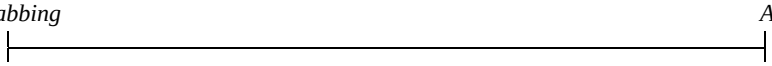
1. Is the main object (not including any sign/logo attached to it or associated with it) brightly coloured or lit?

Very dull — *Very bright*



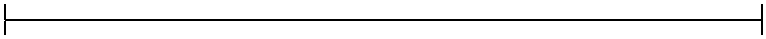
2. Does the main object (not including any sign/logo attached to it or associated with it) have characteristics that are attention-grabbing (e.g. moving, flashing lights or animated)?

Non-attention grabbing — *Attention grabbing*



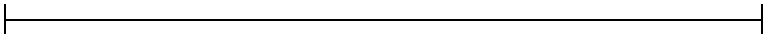
3. How big is the main object (not including any sign/logo attached to it or associated with it)?

Very small — *Very big*



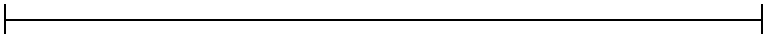
4. Does the main object (not including any sign/logo attached to it or associated with it) have a unique shape, profile or colour (can you identify the object without seeing the detail on it)?

Very common shape, profile or colour — *Unique shape, profile or colour*



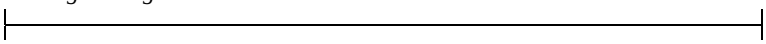
5. For any sign or logo attached to the main object or associated with it - is it brightly coloured or lit?

Not there, very dull — *Very bright*



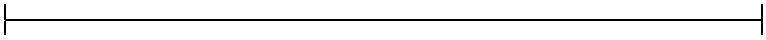
6. For any sign or logo attached to the main object or associated with it - are there any characteristics that are attention-grabbing (e.g. moving, flashing lights or animated)?

Not there/ non attention grabbing — *Attention grabbing*



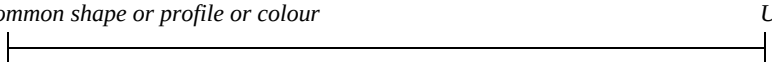
7. For any sign or logo attached to the main object or associated with it - what size is this sign or logo?

Not there, very small — *Very large*



8. For any sign or logo attached to the main object or associated with it - does this have a unique shape, profile or colour (can you identify the sign or logo without seeing the detail on it)?

Not there, very common shape or profile or colour — *Unique shape*

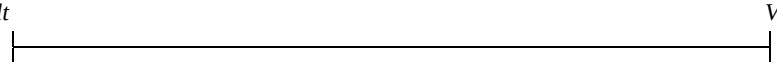


MAIN FACTOR

Taking into account the previous 8 sub-factors you have rated, please now rate the object (including any sign it may have) for Visual Characteristics i.e. how easy it is to see the object.

How easy is it to see the object, disregarding its surroundings and positioning?

Very difficult — *Very easy*



VISUAL EFFORT FOR SCANNING

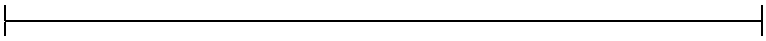
Rate the object (including any sign/logo attached to it or associated with it) on the factor of Visual Effort For Scanning. Visual Effort For Scanning will take into account 5 sub-factors.

SUB-FACTORS

Mark on the scale your rating for the object against each sub-factor.

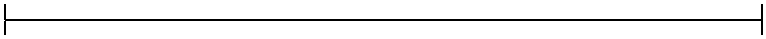
1. How close to the roadside is it, is it set back in relation to other buildings?

   Very far, set back — *Very close*



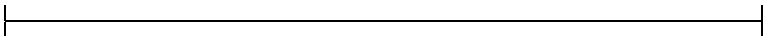
2. Considering what type of object it is, is it in a typical location for that object?

   Where you don't expect it to be — *Where you expect it to be*



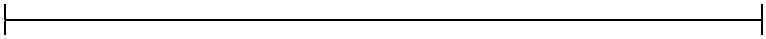
3. How central is the object to the driver's vertical (up or down) line of site, taking into account where they would be looking whilst approaching /undertaking a manoeuvre?

   Peripheral — *Central*



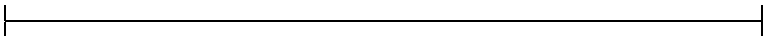
4. How central is the object to the driver's horizontal (left or right) line of site, taking into account where they would be looking whilst approaching /undertaking a manoeuvre?

   Peripheral — *Central*



5. To what extent is the object sited so that you can it from a distance?

   Only visible when close — *Visible from far away*

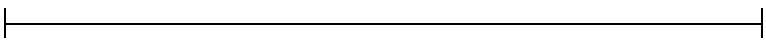


MAIN FACTOR

Taking into account the previous 5 sub-factors you have rated, please now rate the object (including any sign it may have) for Visual Effort For Scanning i.e. how easy it is to spot/find the object.

How much effort in terms of visual scanning is required to locate the object? (How easy is it to spot it?)

Very difficult — *Very easy*



PRE-WARNING

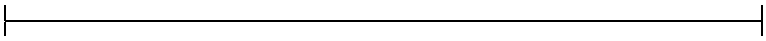
Rate the object (including any sign/logo attached to it or associated with it) on the factor of Pre-Warning of its appearance, before the object is actually visible. Pre-Warning will take into account 2 sub-factors.

SUB-FACTORS

Mark on the scale your rating for the object against each sub-factor.

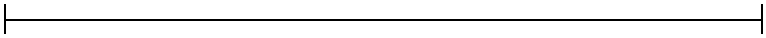
1. What degree of (explicit) preview information is there (e.g. for traffic lights, there may be a warning sign indicating traffic lights ahead, for a museum, a tourist sign may indicate its location)?

None *A lot*



2. How much additional (implicit) information is there to suggest that the object might be coming up (e.g. entering a village may suggest a pub or church will be present; the flow of a river may indicate where a bridge is likely to be)?

None *A lot*

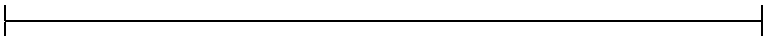


MAIN FACTOR

Taking into account the previous 2 sub-factors you have rated, please now rate the object (including any sign it may have) for how useful additional information is for Pre-Warning you that the object is there.

How useful is other information for pre-warning you that the object is there?

No information, not at all useful *Very useful information*



FAMILIARITY

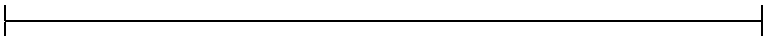
Rate the object (including any sign/logo attached to it or associated with it) on the factor of Familiarity with the object. Familiarity with the object will take into account 2 sub-factors.

SUB-FACTORS

Mark on the scale your rating for the object against each sub-factor.

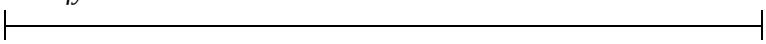
1. Does the visual appearance of the object (not including any sign or logo) make it easy for a British driver to identify what it is, i.e. is the building itself stereotypical and easily identified?

   Very difficult to identify — *Very easy to identify*



2. Does the visual appearance of the sign or logo make it easy for a British driver to identify what the object is? (e.g. a sign stating 'Mr Chan's Chinese Restaurant', or a restaurant logo with a knife and fork would both help to identify a particular object).

   Very difficult to identify — *Very easy to identify*

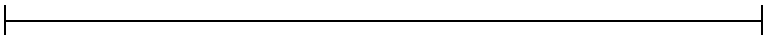


MAIN FACTOR

Taking into account the previous 2 sub-factors you have rated, please rate the object (and any sign it may have) on its Familiarity, i.e. the ease with which a British driver could identify what it is.

Taking into account the object and any sign or logo, how easy is for a British driver to identify what the object is?

Very difficult to identify — *Very easy to identify*



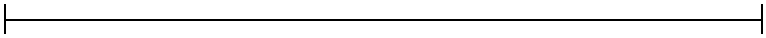
EASE OF NAMING

MAIN FACTOR

Rate the object (including any sign/logo attached to it or associated with it) on the factor of Ease Of Naming. Ease Of Naming has no sub-factors. For the object (and any sign it may have), please give an overall rating for the extent to which you could give the object one unique, unambiguous name.

If all British drivers were asked to name this object (taking into account any signs/logos), how many different names could be given to it?

Many different names *A unique name*



INFLUENCE OF SURROUNDINGS

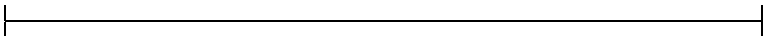
Rate the object (including any sign/logo attached to it or associated with it) on the factor of Influence Of Surroundings on how easy it is to pick out the object from its surroundings. It is important that this is considered when close to the object. Influence Of Surroundings has 2 sub-factors.

SUB-FACTORS

Mark on the scale your rating for the object against each sub-factor.

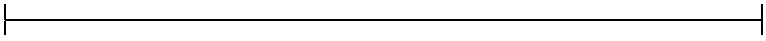
1. How much visual clutter is there next to or behind the object?

A lot of clutter — *No clutter*



2. How much visual clutter is there in front of the object?

A lot of clutter — *No clutter*

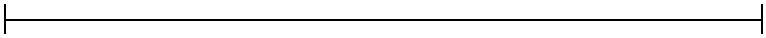


MAIN FACTOR

Taking into account the previous 2 sub-factors you have rated, please now rate the object (including any sign it may have) for Influence Of Surroundings on how easy it is to see the object.

How easy is it to pick out the object from its surroundings?

Very difficult — *Very easy*



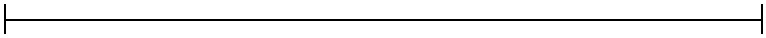
SIMILARITY OF APPEARANCE

MAIN FACTOR

Rate the object (including any sign/logo attached to it or associated with it) on the factor of Similarity Of Appearance with other objects in view. Similarity Of Appearance has no sub-factors. For the object (and any sign it may have), please give an overall rating for the number of other objects in view of same or similar type.

How many other objects of similar appearance are there around the object?

Object looks completely different to everything around it — *Object looks exactly the same as several things around it*



USEFULNESS OF LOCATION

Rate the object (including any sign/logo attached to it or associated with it) on the factor of Usefulness Of Location of the object in relation to its use either in (1) helping you to identify a manoeuvre, or (2) providing confirmation of your progress along a route.

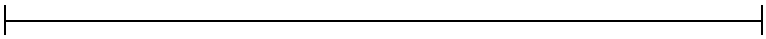
For each object, you will be told whether it is being used in relation to a manoeuvre or for progress. Please follow the instructions contained within each sub-factor according to whether the object is a manoeuvre or progress object. Usefulness Of Location will take into account 3 sub-factors for manoeuvre objects, and only one factor for progress objects.

SUB-FACTORS

Mark on the scale your rating for the object against each sub-factor.

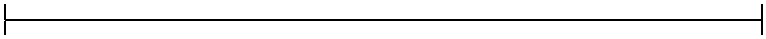
1. For manoeuvre objects only, how useful is the lateral (side to side) positioning of the object in relation to the manoeuvre? For a manoeuvre, the closer laterally the object is the point where you would start to make a turn the better. For progress objects, please place a mark at 'very useful'.

   Not at all useful *Very useful*

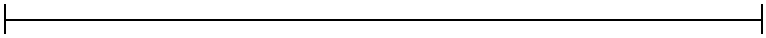
2. For manoeuvre objects only, how useful is the longitudinal positioning (i.e. along the road) of the object in relation to the manoeuvre? The usefulness of an object decreases rapidly with distance after a manoeuvre, and decreases at a lesser rate with distance before a manoeuvre. You should ignore whether the object is to the left or right of the road. For progress objects, please place a mark at 'very useful'.

   Not at all useful *Very useful*

3. For manoeuvre and progress objects, is the perceived spread of the object useful for the task? (For 'progress' it may be good for the object to be spread over a large distance, for a 'manoeuvre' it may need to be more precisely locate.)

   Not at all useful *Very useful*

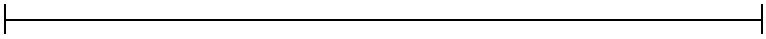
   

MAIN FACTOR

Taking into account your ratings on the previous 3 sub-factors (for manoeuvres) or last sub-factor only (for progress), please now rate the object (including any sign it may have) for how Usefully Located it is in relation to either helping identify a manoeuvre, or confirming that you are on the right route.

How useful is the location of the object in terms of being able to use it for the stated task?

Not at all useful *Very useful*



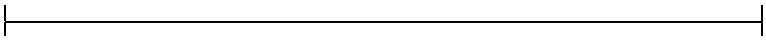
LEVEL OF TASK DEMAND

MAIN FACTOR

Rate the object (including any sign/logo attached to it or associated with it) on the factor of Level Of Task Demand due to the driving environment. We are interested in the demand on the driver while they are looking for the object and using it for navigating. We are not interested in the complexity of any manoeuvre the driver actually carries out. Level Of Task Demand has no sub-factors. For the object (and any sign it may have), please give an overall rating for the likely Level Of Task Demand on the driver.

How high are the driver's task (driving) demands likely to be when they are looking for this object?

Very high *Very low*



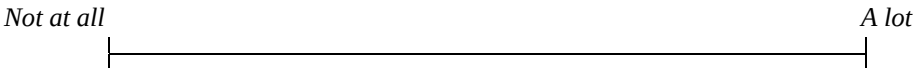
DEGREE OF INTERACTION

Rate the object (including any sign/logo attached to it or associated with it) on the factor of Degree Of Interaction with the object while driving. Degree Of Interaction with the object while driving will take into account 2 sub-factors.

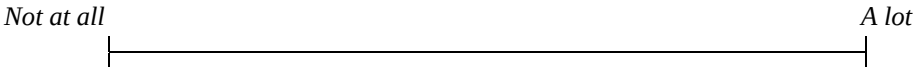
SUB-FACTORS

Mark on the scale your rating for the object against each sub-factor.

1. How much do you use the object for planning (strategic) aspects of your journey (e.g. a driver may use objects such as signs, car parks and petrol stations to help them decide on routes, where they might stop on-route, where to park etc)?



2. How much does the object impact on the physical driving (control) task (e.g. a driver will physically react to objects such as traffic lights, lane markings, give way signs, bends etc)?



MAIN FACTOR

Taking into account the previous 2 sub-factors you have rated, please now rate the object (including any sign it may have) for how much a driver would Interact with it (thinking, planning, physical car control) while driving.

How conscious will you be of this object because you interact with it as part of the driving task?