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ROUTING ASSESSMENT OF DYNAMIC ROUTE GUIDANCE SYSTEMS

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Executive summary

The Department for Transport (DfT) contracted TRL to produce a Routing Assessment Guide that can be used by industry, Government authorities or an independent body to contribute to the assessment of dynamic route guidance systems (DRG). This final report describes the work done and includes the Routing Assessment Guide in the appendices.

In the UK a DRG is required to be licensed under the Road Traffic (Driver Licensing and Information Systems) Act 1989. Before issuing a license the DfT assesses a system for satisfactory human machine interaction and safe routing and the guidelines developed by this project were intended to provide a tool which could be used to assess licensable systems for good routing. The licensing regime is now under review and therefore the guide has been produced as a best practice guide, including checklists, to assess whether a system meets minimum criteria for safe routing. Consequently the guide may be used internally by an organisation for developing and assessing a system and externally as an assessment tool. Within industry the guide is aimed at the Product Responsible Organisation (PRO), that is, the entity with authority to establish a new, or change an existing, product specification.

The first stage of the project was a state-of-the-art review, which revealed the proliferation of route guidance devices for use in vehicles. There are many different types of devices offered: original equipment integrated into the vehicle, in-car entertainment equipment incorporating route guidance, purpose designed units fitted by the aftermarket, portable devices to be temporarily mounted in the vehicle, personal digital assistants and mobile phones. In addition it is possible for drivers to assemble their own system from, for example, a PDA, separately purchased software and a Bluetooth enabled GPS receiver. The possibility to assemble a system from separate parts or to enhance a system by buying an extra component, such as a traffic data service, makes it difficult to define the route guidance product and the organisation that should follow a design guide.

An important part of the project was to consult with industry stakeholders and ensure that the guidelines produced by the project not only represented best practice, but were broadly acceptable to responsible members of the industry. One of the results of the review was a structured list of stakeholders (motor manufacturers, DRG suppliers and database suppliers) and consultations were held with representatives of each. Before this consultation could start, draft guidelines were produced and the mechanics of the licensing process defined to present to the stakeholders. The draft consultation document included the recommendation that approval for a licence should be based on a self-assessment, against the assessment guide, by the product responsible organisation and this recommendation was well received by the industry.

Some of the other comments received during the consultation were more critical and partly reflected the early draft state of the guide. These comments showed a need to develop performance criteria and to place more emphasis on performance and less on process assessment. The checklists had been proposed but not developed at the time of the consultation. Those consulted believed that the addition of checklists would be a considerable enhancement.

Many of the remaining issues related to map accuracy, which the developers emphasised are controlled by the map database suppliers, not the system developers / suppliers.

One mapping issue not controlled by the map supplier, is the age of the map data when the system is delivered to the customer. Good guidance requires good knowledge of the current road network, including traffic management regulations such as one-way streets and banned turns. Therefore, DRG systems need map data that are as up to date as possible. The original draft specified that map data should be no more than a year old at the point of sale. Many industry representatives said that a year was unattainable and so 18 months has been included in the final version.

The concerns about the lack of performance criteria have been addressed, but it is difficult to specify exact pass criteria for routing algorithms. The approach taken has been to specify a set of trials A, B and C:

- Trial A to assess the proportion of illegal or inappropriate instructions

- Trial B to assess the overall routing strategy
- Trial C to assess the response to driver behaviour, e.g. diversion from route

Minimum standards for the coverage of the trials are set out in the guidelines. Trials A and C are undertaken by driving equipped vehicles, but trial B is expected to be conducted using a simulation system. This allows for a very large set of routes to be tested in a relatively short length of length of time.

DRG systems reroute drivers in response to information about traffic problems and delays on the network. It is difficult to test the quality of traffic data. The requirements are that notification is received of all significant delays and that notified delays are realistic. Therefore, the guidelines suggest that if the provider of traffic data is not recognised in the industry as good and reliable, then there is a need to demonstrate the quality of the data.

Traffic problems are unpredictable and variable. Therefore, structured development and testing requires a simulation system that can inject specific traffic information to test the DRG system's response; the guide specifies the use of such a system for development and testing.

The final stage of the project was to pilot the guide with two DRG system providers to test the feasibility of following the guide and to ensure that it fitted with industry good practice and did not create unnecessary extra work. Honda and Trafficmaster kindly volunteered to undertake pilots. The pilots proved to be very useful and revealed several places where refinements were required. They also demonstrated the benefit of the guide as some potential improvements in the systems were revealed.

The overall conclusions from the pilot were that the guide is compatible with the development and testing programmes of responsible DRG product developers and is sufficiently comprehensive to represent a good standard of best practice in the DRG industry, supporting the development of safe and effective routing strategies.

Abstract

This report describes work done in a project to develop a Routing Assessment Guide for Dynamic Route Guidance systems for vehicles. The resulting guide is included in the appendices. An initial state-of-the-art review emphasised the range of devices available to drivers and analysed the industry to identify the range of stakeholders who should be consulted to ensure that the guide was acceptable and helpful to the industry; a fundamental requirement of the project. The vehicle and route guidance industry was consulted on an initial draft, which was designed to present guidelines for system development and to be used by the developer to self-assess the resulting product. The industry approved of the principle of self-assessment, but asked for additional performance criteria and less emphasis on assessment of process rather than performance. The guide was modified and developed in light of those comments. The revised document was piloted with representatives of two companies before the final guidelines document was produced. It was concluded from the pilot that the guide is compatible with the development and testing programmes of responsible DRG product developers and is sufficiently comprehensive to represent best practice in the DRG industry, supporting the development of safe and effective routing strategies.

1 Introduction

The Department for Transport (DfT) commissioned TRL to produce a "Routing Assessment Guide" which can be used by a Government Authority as well as industry to assess a DRG for satisfactory navigation routing.

This final report summarises the work done and the findings of the project.

1.1 Background to the project

In vehicle navigation systems can help reduce congestion and improve road safety but if the routing information is not well presented these systems could have an adverse effect.

A system providing Dynamic Route Guidance (DRG) currently (April 2006) requires a licence under the Road Traffic (Driver Licensing and Information Systems) Act 1989 and the associated Exemption Order (Statutory Instrument, 1990)[1]. Dynamic systems, as defined by the Exemption Order, provide specific directions to the driver as to the precise route which that vehicle should follow, in such a manner that the directions may be revised as the traffic conditions change, during the course of the journey. (NB route guidance systems which do not take prevailing traffic conditions into account, sometimes known as static systems, are not required to be licensed). Before issuing such a licence, the Department assesses a system for satisfactory Human-Machine Interaction (HMI) safety as well as safe navigation routing. The DfT is currently reviewing the licensing regime.

There is a satisfactory means of assessing the HMI safety (*A Safety Checklist for the Assessment of In-Vehicle Information Systems (*Stevens et al, 1999)). However, apart from a brief "draft" minimum requirements document, no agreed guide or checklist existed to carry out the assessment of routing strategy of a navigation system. There was therefore a need for developing a "Routing Assessment Guide".

The development of guidelines under this project is intended to serve two purposes: as a tool which the system provider can use for designing / producing safer route guidance systems (both static and dynamic); and as an agreed (with the industry) method of carrying out an assessment of the routing strategy. As well as providing support for a self-assessment by the system supplier, the guide can also

[1] The administration of and requirement for a licence for DRG suppliers are currently under review as part of the government's overall review of regulations.

be used for an assessment, or audit of the self-assessment, by an external organisation. The principle target of the guide is the Product Responsible Organisation (PRO), that is, the entity with authority to establish a new, or change an existing, product specification.

1.2 Objectives

The overall project objective was to produce a guide for the assessment of a routing strategy. The specific objectives were to:

- Develop principles for safe and appropriate navigation system routing.
- Identify possible test methods and procedures for assessing a navigation system's routing strategy.
- Develop a guide (checklist) for system operators and the Authority to use for assessment of a routing strategy for licensing purpose.
- Design and cost a programme of dissemination, identifying the targeted audience for maximum impact of the routing assessment guide. This objective was not pursued as it was considered inappropriate to design dissemination of the guidelines whilst the licensing requirements are under review.

The guide to the assessment of a routing strategy has been written in the form of guidelines and is reproduced in Appendices A, B and C, the latter two appendices are appendices to the guideline document.

2 Methodology

2.1 State-of-the-art review

A review of the "state-of-the-art" of static and dynamic route guidance systems was undertaken as the first stage of the project to confirm current system capabilities and indicate how technology is likely to develop in the future.

The review was undertaken to provide a comprehensive picture of DRG systems including; the requirement for licensing and regulations for DRG manufacturers and suppliers, a description of DRG system components, examples of DRG products and investigation of the market of DRG systems to identify the major market players and stakeholders. A second important objective was to identify industry stakeholders and representative groups for use during the consultation phase.

DRG systems in the UK require an operating licence from the Secretary of State for Transport under Part II of the Road Traffic (Driver Licensing and Information Systems) Act 1989 and associated Exemption Order 1990. The review found that there is currently no European legislation that applies to route guidance systems and the UK is alone in licensing dynamic route guidance systems.

The various components of a dynamic route guidance system were identified as a digital map, vehicle positioning or location technology, communication link, in-vehicle computer to manage the system components and a driver interface to provide means by which the driver can enter and receive visual and audio information.

The review also provided a description of available DRG products. The market sector of navigation systems along with its value chain was investigated. The market was divided into Original Equipment Manufacturer (OEM) and aftermarket suppliers. Major manufacturers and suppliers in each segment and their responsibilities within the value chain were explored. The review found that, the DRG market is rapidly growing with increasing demand from car users. As for responsibility within the value chain, car manufacturers are usually responsible for the definition of built-in DRG system requirements. However, several other factors, such as government regulations or affordability of lifestyle products, also impact on the development of the DRG market.

Finally, relevant DRG studies and projects were identified and reviewed briefly and the future trends, both market and technological were investigated.

2.2 Draft assessment guidelines

An important part of the project was to consult with industry stakeholders and ensure that the guidelines produced by the project represented best practice and were acceptable to responsible members of the industry. Before this consultation could start, first draft guidelines had to be produced and the mechanics of the licensing process defined to present to the stakeholders. The initial consultation document was drafted and distributed soon after the start of the project so that industry feedback could be received at an early stage. This initial document was, of necessity incomplete, but was designed to contain sufficient information to elicit useful comments from stakeholders. Elements of the document to be developed later included testing procedures and checklists. In the consultations the method proposed by TRL for licensing was a self-assessment regime, where an organisation certifies to DfT that it meets the guidelines, but the DfT reserves the right to audit (or appoint an agent to audit) the assessment.

The main components of the draft document were:

- An introduction giving an overview of the licensing arrangements and the assessment framework
- Quality Management System requirements
- The audit procedure
- The routing assessment procedure – to be completed.

- Technical criteria and performance requirements for DRG. The criteria were based upon the draft minimum requirements document. The performance requirement levels given in the consultation document were largely subjective and were to be discussed with industry during the consultation.
- Annexes covering an audit checklist, audit report template, audit completion form and routing assessment tests – all to be completed.

It was felt that an introduction giving an overview of the licensing arrangements was essential to set the context for those being consulted, although the licensing and associated policy arrangements are outside the scope of the project.

2.3 Industry consultation

One of the outputs from the initial review was to recommend relevant stakeholders to be consulted. The key market players who are driving the technological development of the DRG sector were identified. Potential Consultees were split into 3 market segments. These were:

- Category 1: car manufacturers who have a strong impact since they are responsible for defining DRG requirements
- Category 2: DRG suppliers, since they have to conform to national or international standards and requirements in the manufacture and supply of safe systems
- Category 3: the map database providers, who provide the routing software and real-time data that should be accurate if users are to trust these systems

The organisations consulted are listed in Table 2-1. In addition, the map database providers Tele Atlas, NAVTEQ, and Ordinance Survey were contacted and information received on their systems and capabilities. Other organisations were contacted, but were unable to be involved in consultations.

Table 2-1: Organisation consulted

Organisation	Type of organisation	Main form of feedback
DfT	Central government	Meeting
Traffic*master* (SmartNav)	Traffic information and route guidance system supplier	Meeting
SBD	Consultant (to Toyota on DRG)	Meeting
Nissan	Car manufacture	E-mail
Jaguar	Car manufacture	Meeting
ITIS	Traffic information supplier	Meeting
DENSO	Route guidance system supplier (inc Ford)	Telephone

The main technical comments on the draft guidelines were that:

- Self-assessment is the right approach
- The scope of the assessment needed to be better defined
- The proposed checklist would considerably improve the document
- There was too much emphasis on process and insufficient on performance criteria that are practically achievable

- Many of the issues related to map accuracy, which are controlled by the map database suppliers, not the PRO

2.4 Development of the guidelines

Following the initial consultation, the guidelines were developed in the light of the comments and the missing sections produced. A further round of consultation was held with Trafficmaster and the company kindly invited TRL to attend one of their monthly feedback meetings and witness how customers' comments and complaints are dealt with.

2.5 Audit

The original project objective was to develop a system for approval of the routing strategies of DRG systems under the licensing regime defined in the Road Traffic (Driver Licensing and Information Systems) Act 1989. TRL proposed a system in which the primary process for award of a licence for DRG operation would be through self-certification by the Product Responsible Organisation. However, the Authority (DfT under the current licensing regime or a body appointed by the DfT) would probably reserve the right to undertake an audit of technical performance and quality processes within an Organisation and the internal assessments undertaken by the Organisation, or others, of the system routing performance. This Audit would be undertaken by the Authority or an appointed Agent.

2.6 Pilot trial of the guidelines and process

It was considered throughout the project that the final guidelines and approval process needed to be acceptable to members of the industry. Therefore, it was essential to pilot the process and Honda and Trafficmaster kindly agreed to commit resources to the pilot study.

The process adopted was to undertake a dummy audit followed by demonstration test drives. TRL and manufacturer's staff jointly went through the guidelines document, which had been supplied sometime before the meeting for appraisal. After this general review, the dummy audit started. The objective was not to undertake an audit, but to assess the practicality of the process. Each question on the checklist was considered by the manufacturer and commented on:

- Yes we do that and the evidence is *xxx* or in document *yyy*
- That does not fit our processes, we do *zzz*
- Not applicable to our system (e.g. a Honda system is fitted in a specific model in the range and so the user documentation does not need to specify which vehicles it is suitable for)
- Not compliant, how serious a non-compliance is that? (The issue of non-compliance is considered further in section 4.1.1.)

Following this desk based exercise, the manufacturer drove TRL staff on a demonstration of how the specified trial drives would be undertaken. An objective of the demonstration was to see how the system performed in a brief demonstration, but the main aim was for the manufacturer to confirm that the trials fitted well with its normal development and testing process.

The guidelines were revised and published as an aid to good system design and development following the pilot trials (Thompson et. al. 2006).

3 Results

3.1 State-of-the-art review

3.1.1 Categorisation of stakeholders

The categorisation of stakeholders into car manufacturers, DRG suppliers and map database and routing software suppliers has already been discussed in section 2.3 and will not be elaborated further here.

3.1.2 Types of devices

The review confirmed the proliferation of devices that can offer route guidance.

- Dedicated units integrated into the vehicle by the OEM
- In car entertainment devices with guidance installed as a replacement for the normal radio / CD / tape player
- Dedicated after-market devices permanently installed in the vehicle, e.g. Trafficmaster SmartNav
- Dedicated free standing after-market devices that can be temporarily installed in a vehicle (suction cup on the windscreen etc.) e.g. TomTom GO
- Personal digital assistants or tablet PCs with suitable software and may need connection to a GPS receiver
- Mobile phones
- Mobile data terminals

The mobile devices may link, by Bluetooth or other means to other devices: GPS receiver, RDS-TMC receiver, mobile phone. This proliferation of devices and opportunities for turning a static guidance device into a dynamic one capable of rerouting in response to traffic information considerably complicates a licensing regime.

Devices can be *on-board* or *off-board*. In a fully on-board unit, the map data, routing software and GPS receiver are all in the vehicle. An off-board device has the GPS receiver in the vehicle, but uses infrastructure links to the map database and routing software which are stored in a central server. Hybrids, in which the map data is held off-board, but the routing software is on-board are also possible.

3.1.3 Sources of traffic data

Apart from the Trafficmaster SmartNav off-board system, which uses Trafficmaster traffic data as it is collected in the Trafficmaster HQ, those systems that use dynamic traffic data employ delivery of information by RDS-TMC, which is periodically updated by the supplier.

3.1.4 Research projects

There are several projects across the world looking at advanced route guidance systems and there have been earlier projects that looked at the benefits of dynamic route guidance. These latter projects are of most relevance in identifying important points for the guidelines. In 2000, TRL undertook a comprehensive review of network assessment for DRG as well as computer modelling studies into the benefits and effects of such systems. That modelling review of DRG identified several issues relating to the implementation of systems in the UK, which included:

- **Penetration and multi-routing** – Dynamic route guidance systems can yield significant savings in travel time. However, the travel time savings are reduced at higher market penetration levels (e.g. travel times are negative at penetration levels of higher than 25%; Hounsell et. al. 1992) unless a multi-routing guidance strategy is adopted. In turn, the effective use of multi-routing requires predictions of an incident's duration and its effect (e.g. on traffic flows), and co-ordination of the guidance given to vehicles. For example, in the event of an incident, if a DRG system diverted all users to the same alternative route to avoid the delay, there is a danger of creating congested traffic conditions on the diversion route. Once the guidance system recognised increased traffic on the alternative route, it would start to divert traffic back onto the original or an alternative route to avoid such congestion. This process of "all-or-nothing" switching between alternative routes can result in large oscillations in traffic flows at higher penetration levels, which can prove problematic for some traffic control systems. In practice multi-routing may well be provided by different systems with different routing algorithms and different real-time data fidelity.
- **Link impedance –** additional link impedances can be applied to certain classes of links e.g. residential and minor roads to discourage systems from recommending "rat-runs", but there is a trade-off between limiting the road network available to dynamic route guidance systems and travel time savings. By applying impedance factors on the time taken to travel along a link, some studies have reported overall time savings of 3.3% with the whole of network available and 20% of traffic equipped with guidance Stoneman (1992). Restricting the guided vehicles to less of the network led to increasing travel times and dis-benefits to all road users. Another study, Hounsell et al (1992, 1994), showed that at a penetration level of 20% it was necessary to restrict the impedance value applied to minor roads to maintain a reasonable level of time savings for guided vehicles.
- **Network safety effect** – The use of dynamic route guidance can yield accident savings, typically proportional to the reduction in distance travelled by the guided vehicles. Network safety effects of DRG have been studied by Chatterjee and McDonald (1999) using the RGCONTRAM traffic model applied to a specific road network. The results suggested that travel time optimised dynamic route guidance in a congested urban network would result in accident reductions of a similar proportion to distance reduction. The authors also examined the use of accident risk as a guidance criterion. They felt that accident prediction models were not sufficiently disaggregate to be applied as part of the guidance process as they took no account of the immediate prevailing traffic conditions.
- Early studies into the potential benefits of the safety-optimised guidance suggest that the "safest" route is usually also the quickest route. There is, however, potential for developing better safety optimised guidance through the development of more accurate accident prediction models.

The pertinent results from this review for the guidelines are that:

- It is not possible to accurately design routes based on a "minimum accident risk" strategy directly, but the common choice of "fastest" route is a good proxy
- Link impedances to restrict use of residential routes should not be so high that a vehicle is likely to be routed away from the destination where the natural route from the origin to the main road is longer than the alternative in the "wrong" direction and vice versa when arriving at the destination.
- If in the future penetration rates for DRG approach 20%, or higher, then the guidelines may need to include advice to avoid "all-or-nothing" rerouting.

3.1.5 Technology trends

An observation of the market shows the current trend of navigation technology is towards the integration of route guidance systems with other units e.g. Personal Digital Assistants that will provide door to door navigation even once the user is out of the vehicle. Many manufacturers are now utilising off-board map technology too, so that an entire map database does not need to be stored on the device. They also require the user to pay for each route they download.

Some reports have suggested that future route guidance systems are likely to integrate radio-based internet access so that they can incorporate real-time information on congestion and roadworks. These systems are likely to be voice activated to allow drivers to verbally seek and retrieve information.

3.1.6 Market Trends

The navigation systems market has been restrained in the past by several factors such as the high initial cost, the incomplete availability of digital mapping and to some extent the feeling that these systems are complex and time consuming to set up. However, given the technology trend towards the integration of systems, key market players are consolidating in the market to produce integrated systems from disparate modules to reduce system complexity from the operator's point of view. For example, Robert Bosch and Blaupunkt Werke have merged to become major players in producing car radios, navigation equipment and telematics systems. Mannesmann VDO is also the result of the merger of two separate companies which has emerged as a leading first-tier supplier of integrated systems for the information, navigation and traffic management to the world's vehicle manufacturers.

As technology continues to improve, the market driver is also towards increasing accuracy of navigation systems. This will lead to the opening of more mainstream markets for applications with higher accuracy previously restricted to niche markets.

3.2 Consultation

The main themes coming out of the consultation on the guidance document were industry approval of the self-certification approach and the need for a strong set of routing principles and guidelines (which was not in the original outline draft). Below is a summary of the main comments received from industry during consultation:

- Consultees approved of the self-certification approach.
- The document should identify who the licence applies to.
- Need to clarify the scope of the assessment – e.g. one party falsely read that the QMS audit covered the production of the hardware components.
- Explain the safety and traffic issues associated with DRG and thus why a licence is needed.
- Specify routing principles to address the safety and traffic issues. From this develop guidelines and performance requirements to achieve these principles.
- The process approach is needed after licence approval in-order to avoid regular external performance testing after updates to the system / map etc.
- The process approach should not be used in isolation.
- Simplify the process requirements.
- The proposed audit checklist will be useful.
- Many of the performance criteria levels (in the first draft document) are unlikely to be achieved even with the highest quality systems on the market.
- Most of the performance criteria are based upon map quality. It is important to research what is currently available and set realistic targets.
- Fidelity of map performance criteria should be time dependent based on how long ago a change to the road network occurred.
- Some of the performance criteria in the first draft document are HMI issues not routing.

- The assessment framework should address more dynamic routing issues.
- The quality of traffic information and routing will tend to be market driven with the "better" systems dominating.
- Many of the leading systems on the market are German or Japanese. This could create language and contact difficulties.

The age of the basic map data supplied with a system was a problematic area. Although all agreed on the need for up to date maps, the proposed 12 months age limit could not be met by some organisations with their current procedures. Map data needs to be tested and verified after delivery from the producer before delivery in a DRG. Several suppliers have a one year development and testing cycle, which includes system and software improvements as well as map database updates and testing. Consequently maps delivered to users are often over 1 year old from the date of release from the database supplier. System suppliers can minimise the age of the map data by supplying systems without map data and the dealer adding the latest version at the point of sale.

3.3 Development following consultation

The draft guidelines document was reviewed in the light of the comments received and the missing sections, such as the checklist completed. Several of the comments from stakeholders emphasised the dependence of the PRO on the map database supplier for the accuracy of information on the classification of roads and traffic management measures, one-way streets banned turns etc. and the practical difficulties of specifying thorough testing in the guidelines.

The approach taken to certification of map data had three elements:

- Map data should be from a source generally accepted as reliable in the industry, otherwise, the PRO should be able to justify the quality of the data
- On-road trials should be used to ensure that the system use of the map data results in sensible routing instructions to drivers; that is, instructions to make illegal or inappropriate manoeuvres are rare events.
- Procedures should be in place to report errors to the map supplier and to audit the response to the reports.

The issue of the age of map data was addressed by stating that the map data should not be more than 18 months old at the time of supply to the customer. The intention was to allow a reasonable period for checking a new release from the map supplier before releasing to customers and allowing that tested database a reasonable life.

One aim of the guidelines is to minimise the probability of inappropriate use of DRG, such as use of a system designed for cars in an HGV. Unfortunately, comprehensive map data relevant for large vehicles (bridge heights and weight and size restrictions) is not available. Therefore, the guidelines can only say that the type of vehicle for which the system is designed should be clearly stated in the instructions. It is not currently possible to provide reliable route guidance for large vehicles.

A further consultation was undertaken with Trafficmaster, which resulted in refinements of the document. In particular it was noted that specifying the quality of dynamic traffic information is similar to the problem of specifying how to assess the accuracy of map data and a similar approach to that previously adopted for the map data was taken for the traffic data:

- Dynamic traffic data should be from a known reliable source or the reliability demonstrated.

The use of the traffic information to initiate rerouting when appropriate, and not when the diversion does not offer significant benefits, should be demonstrated by simulation. As traffic incidents are not predictable, structured testing requires generated traffic events in a simulation system.

3.4 Pilot

As described in the methodology section, the revised guidelines were piloted with Honda and Trafficmaster. The exercise proved very useful with an example of an on-board OEM system and an off-board one. Some of the initial comments pointed out the need for care in noting where certain issues are not applicable to all systems. For instance, a guideline to ensure that ‘the user documentation specifies the types of vehicle for which the system is suitable’ is not applicable to an OEM system that is tuned for the specific vehicle model in which it is fitted.

The difficulty of defining a DRG system when nomadic devices can be built up by a user was pointed out. Initially a device may not have the capability to receive and respond to traffic information, but can be enhanced to do so. It was also noted that some devices provide in-vehicle guidance and pedestrian guidance, which can be used to complete a journey after parking the vehicle. However, the possibility of providing routes in a vehicle that are only relevant to pedestrians, e.g. in a pedestrian shopping area, requires special precautions to avoid use of the ‘pedestrian mode’ in a vehicle.

The need for accurate location of the vehicle had already been specified; for systems that use GPS a good antenna is required. However, where a system receives traffic information via RDS-TMC the reliability of the response to traffic information relies on good reception of the message, which should also be included in the guidelines.

3.4.1 Age of supplied maps

It was pointed out that the requirement for up to date maps also applies to location referencing systems, e.g. post codes used to define destinations and “points of interest” data.

3.4.2 Checklists

There were various comments on the checklist, both general ones and specific points when going through the demonstration “audit” as described in section 2.6.

The use of simulation to enable testing of the routing algorithm quickly over a large range or routes was considered to be an important tool for responsible manufacturers and should receive greater emphasis in the checklist. Similarly more detail should be specified to ensure that the road tests are sufficiently comprehensive. Question 7.3 in the technical checklist on the response to the clearance of a traffic delay only asks that the system does not continue to reroute after the clearance. The guidelines are more demanding, saying that when an incident clears, then affected routes should be reassessed to see whether any drivers would be better returning to the original route. It was felt that the checklist question was adequate for current purposes, but that rerouting when an incident clears is a useful suggestion for future developments.

A comment was received that the quality checklist appeared to be intrusive and to delve deeply into company procedures. The TRL opinion is that if an external audit of a company is required, then it will *need* to be detailed and intrusive. It was noted that section 4 of the quality checklist needed to explicitly consider both off-board and onboard components and interactions between them. Section 9 included the need to *verify* the performance of agents. It was pointed out that an organisation could be an approved supplier for many motor manufacturers and under the guidelines would be responsible for verifying the performance of all those manufacturers’ franchised outlets; an extremely large task. The need to *verify* has been changed to one to *define* the work to be done by the agent and to have procedures in place to resolve problems with dealers’ performance.

3.4.3 Test drives

The principal aim of the test drives in the pilot trial was to confirm that the assessment proposals fitted the development and testing programme of responsible developers and did not omit any important points covered by the developer’s testing. This objective was met.

It was also pointed out that a system that uses just GPS will need to go a minimum distance off route, before it can be certain that a reroute is required. In very slow moving, congested traffic it could take an appreciable time to cover that distance, causing a delay in the overall system response. Also, calculating a new route to a destination several hundred kilometres away will take longer than calculating one to a nearby destination. The guidelines were modified to reflect the delay in detecting that a vehicle is off route in slow moving traffic, but the complication of recommending different recalculation times for different lengths of routes was not felt to be justified.

3.4.4 Conclusions following pilot

The guidelines and checklists are compatible with the two example systems assessed in the pilot study and with the development and testing programmes of the organisations responsible for those systems. The system suppliers found the guidelines useful and agreed that the points covered by them should be included in the development process. Some improvements have been identified and incorporated in the published version of the guidelines (Thompson et. al. 2006), which is reproduced in appendices to this report. It is believed that the published guidelines are reasonably comprehensive and the assessment provides a good exercise and verification of system routing capabilities.

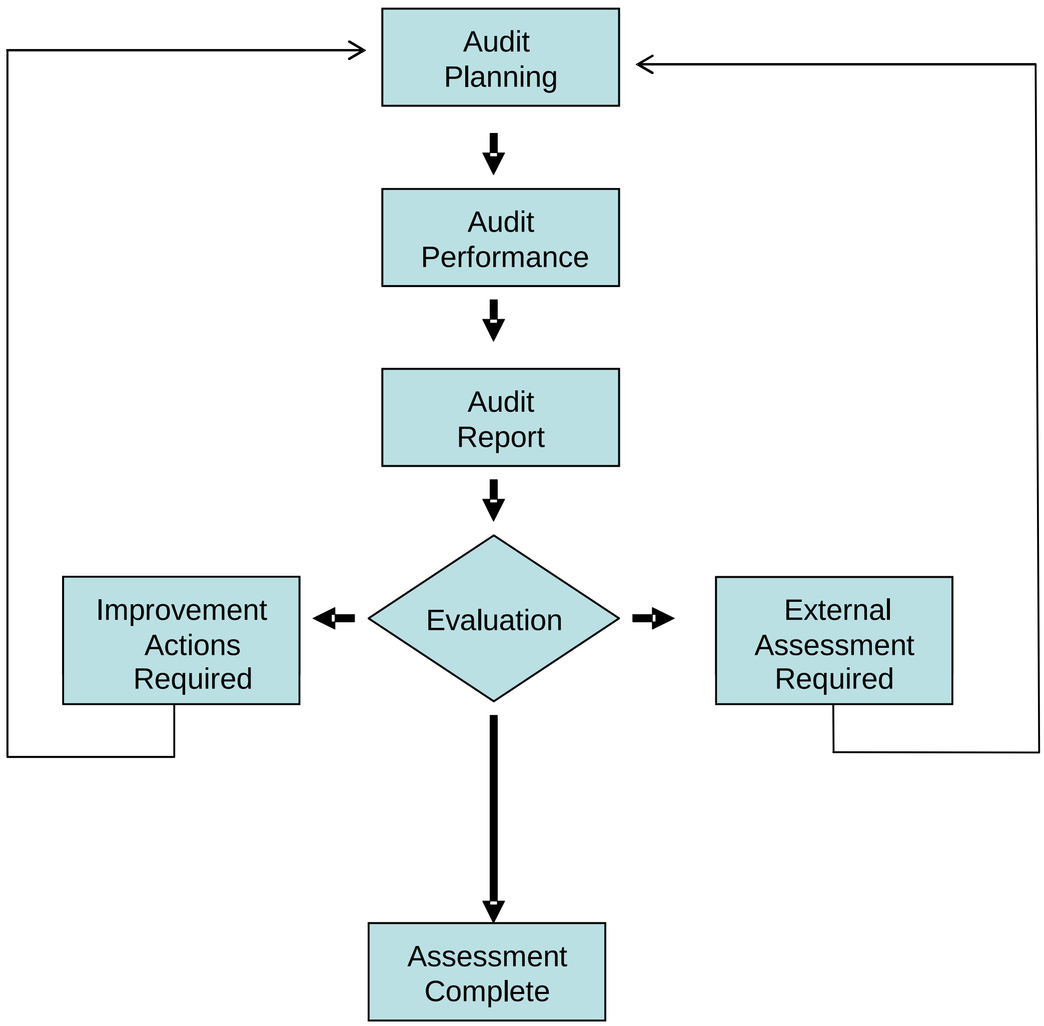
3.5 Audit

The project brief included the requirement to recommend how licensing of the routing element of DRG should be undertaken as well as to produce guidelines on developing good routing systems. TRL proposed that the procedure should be by each organisation self-certifying its DRG system or systems against the guidelines produced in the project, but backed up by an audit process where the licensing authority considered that the self-certification should be confirmed by an outside body.

A draft audit process was developed and discussed with industry during the consultations and used during the pilot as described in section 2.6.

The process is described below and could form part of the licensing regime, depending on the outcome of the licensing review.

3.5.1 Overview of audit process



3.5.2 Audit planning and preparation

When planning and preparing to carry out the Audit, the Auditor will:

- Review any relevant Procedures and previous audit reports.
- Contact the Applicant Organisation.
- Confirm the purpose of the audit with the Organisation.
- Discuss / agree the scope of the audit; this will include two main areas:
    a) The Organisation's own technical assessment of routing performance.
    b) Relevant quality processes and use of appropriate standards by the Organisation.
- Plan a timescale for the Audit with the Organisation within an overall timescale agreed by the Authority.
- Arrange an initial meeting with the Organisation.

The Organisation will be invited to:

- Identify to the Auditor a primary contact person and a nominated Deputy.
- Provide a full description of the System.

- Provide a summary of the documentation available in support of the audit.

If a DRG system scheduled for audit is subsequently identified as unsuitable for audit in the timescale e.g. too early in its lifecycle, the Authority will be informed and an estimate provided of when the system is likely to be ready.

3.5.3 Opening meeting

When the Auditor and Organisation have agreed that the Audit can commence, an initial meeting will take place when the Auditor will:

- Confirm the audit purpose and scope.
- Explain the overall process of Assessment.
- Confirm the agreed timetable.

3.5.4 Audit performance

The Auditor will:

- Use a checklist to record progress (expected to be the checklists in the appendices to the guidelines).
- Record facts which provide evidence of appropriate:
  - ➢ Internal Quality processes.
  - ➢ Use of appropriate standards.
- Record facts which provide evidence of appropriate technical assessment by the Organisation of DRG routing performance.
- Identify non-conforming areas.
- Review and provisionally agree the facts and evidence of each non-conformance.
- Summarise at the end, to ensure no doubt about key issues.

3.5.5 Draft audit report

Following completion of the audit, the Auditor will:

- Analyse the issues identified seeking further clarification from the Organisation, as required.
- Produce a draft Audit Report.
- If there are any non-conforming areas:
  - ➢ Clearly identify the issue.
  - ➢ Draft proposed actions that would be required to address the issues reported and the root causes.
- The Auditor will provide a copy of the draft Audit Report to the Authority and to the Organisation.

3.5.6 Agreed audit report

The Organisation will be invited to:

- Respond in writing to the draft Audit Report.

- Identify, in principle, areas of agreement and disagreement with non-conforming items.

The Auditor will then:

- Agree a final Audit Report with the Organisation (identifying, if necessary, any areas of specific disagreement).
- Provide a copy of the Audit Report and evaluation (see below) to the Authority and to the Organisation.

3.5.7 Evaluation

The auditor will evaluate the audit. The possible outcomes are:

- No non-conformances identified, auditor recommends to the Authority that a licence should be granted.
- Non-conformances identified and improvement actions agreed with PRO. PRO undertakes improvement actions and applies to be re-audited.
- Auditor is not satisfied with some of the evidence of claimed conformance and cannot agree relevant improvement actions with PRO. Auditor reports to the Authority that an external assessment of the relevant items is required.

3.5.8 Improvement actions

In areas identified by the Audit Report as non-conforming, the Organisation will be invited to:

- Propose what Improvement Actions they will take.
- Ensure all actions have clearly defined deliverables and timescales.
- Notify the Auditor that a follow-up audit will be required.
- Keep the Auditor advised of any potential problems before a delay occurs.

Self certification from the Product Responsible Organisation and auditing of routing performance is considered to be the primary mechanism for assessing suitability for licensing. However, exceptionally, after auditing, additional external assessment of routing performance may be requested by the Authority.

The technical content for external assessment will be a matter for the Authority, but is likely to be based on the relevant sections of the guidelines produced in this project. Results will be prepared in a form such that re-auditing can take place.

3.5.9 Completion of audit

An audit is complete when one or more of the following conditions apply:

a) there is an Agreed Audit Report that does not identify any non-conforming areas.
b) the Organisation has confirmed that it has withdrawn its application for a licence.
c) Such time has elapsed that it becomes apparent that the Organisation will not complete all the identified Improvement Actions.
d) The Authority formally requires the assessment process to be terminated.

On completion of the audit, the Auditor will:

- Prepare an Audit Completion form clearly identifying the outcome of the audit.

- Inform the Authority and the Organisation, in writing, to confirm closure of the assessment and provide a copy of the Audit Completion form.

3.5.10 Re-auditing of improvement actions

If a follow-up Audit is requested by the Organisation, the Audit Planning and Preparation process will be re-commenced taking particular note of Improvement Actions carried out by the Organisation or of other external assessments completed.

4 Discussion

4.1 DRG licensing regime

The licensing regime is currently under review, but its existence has had a considerable influence on this project. Manufacturers have provided valuable input to the development of the guidelines based on their current position with regard to DRG licences and the proposal in the discussion document that licences should be granted on the basis of a self-assessment. The manufacturers strongly supported the principle of self-assessment. They were of the opinion that the motor trade is a responsible industry that takes the need to develop safe systems very seriously. However, some concerns were expressed that manufacturers of nomadic devices may not have the same background and portable devices do not have to meet the same safety standards as those installed in vehicles.

Because of the uncertainty of the future licensing requirements, the guidelines document (Thompson et. al. 2006) has been written as a good practice guide that includes a self-assessment which can be used by an organisation as an internal audit to assess how well it has followed the guidelines. The checklists could also be used by an external organisation to audit the product and developer, possibly as part of a licence requirement. It is believed from the experience of piloting the guidelines that they will be valuable irrespective of the outcome of the licensing review.

4.1.1 Non-compliance

The guidelines have been developed as a good practice guide. However, if systems are to be licensed and the guidelines used as a benchmark, then the issue of whether a system is compliant becomes much more serious. It would then be necessary for the licensing authority to assess any non-compliance and decide whether the non-compliance is acceptable (and a licence can be issued), or whether total compliance is required. The area where non-compliance is most likely to occur in otherwise good systems is in the maximum age of map data at the point of system sale.

4.2 Nomadic devices

There is a particular problem in assessing nomadic devices as the final DRG system may be assembled by the user from separately sourced parts, e.g. PDA, routing software, Bluetooth enabled GPS receiver, Bluetooth enabled RDS-TMC receiver. The final performance will depend not only on the quality of the components, but also their compatibility and, crucially, the skill with which the driver assembles and installs the packages to provide good reception of GPS and RDS-TMC, and usability from the driver's seat.

It is hoped that a developer of hardware or software for in-vehicle route guidance would want to follow the guidelines to the greatest extent possible. For example a developer of routing software would identify and follow the relevant principles:

- The system and supporting literature should be designed to convey expectations to the driver that are consistent with the system's performance.
- The system should not direct vehicles onto roads that are inappropriate for the class of vehicle.
- The system should properly take account of Road Traffic Orders and the Highway Code.

It should also follow all the guidelines relevant to these principles and the quality system guidance. In addition the instructions should make clear to the purchaser that the system requires:

- A GPS unit that will provide the location of the vehicle sufficiently accurately that illegal or inappropriate instructions are not given to the driver, and any map displays the correct position.

- Map data that is sufficiently accurate, comprehensive and current that the driver can be given guidance consistent with the road network.
- A good source of dynamic traffic data and a reception system to ensure reliable receipt of traffic messages.

Similarly, the maker of a custom route guidance device that can be enabled to use traffic information should follow the guidelines, including those for using dynamic traffic information even when the product requires an extra purchase to become DRG.

Although this project is not directly concerned with HMI issues, it is important to note that nomadic devices should include adequate guidance on HMI issues.

4.3 Mapping and location issues

4.3.1 Age

The guidelines specify that maps should not be more than 18 months old and it is considered that a good practice guide cannot specify a greater age as some manufacturers easily meet this standard. However, it is acknowledged that some suppliers (whilst providing systems that would otherwise be considered of high quality) do not always meet this standard. It would be for the licensing authority, pending the licence review, to decide whether supplying maps less than 18 months old is an absolute requirement for a licence or whether some leeway may be allowed to cover testing the map data by the PRO.

In addition to map data DRG systems need some means for the driver to specify his or her destination. The normal means is by post codes. To ensure efficient and accurate routing, that location data must also be up to date. The guidelines, therefore, specify the same maximum age for location referencing data as for map data.

4.3.2 Map supplier performance

NAVTEQ and Tele Atlas are the two main map suppliers and are in effective control of when changes are made to the map databases. It is not realistic to expect a DRG organisation to specify that a specific change should be made within a set time period. Hence, some parts of the guidelines have been written to specify the process whereby the PRO should report mapping problems and monitor the response of the supplier, rather than in terms of the performance of correcting the problems, which is controlled by the map supplier.

4.3.3 Quality of map data

It is difficult to test the quality of map data comprehensively and so the guidelines specify that the map data should be from a source generally accepted as reliable in the industry, or the PRO should have other evidence that it is reliable and accurate. As described above, the PRO should have a procedure to report known map errors.

4.4 Traffic data

Similarly it is difficult to test the quality of traffic data. The guidelines suggest that the traffic data supplier notifies the DRG system of all significant delays and that those notified delays are a realistic representation of on-street conditions. A similar approach was taken to guidelines concerning the quality of traffic data to that used with the map data; the data should be from a source generally accepted as reliable in the industry or its reliability should be demonstrable.

Because traffic problems are variable, it is not sensible to drive around and wait for a problem to occur on the route that the vehicle is on and see how it responds. Structured development and testing requires a simulation system that can inject specific traffic information to test the DRG system's response; the guidelines identify the use of such a system for development and testing.

4.5 Performance criteria

One of the criticisms by the manufacturers of the draft guidelines in the initial consultations was that they relied too heavily on assessment of processes and did not specify sufficient performance criteria. These concerns have been addressed, but it is difficult to specify simple criteria that will reliably indicate the overall quality of routing algorithms. The approach taken has been to design a set of trials A, B and C.

- Trial A to assess the proportion of illegal or inappropriate instructions
- Trial B to assess the overall routing strategy
- Trial C to assess the response to driver behaviour, e.g. diversion from route

Minimum standards for the coverage of the trials are set out in the guidelines. Trials A and C are undertaken by drives in equipped vehicles, but trial B is more likely to be undertaken using a simulation system. Using simulation allows for a very large set of routes to be tested in a relatively short length of time.

4.6 Omitted item

The review of relevant research identified the problem of "all or nothing" routing when system penetration rates approach 20%. Currently all vehicles using the same DRG system on a given route will receive the same guidance in response to a traffic incident. There are limited sources of traffic and map data and different routing engines will probably give similar routes when given the same information; therefore, it is likely that many systems will give the same advice in response to a traffic alert. However, despite the rapid growth in sales of nomadic devices, it is not considered that the penetration of Dynamic Route Guidance is yet approaching a level at which the need for proportional rerouting is justified in the guidelines.

One difficulty with only rerouting a proportion of drivers is in calculating that proportion. The desired solution is to divert *x*% to route *a*, *y*% to route *b* etc. so that the journey times on each diversion route, and on the original, are all the same. As with all-or-nothing rerouting, suitable measures are also needed to avoid large diversions along sensitive (e.g. residential) roads. Unfortunately, such a calculation requires extensive knowledge of the current network conditions and the changes that will be caused by the diversion. Given the complexity, it is considered impractical to include meaningful guidelines to system producers on this aspect of routing.

5 Conclusions

A set of guidelines for the development and testing of the routing properties of DRG systems has been developed as a good practice guide.

The guidelines document includes checklists that can be used for a self-assessment of adherence to the guidelines (or could be used by an external body to audit the performance of a system and product responsible organisation).

The guidelines and checklists are compatible with the two example systems in the pilot and with the development and testing programmes of the organisations responsible for those systems. The system suppliers found the guidelines useful and the points covered should be included in the development process. It is believed that the published guidelines are reasonably comprehensive and provide a good exercise and verification of system routing capabilities.

Following the guidelines is likely to result in safer and more effective routes.

The status of the guidelines will depend on the outcome of the review of DRG licensing requirements, but, regardless of the outcome of that review, the guidelines are expected to be a valuable aid to developing good systems.

6 Recommendations

The guidelines should be publicised as a good practice guide (and to get further feedback). Specific opportunities are the Nomadic Devices Forum and the TMC Forum.

The status of the guidelines will depend on the outcome of the licensing review. If they are to be required to be followed by organisations wishing to obtain a licence for a product, then further work will be required to formalise the guidelines and assessment criteria.

Acknowledgements

TRL is grateful for the time and resources provided by members of the route guidance industry in consulting on this project, particularly to P. Warner and C Barnes of Trafficmaster and J Aylett of Honda for piloting the guidelines document. The contributions to the consultation of members of: DENSO, DfT, ITIS, Jaguar, NAVTEQ, Nissan, Ordnance Survey, SBD, Tele Atlas and Trafficmaster is also acknowledged.

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Thompson S, Stevens A, Maxwell A and Wood K (2006). *Guidelines for safe and effective vehicle routing.* TRL Published Project Report PR091. TRL: Wokingham

Appendix A. Guidelines for safe and effective vehicle routing

By S Thompson, A Stevens, A Maxwell and K Wood. TRL published project report PR091, 2006

Executive summary

Driver information systems have the capability to improve the operation of traffic on roads when well designed. Conversely, poorly designed systems may distract drivers or provide inappropriate assistance resulting in a deterioration in travelling conditions, potentially both in terms of safety and efficiency. The Department for Transport commissioned TRL to develop guidelines for the development and assessment of efficient routing within Dynamic Route Guidance (DRG) systems. In-vehicle route guidance systems calculate a route between the origin and desired destination and provide turn-by-turn directions to the driver. Dynamic Route Guidance systems are those guidance systems that can re-optimise a route in response to information about adverse traffic conditions whilst the vehicle is being driven along the route. Guidance systems can be either onboard or off-board. In an off-board system the required route for each vehicle is calculated centrally and sent to the vehicle over the infrastructure. In the onboard system all the routing is done in the vehicle, the only external link is to a source of dynamic traffic information.

Project methodology

The project started with a review of existing systems and market trends. Following the review, TRL drew up draft guidelines and consulted widely with the DRG industry. Following the consultation, the draft was modified and extended and then piloted with a motor manufacturer that supplies an onboard system and a producer of an off-board DRG system. TRL would like to acknowledge the assistance of all those who participated in the consultation and particularly the two organisations that piloted the guidelines.

Guidelines

The guidelines were revised following the pilot trials and the result is this document, which is published as a guide to designers and developers of DRG systems to aid the development of good routing algorithms that will enhance the efficiency and safety of traffic. These guidelines are designed principally for DRG, but only some parts refer to the use of traffic information and the consequent dynamic rerouting. The remainder is equally applicable to other route guidance systems that do not dynamically reroute. The principle target audience for this document is the Product Responsible Organisation (PRO), that is, the entity with authority to establish a new, or change an existing, product specification. This responsibility includes testing and verification of design performance for the DRG product and also includes compliance with all applicable regulations.

DRG systems come in different forms, from original equipment integrated into the vehicle by the motor manufacturer, through custom after-market units professionally installed to nomadic devices that can be placed in a vehicle by the driver.

The first section of the guidelines sets out the principles that should be followed by good routing algorithms as a set of headline principles, which are expanded in a series of bullet points giving details of what contributes to the headline. In turn, the bullet points are followed by a rationale to explain both the principle and the more detailed requirements. Good system development requires a quality control system to ensure that the development meets the design objectives. Consequently, the document includes guidelines on the quality system required. These guidelines are designed specifically for the technical requirements of DRG routing. It is recommended that all organisations, including those that are ISO9001 accredited, consider how the processes in their own quality management systems relate to routing quality issues specified in the document. The technical and quality principles are followed by a guide to assessing how well an organisation follows them. Check lists to assist the assessment are included as appendices.

These guidelines focus on routing issues, but a good DRG system also requires a well designed and implemented interface for the driver. Human-machine interface (HMI) issues are not covered in this document, but comprehensive guidance already exists, e.g. in *Design Guidelines for Safety of In-vehicle Information Systems* (Stevens, A, Quimby A, Kersloot T and Burns P, TRL report number PA372/01. TRL, Crowthorne, 2001).

A.1 Introduction

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The guidelines were revised following the pilot trials and the result is this document, which is published as a guide to designers and developers of DRG systems to aid the development of good routing algorithms that will enhance the efficiency and safety of traffic. These guidelines are designed principally for DRG, but only some parts refer to the use of traffic information and the consequent dynamic rerouting. The remainder is equally applicable to other route guidance systems that do not dynamically reroute. The principle target audience for this document is the Product Responsible Organisation (PRO), that is, the entity with authority to establish a new, or change an existing, product specification. This responsibility includes testing and verification of design performance for the DRG product and also includes compliance with all applicable regulations.

DRG systems come in different forms, from original equipment integrated into the vehicle by the motor manufacturer, through custom after-market units professionally installed to nomadic devices that can be placed in a vehicle by the driver.

The guidelines are separated into technical issues related to the routing algorithms and software and quality guidelines for the organisation responsible for the development of the system. The quality guidelines are based on ISO 9001, but customised to the requirements of DRG developers. Section A.2 details the technical guidelines and the principles on which they are based and section A.3 describes the quality guidelines for the organisation. A method to test the application of the technical principles and guidelines has been developed and is presented in section A.4. Checklists to help in this testing and the assessment of the quality system are presented in Appendices A and B.

These guidelines focus on routing issues in the system design. A good human-machine interface is also essential for safe operation of DRG. Guidance on the HMI design is available in *Design Guidelines for Safety of In-Vehicle Information Systems* (Stevens et al, 2001).

A.2 Technical Guidelines for DRG Routing

A.2.1 Introduction

This section provides a set of principles and guidelines representing best practice in the design of routing strategies for Dynamic Route Guidance systems. It draws, particularly, on Human Factors Design Guidelines for *Advanced Traveller Information Systems (ATIS) and Commercial Vehicle Operations (CVO)* (Campbell et al, 1998).

The guidelines are intended to be used by the Product Responsible Organisation as part of their design process. Nevertheless, there may be additional issues of concern to the product responsible organisation, who should, in particular, be aware of all relevant legislation, standards and guidelines.

A.2.2 Safety impacts of routing

Poor routing affects driver confidence in the instructions and the quality of the mapping database and routing algorithms have an impact on driver safety in a number of ways, including:

- Use of unsuitable roads – A system's use of a route may be one that is unsuitable for particular vehicles, e.g. high or heavy vehicles. Additionally, the route may be considered part of an environmentally or residentially sensitive area by the local authorities who are trying, for whatever reason, to minimise traffic flow down particular roads (e.g. past schools). The only acceptable use of unsuitable roads is where the origin or destination falls on that road.
- Use of less safe routes – Higher categories of roads tend to have lower accident rates, but a dynamic system may use lower category roads in order to avoid a traffic disturbance.
- Use of old map data – Systems that use on-board mapping are often not updated regularly. With an ever changing traffic environment, this could lead to instructions to take, for example, an illegal or inappropriate U-turn, the wrong way down a one-way road, a no through route.
- HMI issues of safety in use – Complex routing instructions make a system visually and cognitively demanding, increasing the distraction potential.
- Conflict between road signs and on-board guidance – Conflicting information between the system and the driver's environment may lead to confusion and an increased mental workload for a driver, all likely to increase the chances of that particular driver having an accident. In general conflicts should be avoided, but there are some circumstances where conflict is inevitable. For example:
    - When a vehicle is being routed away from the normal route due to traffic problems.
    - Where the in-vehicle information is more up to date than that displayed at the road side, e.g.on variable message signs (VMS).
    - Where a local diversion, e.g. for events or emergency roadworks, has not been notified to the traffic information supplier.

A.2.3 Principles and guidelines

The following principles and guidelines should be followed, but it is acknowledged that there will be circumstances when in practice it is impossible to follow them exactly. For instance, even with frequently updated map data there can be unmapped changes to the road network such as emergency road closures or newly introduced traffic management orders, which will result in apparent routing errors.

1. The system and supporting literature should be designed to convey expectations to the driver that are consistent with the system's performance.

- Information supplied with a system, which is not integrated into the vehicle by the vehicle manufacturer, should make it clear which vehicle classes are supported (e.g. passenger cars) and which are not supported (e.g. HGVs, motorcycles) in terms of routing.
- The routing strategies available to the driver, and the effect of choosing a particular strategy, should be described for all systems, those integrated into the vehicle by the manufacturer as well as after market and nomadic devices.
- Where a strategy may be inappropriate the current strategy should be clearly displayed when a destination can be entered. This warning is particularly important for nomadic devices that can be used to guide a pedestrian.
- Modes of use designed for pedestrians should be cancelled when the speed exceeds 25 km/h or the unit is docked in a vehicle cradle.

Rationale:

Long or wide vehicles should not be guided along roads which are physically or environmentally unsuitable and cause traffic congestion or safety problems (e.g. HGV bridge strikes).

Apoorly fitted system may not function correctly (e.g. GPS reception, traffic data reception) or cause other safety problems.

The information should support the driver in their choice of routing strategy e.g. fastest route.

The inappropriate use of pedestrian mode could result in a vehicle being guided into a pedestrianised area.

2. The location of the vehicle should be correct so that illegal or inappropriate instructions are not given to the driver, and any map displays the correct position.

- System positioning error should be small enough for the system to function correctly and enable appropriate instructions to be given to the driver (e.g. *Human Factors Design Guidelines for ATIS/CVO*, 1998, suggests 30m as an absolute maximum error. This is approximately equivalent to a one second positional update delay for vehicles travelling at 100 km/h). Under certain circumstances, such as where roads run close together, at complex junctions or urban areas greater location accuracy may be needed to avoid illegal or inappropriate instructions being given.
- There should be measures in place to protect drivers from illegal or inappropriate routing when the vehicle position information becomes degraded, or there is uncertainty about the level of accuracy.
- The system should protect against positioning errors that could, for instance, cause the system to assume that the vehicle is on a parallel road where there is no link between them.
- Where a system is supplied for after market fitting the information supplied with it should make it clear how to correctly fit, install and test it to obtain correct location information.
- For a nomadic device, the information should detail how to position it in the vehicle to obtain correct location information and test the quality of the location information.

Rationale:

Inaccurate positioning could lead to false instructions being given to the driver causing inappropriate actions to be taken, e.g. making an illegal or inappropriate manoeuvre.

The driver may be confused if the displayed position does not accord with reality.

3. Map data should be sufficiently current that drivers are given advice consistent with the road network.

- DRG system base maps, location referencing, e.g. Post Code data and points of interest should not be more than 18 months old at the time of system sale to the end user.
- The map data should be from a reliable source and include all routing relevant information (road numbering, speed limits permitted manoeuvres etc.).
- The DRG system should be able to incorporate base map updates. The updates should be easy for users to apply and not cost prohibitive.
- New map updates should be regularly available to users. The average update frequency should not exceed 18 months.
- The PRO should have procedures in place to report all known map errors to the supplier and audit the response.
- Users should be informed that maps should be updated on a regular basis and also be informed how the update can be accomplished.

Rationale:

As new roads are built or different traffic management measures are put in place, the existing map database will become outdated. This will therefore affect the fidelity of the information used to calculate routes and could potentially lead to directions being given which are at variance with actual roads or traffic regulations. The PRO may not have direct control of updating information in the map database, but should track progress on resolving known problems and press for their resolution.

4. The system should not direct vehicles onto roads that are inappropriate for the class of vehicle.

- All roads used in routing calculations should be legal for the type of vehicle
- The characteristics of each class of vehicle for which routing is intended, or, for original equipment, the class of vehicle in which the system is installed, should be taken into account during route calculation, including:
    - Vehicle Height.
    - Vehicle Weight.
    - Vehicle speed limits & capabilities (e.g. HGVs have restricted top speeds).

Rationale:

Long or wide vehicles should not be guided along roads which are physically or environmentally unsuitable and cause traffic congestion or safety problems (e.g. HGV bridge strikes; mopeds should not be routed down motorways).

5. The system should properly take account of Road Traffic Orders and the Highway Code.

- The route calculation should properly take account of:
    - Regulatory and advisory traffic signs and road markings.
    - Illegal manoeuvres.
    - Good driving practice as set out in the Highway Code.
    - National and local speed limits (which should be implicit in route calculations).

Rationale:

The Highway Code should normally be obeyed at all times.

Poor information could lead to drivers making inappropriate manoeuvres which could prejudice road safety and network efficiency.

6. Routes should favour higher road classes.

- In the absence of traffic information the navigation system should route along the highest class of road consistent with the road hierarchy and overall routing strategy chosen by the user (e.g. fastest route).
- Some major roads, including trunk roads, are subject to speed limits e.g. 50mph outside urban areas for safety reasons. More minor roads in the vicinity are not subject to the same limits. In such circumstances the major road should be used in preference to the minor road and the forecast journey time should reflect the lower speed limit.
- Except at the start and end of a journey, use of residential and environmentally sensitive areas should be avoided as a general rule.
- Baseline speeds used in route determination should not exceed legal speed limits (both posted and permitted by vehicle type).
- Road classes should be stratified by traffic-relevant parameters (e.g. speed/capacity/safety).
- At least 4 distinct road classes and 6 distinct speed categories should be separately defined and their properties taken into account in routing calculations.

Rationale:

The higher the classification of road the lower the accident rate. (E.g. Motorways have fewer accidents per unit travel distance than A or B-road).

Main through routes should be used wherever possible so that the system does not cause additional traffic to be carried on unsuitable roads that are residential or environmentally sensitive areas.

Higher classification of the road also usually means a higher allowable speed limit. Baseline speeds should reflect the road hierarchy so that the most appropriate route is calculated.

7. The system should take proper account of dynamic information.

- The system should have consistently good access to a reliable source of dynamic traffic information.
- System routing and any re-routing should take account of:
  - Congestion warnings and the predicted levels of warning accuracy.
  - Reported length of the traffic disturbance, so that the route should remain unchanged if driving through the traffic disturbance takes insignificantly more time than the diversion.
- Traffic disturbances should be displayed to the driver in a logical order. For a visual display, the traffic disturbance with the highest effect on the driver's journey (e.g. the largest traffic disruption) should always be the most important warning. For an auditory system disturbances may be better ordered by location, that is, nearest announced first.

- Routes should be recalculated when traffic disturbances clear or change significantly. If the recalculated route is more suitable (faster or shorter; as appropriate for the driver's preference) that route should be offered to the driver.
- Drivers may be warned of problems ahead e.g. roadworks, but should not be diverted unless there is a significant delay.

Rationale:

Inaccurate data could lead to drivers taking inappropriate routing choices which could prejudice road safety and network efficiency.

8. The system routing should be robust in the context of anticipated driver behaviour.

- The system should rapidly re-evaluate the route when a driver takes a wrong turn.
- Rerouting should generally avoid U-turns and specifically when on dual-carriageways without suitable junctions or elsewhere where a U-turn would be illegal.
- When re-routing, the system should take account of whether sufficient warning time can be given to direct the driver to the new route.

Rationale:

The timing of information provision is critical so that the driver can safely manoeuvre the vehicle to e.g. select the correct lane or to make a turn. It may be safer to continue to a roundabout or junction than perform a U-turn.

A.3 Quality Guidelines for DRG Processes

A.3.1 Introduction

The guidelines in this section outline the minimum quality processes expected of an organisation developing a Dynamic Route Guidance product. The exact form of the processes implemented depends on the structure of the organisation and the product offered.

This section emphasises the importance of:

a) Developing and meeting requirements for DRG routing performance.

b) The need to consider processes.

c) Obtaining results of process performance and effectiveness.

Even an organisation that is ISO 9001 accredited needs to consider how the processes in its own Quality Management (QM) Systems relate to routing quality issues described below.

A.3.2 General requirements

The Product Responsible Organisation should be responsible for the product they provide irrespective of the supply of hardware, software and services from suppliers.

One person should be identified as responsible for the quality of DRG products and services.

The Product Responsible Organisation has responsibility for verifying all inputs provided by suppliers that affect routing quality before they are made available to customers.

Where an organisation chooses to outsource any process that affects product conformity with requirements e.g. map data, routing software, the organisation should ensure control over such processes. Control of such outsourced processes should be identified within the quality management system.

A.3.3 Control of records

Records should be established and maintained to provide evidence of conformity to requirements and of the effective operation of the quality management system. Records should remain legible, readily identifiable and retrievable. A documented procedure should be established to define the controls needed for the identification, storage, protection, retrieval, retention time and disposition of records.

A.3.4 Product Issues

A.3.4.1 Planning of DRG system product

The organisation should plan and develop the processes needed to realise the DRG product.

In planning product realisation, the organisation should determine the following, as appropriate:

a) Quality objectives and requirements for the product in terms of routing performance.
b) The need to establish processes, documents, and provide resources specific to the product.
c) Required verification, validation, monitoring, inspection and test activities specific to the product and the criteria for product acceptance.
d) Records needed to provide evidence that the realisation process and resulting product meet the routing quality requirements.

Acceptance criteria should be defined by the organisation e.g. for mapping quality.

A.3.4.2 Determination of requirements related to the DRG product

The Product Responsible Organisation should determine:

a) Requirements for product servicing, maintenance and post-delivery activities, including off-board and onboard elements of the system and interactions between them where appropriate.
b) Statutory and regulatory requirements related to the product.
c) Any additional requirements determined by the organisation.

A.3.4.3 Control and monitoring of inputs from suppliers

The organisation should establish processes to ensure that supplier monitoring and measurement can be carried out and are carried out in a manner that is consistent with the monitoring and measurement requirements of elements affecting routing quality including:

a) Map database and other data input.
b) Hardware.
c) Software.

When used in the monitoring and measurement of specific requirements, the ability of computer software to satisfy the intended application should be confirmed. This should be undertaken prior to initial product release and reconfirmed as necessary.

A.3.4.4 Control and monitoring of traffic data

This should include data generated as a result of monitoring and measurement and from other relevant sources.

The PRO should be able to demonstrate that it can collect and analyse appropriate data, internally or from an external supplier, for the effective and suitable dynamic routing of vehicles in real-time.

The analysis of the traffic data should provide information relating to conformity to product requirements.

Each input of data should be time recorded and date stamped.

The quality and age of the input should be checked and verified to be suitable, by the supplier and/or the PRO, before it is released for customer use.

Traffic data should be applied to *all* relevant routes.

A.3.4.5 Production of the DRG product

The organisation should plan and carry out production and service provision under controlled conditions. Controlled conditions should include, as applicable:

a) The availability of information that describes the characteristics of the product.
b) The availability and use of monitoring and measuring software or equipment.
c) The implementation of monitoring and measurement.
d) The implementation of release, delivery and post-delivery activities.

A.3.4.6 Design and development verification

Verification should be performed in accordance with planned arrangements to ensure that the design and development outputs have met the design and development input requirements.

Records of the results of the verification and any necessary actions should be maintained.

A.3.4.7 Supply by third parties

Where equipment or data (map updates, dynamic traffic information etc.) is supplied and / or installed by third parties, e.g. retail outlets, franchised motor traders, internet sales sites, the PRO shall specify the level of service required from the third party and have procedures in place to rectify any shortcomings in the service supplied.

A.3.4.8 Validation of processes for production

The organisation should validate any processes for production where the resulting output cannot be completely verified by good subsequent monitoring or measurement. This includes any processes where deficiencies become apparent only after the product is in use or the service has been delivered.

Validation should demonstrate the ability of these processes to achieve planned results.

The organisation should establish arrangements for these processes including, as applicable:

a) Defined criteria for review and approval of the processes.
b) Approval of equipment and qualification of personnel.
c) Use of specific methods and procedures.
d) Requirements for records.
e) Revalidation.

A.3.4.9 Change control

The organisation should have a process to control and react to changes that impact the product. The effects of any change, including those changes caused by any supplier, should be assessed, and verification and validation activities should be defined, to ensure continued compliance with minimum criteria related to routing quality. Changes should be validated before implementation.

The organisation should have a defined process for evaluating any changes to a supplied product from a supplier that affects routing quality, including:

a) Map database and data input changes.
b) Hardware changes.
c) Software changes.

The organisation should check any changes against their original specification for the product.

If map modifications are involved there should be a documented procedure for testing and validation of any changes made to ensure that they have the desired effect.

A.3.5 Measurement and assessment

A.3.5.1 Monitoring and measurement of processes

The organisation should apply suitable methods for monitoring and, where applicable, measurement of the quality management system processes. These methods should demonstrate the ability of the processes to achieve planned results. When planned results are not achieved, correction and corrective action should be taken, as appropriate, to ensure conformity of the product.

A.3.5.2 Monitoring and measurement of product

The organisation should monitor and measure the outputs of the product to verify that product requirements have been met. This should be carried out at appropriate stages of the product realisation process in accordance with the planned arrangements.

Evidence of conformity with the acceptance criteria should be maintained. Records should indicate the person(s) authorising release of product.

Product release and service delivery should not proceed until all the planned arrangements have been satisfactorily completed, unless otherwise approved by a relevant authority.

A documented procedure should be in place for reporting problems to the system's map supplier. Any past noted problems should be checked against each new map release until the problem has been resolved.

Note: When selecting product outputs to monitor for compliance with specified internal and external requirements, the organisation should determine the relevant:

a) Types of measurement.
b) Suitable measurement means.
c) Capability and skills required.

The organisation should determine, collect and analyse appropriate data to verify the suitability and effectiveness of the route guidance system.

A.4 Assessment of compatibility with guidelines

A.4.1 Introduction

This section describes a process that can be used by an organisation to assess its compatibility with the technical guidelines for DRG routing. It is in the form of an audit, and a checklist is provided in Appendix A to assist in enabling a structured assessment. A separate checklist is provided in Appendix B for the assessment of the organisation's quality and processes.

Assessment of the technical performance of the DRG routing includes three trials: A, B and C. These trials need to be comprehensive to thoroughly test the system and some guidance on minimum content is provided at the start of the description of each trial. The PRO will need to select convenient routes that systematically test the system.

A.4.2 Technical assessment of DRG routing

This approach is based on assessing correspondence between the DRG system and each of the technical routing principles described in Section 2.

1. The system and supporting literature should be designed to convey expectations to the driver that are consistent with the system's performance.	
Assessment Method	**Minimum Requirements**
1. Identify statements in product literature and within system and verify (by inspection) correspondence with actual system performance.	No discrepancy between information and performance.

2. The location of the vehicle should be correct so that illegal or inappropriate instructions are not given to the driver, and any map displays the correct position.	
Assessment Method	**Minimum Requirements**
1. Visual check by inspection during drive of at least 30 minutes on mixed roads of vehicle position on displayed map (if any).	Incorrect position of vehicle on map (e.g. clearly on the wrong section of road) should be a rare event.
2. Road Trial A to count illegal or inappropriate instructions as a percentage of instructions provided.	See Trial A.

3. Map data should be sufficiently accurate that drivers are given advice consistent with the road network.	
Assessment Method	**Minimum Requirements**
Inspection of documentation of DRG system and PRO procedures.	Map is updated centrally (off-board calculation of routes) at least every 18 months OR map updates of the latest map are offered and are available to users at least every 18 months.

4. The system should not direct vehicles onto roads that are inappropriate for the class of vehicle.	
Assessment Method	**Minimum Requirements**
Road Trial A to count illegal or inappropriate instructions as a percentage of instructions provided (for each class of vehicle supported).	See Trial A.

5. The system should properly take account of Road Traffic Orders and the Highway Code.	
Assessment Method	**Minimum Requirements**
Road Trial A to count illegal or inappropriate instructions as a percentage of instructions provided.	See Trial A.

6. Routes should favour higher class roads.	
Assessment Method	**Minimum Requirements**
1. Inspection of mapping documentation to determine existence of road classes.	At least 4 road classes further stratified by traffic relevant parameters (e.g. speed limit / expected speed).
2. Inspection of assignment of base speeds for each class of vehicle supported.	Baseline speeds used in route determination should not exceed legal speed limits, either posted or by vehicle classification where lower.
3. Trial B to assess overall routing strategy.	See Trial B.

7. The system should take proper account of dynamic information.	
Assessment Method	**Minimum Requirements**
1. The dynamic traffic information should be demonstrated to be from a reliable source, or the methods used to obtain the data shown to be reliable.	Comprehensive coverage of major roads with quantitative speed/delay information either supplied directly or reliably calculated by the system from the supplied information.
2. The correct use of dynamic traffic information can be demonstrated through simulation.	System reroutes in response to simulated dynamic traffic information where there is a significantly quicker alternative route, but not otherwise.

8. The system routing should be robust in the context of anticipated driver behaviour.	
Assessment Method	**Minimum Requirements**
Trial C to assess robustness of routing.	See Trial C.

A.4.2.1 Trial A

Objective: to count illegal or inappropriate instructions as a percentage of instructions provided (for each class of vehicle supported).

Method:

1. The system is fitted according to the manufacturer's instructions and any necessary system checks (e.g. GPS positioning accuracy) carried out before use.
2. The trial includes sufficient instructions to give a robust measure of the proportion of illegal or inappropriate instructions and include roads where positioning information is likely to be poor, e.g. urban canyons for GPS.
3. A series of origins and destinations are selected that are expected to involve mixed routes with a variety of road types and type of manoeuvre (motorways, dual carriageways, rural and urban roads with a mixture of road types in each route with opportunities to make banned turns, turn the wrong way down one-way roads and take inappropriate lanes is a minimum)..
4. As each route is driven, the instructions provided by the DRG system are classified into three categories:
    a. Legal and appropriate.
    b. Illegal.
    c. Legal but inappropriate.
5. The percentage of each category are computed and compared with Table 1.
6. Sufficient instructions are assessed to provide robust and significant results.

Definitions and examples:

Illegal instructions are those that state or imply illegal manoeuvres as summarised, for example, in the Highway Code Section 4 "The Road User and the Law". Obvious examples include one-way streets, banned turns and illegal roads for the class of vehicle (e.g. based on engine, vehicle height, width etc.). It also includes illegal use of lanes restricted to specific vehicle classes (e.g. bus or taxi). If a road restriction has been implemented in the time since the map data was released for public use, then the map data cannot guarantee to cover all banned manoeuvres.

Inappropriate instructions cannot be precisely defined as this depends on the driving context and an element of judgement has to be exercised. This judgement should be based on the reasonable expectations of an infrequent system user in an unfamiliar area and possibly in adverse weather conditions.

Examples of inappropriate instructions include:

- U-turns (except in exceptional circumstances).
- Manoeuvres that cannot physically be carried out (e.g. "turn left" where there is no left turn).
- Instructions to take a lane or junction at a roundabout that is not appropriate.
- Instructions to take a lane or junction that is inappropriate at a subsequent manoeuvre.
- Instructions where there is insufficient warning (see HMI guidelines, Stevens et al (2001)).

Inappropriate also covers situations where:

- The situation description is poor or incorrect (e.g. calling a roundabout a junction).
- The instruction contains the wrong road class, road number or exit number.

Inappropriate instructions also include those that would lead to an inappropriate road including:

- A blocked end.
- A road with an extremely soft surface.
- A road that is deeply rutted or presents risk of grounding.
- A road that is too narrow, twisty or steep for the class of vehicle.

Minimum requirement criteria:

It is intended that the minimum requirements are such that good quality systems should easily exceed them. If a DRG system fails to meet the minimum requirements, or comes close to failing, then underlying data quality is poor and users of the system will rapidly loose confidence in it. A system cannot be expected to implement every change in regulations immediately the change comes into force, but a system that updates its mapping information at reasonable intervals will have a very low rate of illegal instructions.

Table 1: Minimum requirements for instructions – Trial A

Category of instruction	Minimum requirement criteria
Illegal	95% correct
Legal but incorrect or inappropriate	95% correct

A.4.2.2 Trial B

Objective: to assess overall routing strategy.

Method:

1. A large sample of routes with multiple routing options is required. For efficiency with such a large sample of routes, it is expected that a simulation system, rather than driving will be used.
2. A series of origins and destinations are selected that are expected to involve mixed routes (a variety of road types and type of manoeuvre within any one route and a representative sample of all road types in the whole set of routes).
3. As each route is simulated using the system data and routing software (or driven) the route is recorded.
4. The route is compared with static routes generated by PC based routing software (e.g. from the AA) or with other reasonable routes by examination of maps or knowledge of the journey.
5. Major unexpected deviations from expected routes are noted.
6. Where there are no obvious explanations for the unexpected route (e.g. major traffic problems or road works etc.) the routes are classified as obscure.
7. The percentage of obscure routes is compared with Table 2.
8. Sufficient routes are assessed to provide robust and significant results.

Criteria:

It is intended that the minimum requirements are such that good quality systems should easily exceed them. If a DRG system fails to meet the minimum requirements, or comes close to failing, then underlying data quality and/or routing algorithms are poor and users of the system will rapidly loose confidence in it.

Table 2: Minimum requirements for overall routing – Trial B

Minimum requirement criteria
No more than 10% of routes include an obscure element.
In an absence of traffic information the system should route along the highest class of road available where there are two or more equivalent routes.
Except at the start and end of journeys, residential and environmentally sensitive areas should be avoided as a rule.

A.4.2.3 Trial C

Objective: to test robustness of routing strategy to driver behaviour.

Method:

1. A series of origins and destinations are selected that are expected to involve mixed routes (a variety of road types and type of manoeuvre).
2. As each route is driven, wrong turnings are made to go deliberately off-route. These off-route excursions should include examples of:
   - Erroneously taking a dual carriageway that would require a long diversion but where a U-turns would not be feasible.
   - Going off-route shortly before a roundabout, such that the system could calculate a re-route round the roundabout, but not deliver the instruction in time for it to be safely obeyed.
3. The time taken to re-route is recorded.
4. The percentage of U-turns requested, time taken to recalculate the routes, and subsequent instruction timing are compared with Table 3.
5. Sufficient routes are assessed to provide robust and significant results.

Criteria:

The criteria reflect the robustness of routing to drivers going off-route. It is intended that the minimum requirements are such that good quality systems should easily exceed them. If a DRG system fails to meet the criteria, or comes close to failing, then underlying data quality and/or routing algorithms are poor and users of the system will rapidly loose confidence in it.

Table 3: Minimum criteria for routing robustness – Trial C

Criteria	Minimum requirement
U-turns are requested infrequently.	Re-routes should only ask for a U-turn if there is no other possible way to turn the vehicle around that does not require a greater than 2 km detour on a single carriageway. U-turns should not be offered on dual carriageways (except at suitable junctions) nor elsewhere where a U-turn would be illegal.
After going off-route, the system recalculates within a reasonable time.	System should calculate a re-route within one minute.
Sufficient time is given to execute new manoeuvres following route re-calculation (judged in the context of the road and traffic situation).	In the event of a re-calculation, a new instruction should be provided with sufficient time to safely make the manoeuvre.

A.4.3 Process assessment in relation to DRG routing

Self-assessment of whether processes are documented in accordance with the minimum guidelines of Section 3 above should be a simple matter of inspection and verification of existing documentation. To assist this process, a simple checklist, based on the quality process guidelines, has been developed (Appendix B) which may be used for self-assessment.

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Appendix B. Technical Checklist

1.	Communication of system performance.	Pass (✓or x)		Review / Comments
1.1	Does the information supplied with the navigation system clearly state for which vehicle classes the system is designed? (Not applicable for OEM systems.)	Yes		No
1.2	If the system is not suitable for all vehicles in a class, does the information supplied with the navigation system clearly state the maximum vehicle height and weight for which it is suitable? (Not applicable for OEM systems.)	Yes		No
1.3	Are the various routing strategies offered by the system explained in the literature?	Yes		No
1.4	Are the various routing strategies offered by the system displayed as appropriate on the driver display?	Yes		No
1.5	Are inappropriate routing strategies for vehicles cancelled at vehicle speeds or when the unit is docked in the vehicle?	Yes		No
2.	**Location and accuracy.**			
2.1	Is system positioning error small enough to allow the system to function correctly?	Yes		No
2.2	Does the system have any precautions to protect against providing drivers with illegal or inappropriate routing information, when positioning accuracy is degraded or uncertain?	Yes, define in comments		No
2.3	Does the system have any precautions to protect against positioning errors?	Yes, define in comments		No
2.4	Does the information supplied with the system make it clear how to correctly fit and install the system, or make it ready for use if not formally installed (e.g. mobile phone unable to reliably receive GPS if placed in cradle)? (Not applicable for OEM systems.)	Yes		No

3.	**Map and location referencing data.**			
3.1	Is the system base map provider a recognised source of reliable data?	Yes		No (Specify reliability)
3.2	Is the age of base map and location referencing data under 18 months old at the time of sale to the end user?	Yes		No
3.3	Can the DRG system simply incorporate base map and location referencing updates?	Yes		No
3.4	How often are base map updates available at a reasonable price?	<18 months		>18 months
3.5	Are users informed that updated maps are available and how the update can be accomplished?	Yes		No
3.6	Does the base map contain information on:			
a.	Road Numbering?	Yes		No
b.	Posted speed limits?	Yes		No
c.	One way streets?	Yes		No
d.	Banned turning movements?	Yes		No
e.	Speed restrictions by vehicle type (required for all vehicle types that the system supports, just specific vehicle for OEM systems)?	Yes		No
f.	Bridge heights (only required if the system supports large vehicles)?	Yes		No
g.	Weight restrictions (only required if the system supports heavy vehicles)?	Yes		No
h.	Sign posted large vehicle routes (only required if the system supports large vehicles)?	Yes		No
4/ 5	**Appropriate roads and manoeuvres.**			
	Trial A	Pass		Fail

6.	**Routes should favour higher classes of roads.**			
6.1	Are road classes stratified by traffic relevant parameters (e.g. speed, capacity, safety)?	Yes		No
6.2	Are there at least four distinct road classes and six distinct speed categories used to classify road properties?	Yes		No
6.3	Are baseline speeds compatible with legal speed limits for all supported vehicle classes?	Yes		No
	Trial B	Pass		Fail
7.	**Re-routing.**			
7.1	Is the dynamic information from an acceptable source? If not, can the information be demonstrated to be comprehensive and quantitative?	Yes		No
7.2	Do simulation results demonstrate appropriate dynamic routing, re-routing when and only when there is a significant benefit?	Yes		No
7.3	Does the system monitor delays in a way that if the original route clears drivers will not be routed unnecessarily down the diversion route?	Yes		No
7.4	Are delays presented to the driver in a logical, comprehensible order?	Yes		No
8.	**Response to driver behaviour.**			
8.1	Are U-turn instructions generally avoided?	Yes		No
8.2	Are U-turn instructions avoided on dual-carriageways and elsewhere where they would be illegal?	Yes		No
8.3	Does the system re-evaluate the route when a driver makes a wrong turn?	Yes		No, it only tries to return the driver to the original route
8.4	Is re-calculation achieved within one minute of the vehicle being 30m off route?	Yes		No
8.5	Does the system take account of whether sufficient warning time can be given to direct the driver to a new route?	Yes		No
	Trial C	Pass		Fail

Appendix C. Quality/Process Checklist

1.	**Quality system general requirements.**	**Pass (✓or x)**		**Review / Comments**
1.1	Has one person been identified as responsible for the quality of DRG products and services?	Yes		No
1.2	Does the PRO verify DRG inputs (more details in sections 5 and 6) before making them available to customers?	Yes		No
1.3	Is the control of outsourced processes identified within the PRO's quality management system?	Yes		No
2.	**Control of records.**			
2.1	Are records maintained that provide evidence of conformity to requirements and the effective operation of the quality management system?	Yes		No
2.2	Are records readily identifiable, retrievable and legible?	Yes		No
2.3	Are documented procedures established to define controls needed for identification, storage, protection, retrieval, retention time and disposition of records?	Yes		No
3.	**Product issues – planning of a DRG system product.**			
3.1	Whilst planning and developing the processes needed to realise the DRG product, does, or did, the PRO have:			
a.	Defined quality objectives and requirements for the product in terms of routing performance?	Yes		No
b.	Defined processes, documents and resources specific to the product?	Yes		No
c.	Verification, validation, monitoring, inspection and test activities specific to the product?	Yes		No
d.	Records providing evidence that the product meets the routing quality requirements?	Yes		No

4.	**Determination of requirements related to the DRG product.**			
4.1	Does the PRO retain evidence of conformity with DfT requirements on DRG?	Yes		No
4.2	Does the PRO have defined and documented:			
a.	Requirements for product servicing, maintenance and post-delivery activities? To include off-board and onboard elements of the system and interactions between them where appropriate.	Yes		No
b.	Statutory and regulatory requirements related to the product?	Yes		No
c.	Any additional requirements determined by the organisation?	Yes		No
5.	**Control and monitoring of inputs from suppliers.**			
5.1	Does the PRO have established processes for the monitoring and measurement of inputs from suppliers including:			
a.	Map database and other data input?	Yes		No
b.	Hardware?	Yes		No
c.	Software?	Yes		No
5.2	Are documented checks made before any product release or update to the public that intended work satisfies specific requirements?	Yes		No
6.	**Control and monitoring of traffic data.**			
6.1	Is the PRO able to demonstrate its ability to collect and analyse appropriate data for the effective and suitable dynamic routing of vehicles in real-time?	Yes		No
6.2	Does the analysis of data provide information relating to conformity to product requirements?	Yes		No
6.3	Are congestion warnings used by the dynamic routing system time, date and source stamped?	Yes		No

6.4	Are expected delays or reduction in link speed applied to all routes that use link/node etc.?	Yes		No
6.5	Is the quality of the input checked and verified before it is released for customer use?	Yes		No
6.6	Is a reminder set by the system or an operator to check on the status of the delay after a period of time?	Yes		No
7.	**Production of the DRG product.**			
7.1	Does the PRO carry out production and service provision under controlled conditions, including:			
a.	The availability of information that describes the characteristics of the product?	Yes		No
b.	The availability and use of monitoring and measuring software or equipment?	Yes		No
c.	The implementation of monitoring and measurement?	Yes		No
d.	The implementation of release, delivery and post-delivery activities?	Yes		No
8.	**Design and development verification.**			
8.1	Does the PRO have planned arrangements for the verification that the system meets the design requirements?	Yes		No
8.2	Are the results of the verification kept and maintained?	Yes		No
9.	**Supply by third party.**			
9.1	Where equipment or data (map, dynamic traffic information etc.) is supplied and / or installed by third parties, e.g. retail outlets, franchised motor traders, internet sales sites, does the PRO:			
a.	Specify the level of service required from the third party?	Yes		No
b.	Have procedures in place to rectify any shortcomings in the service supplied?	Yes		No

10.	**Validation of processes for production.**			
10.1	Does the PRO validate processes where the resulting output cannot be completely verified by good subsequent monitoring or measurement?	Yes		No
10.2	Does the organisation have established arrangements for processes including:			
a.	Defined criteria for review and approval of processes?	Yes		No
b.	Approval of equipment and qualification of personnel?	Yes		No
c.	Use of specific methods and procedures?	Yes		No
d.	Requirements for records?	Yes		No
e.	Revalidation?	Yes		No
11.	**Change control.**			
11.1	Does the organisation have defined processes to control and react to any changes that may impact the product (including changes caused by any supplier)?	Yes		No
11.2	Are verification and validation processes in place to assess and ensure continued compliance with minimum criteria relating to routing quality in the event of a change?	Yes		No
11.3	Does the PRO have a process to check any changes against their original specification for the product?	Yes		No
12.	**Monitoring and measurement of processes.**			
12.1	Does the PRO have methods for the measurement of quality management system processes?	Yes		No
12.2	If planned results are not achieved are processes in place for correction to ensure conformity of the product?	Yes		No

13.	**Monitoring and measurement of product.**			
13.1	Does the PRO monitor and measure the characteristics of the product at appropriate stages to verify that product requirements have been met?	Yes		No
13.2	Does the PRO keep records of conformity with acceptance criteria?	Yes		No
13.3	Do the records indicate the person(s) authorising release of the product?	Yes		No
13.4	Are processes in place such that product release and service delivery shall not proceed until all planned arrangements have been satisfactorily completed unless approved by a relevant authority?	Yes		No
13.5	Is there a documented procedure to report problems to the system's map supplier?	Yes		No
13.6	Is there a documented procedure to check previously noted problems against new map releases?	Yes		No
13.7	Has the PRO determined the following when testing compliance with specified requirements:			
a.	The types of measurement?	Yes		No
b.	Suitable measurement means?	Yes		No
c.	The capability and skills required?	Yes		No
13.7	Does the organisation verify the suitability and effectiveness of the route guidance system?	Yes		No