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GUIDELINES FOR SAFE AND EFFECTIVE VEHICLE ROUTING

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CONTENTS

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).

1 Introduction

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.

1.1 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.

1.2 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 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 2 details the technical guidelines and the principles on which they are based and section 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 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).

2 Technical Guidelines for DRG Routing

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.

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 roadside, 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.

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).

A poorly 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.

3 Quality Guidelines for DRG Processes

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.

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.

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.

3.4 Product Issues

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.

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.

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.

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.

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.

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.

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.

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.

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.

3.5 Measurement and assessment

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.

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.

4 Assessment of compatibility with guidelines

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.

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.

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

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.

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.

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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References

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Appendix A. 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 B. 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