



# TRAMWAY PRINCIPLES & GUIDANCE

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# GUIDANCE ON TRAMWAYS

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# FOREWORD

As with all guidance, this document is intended to give advice and not set an absolute standard.

This publication indicates what specific aspects of tramways need to be considered, especially their integration within existing highways.

Much of this guidance is based on the experience gained from the UK tramway systems, but does not follow the particular arrangements adopted by any of these systems.

It is hoped that promoters of tramways, and their design and construction teams, will find this guidance helpful, and that it will also be of help to others such as town planners and highway engineers, whose contribution to the development of a tramway system is essential.

This document replaces guidance previously published by the Office of Rail and Road, and before that by HM Railway Inspectorate building on the long standing legislation and guidance of the Board of Trade.

This document has been developed with the assistance of the Office of Rail and Road and ORR inspectors may look to see that this guidance has been suitably applied when assessing the safety of tramways.

# 1 INTRODUCTION

- 1.1 This guidance publication is intended to give guidance and advice to those involved in the design, construction and operation of tramways.
- 1.2 This document does not intend to set out mandatory standards. It gives examples of established good practice to provide an acceptable level of safety for the public (passengers and others), employees and contractors.
- 1.3 When constructing or extending tramway systems or subsystems it may be appropriate to consider innovative solutions to particular problems. This document, while providing clear guidance on how tramways should be constructed, is not intended to inhibit technological improvements or restrict solutions to new problems.

## APPLICATION OF THE GUIDANCE

- 1.4 Application of this guidance should generally provide a sufficient level of safety, provided that it has been demonstrated that the use of the guidance is wholly applicable to the works, plant or equipment in question. The term "equipment" is used here and elsewhere in the text to include vehicles.

### Effect on existing works

- 1.5 This document does not apply retrospectively to existing works, plant and equipment. However, new or altered works, plant and equipment might introduce incompatibilities or inconsistencies with the existing works, plant or equipment. In this case, an ALARP condition may only be maintained if appropriate arrangements have been made to address these safety implications, which may include modifications to the existing works, plant or equipment.

### Operating conditions

- 1.6 The choice and design of the works, plant and equipment will depend not only on the guidance expressed in this document but also on the operational requirements of the tramway including any interfaces with other systems.
- 1.7 In assessing the suitability of any proposed safety measures or arrangements, it is important to take into account:
  - (a) normal operating conditions;
  - (b) degraded conditions where any component or part of the tramway materially affecting safety has failed;
  - (c) credible abnormal conditions to which the system may be subjected; and
  - (d) emergency situations.

## Designing and building

1.8 The guidance applies to the finished works, plant or equipment but not to the processes of designing or building. Designers and builders need to be aware of the responsibilities imposed upon them by the Construction (Design and Management) Regulations 2015<sup>3</sup> as amended.

1.9 This document covers any new or altered works, plant and equipment for tramways. Their design and construction should take into account not only the safety of the users of the system but also that of other highway users. Any additions or alterations to a system should not degrade the level of safety of the original system.

1.10 The design of a tramway should be managed, according to best practice in safety management, coherently as a system from the initial concept throughout the project lifecycle. Tramway design and related urban redevelopment should be integrated with respect to managing vehicle and pedestrian safety.

a. Initial stages of responsibility for safety

Responsibility starts at the planning stage of a new or revised tramway

Managing safety should start at the beginning of the design process for altering an existing tramway or planning a new one.

It should be fully understood that in the normal process of developing proposals for a new tramway there are many issues that need to be identified and resolved well before a construction contract is let. System safety issues should be considered at a very early stage in the project. There should be no outstanding safety issues relating to an outline design that remain unconsidered when an application is made for a Transport and Works Act (TWA) order or when a contract is let. Resolution of outstanding safety issues may not be satisfactorily achievable within the legal framework of the TWA order. The safety management process should begin at the start of the design process and transfer via documentation such as a hazard log throughout all the stages of the project.

It is essential that any contractual relationships within the project facilitate clear ownership and management of a continuous safety management process.

The safety management and associated records of design information and assumptions should be capable of being transferred to the relevant Responsible Persons as the contractual process develops. A Responsible Person should be appointed at each stage of the project lifecycle.

b. Contributory factors in safety

Guidance about factors that may affect safety is given in the following sections. Some of these issues may not be applicable in all situations. These sections are not necessarily exclusive and specific project factors need to be taken into consideration. However, evidence of all considerations should be included in the records under the Safety Management System (SMS). Normally these records would be included or referred to in the Hazard Log generated within the SMS, and should include any residual hazards identified as part of the design process in accordance with the Construction (Design and Management) Regulations 2015<sup>3</sup>.

c. Safety management system

A SMS should be implemented which identifies, controls (prevent or mitigate) and records potential hazards. It is essential that safety is managed adequately across the interfaces of different organizations and at all stages in a project.

A successful SMS needs to offer:

- Traceability
- Transparency
- Capability of internal and independent audit
- A formal or legal basis which provides:  
Sanctions for non-compliance  
Protection for employees reporting risks and hazards.

d. Recognition of all stages in a design process

In progressing a design there needs to be recognition of the actions required to proceed to the next level of closing out an identified hazard. It should not be assumed that a hazard can be closed without an understanding of what is required and what can realistically be achieved. Alternative means should always be considered and recorded in the interests of minimising the risk in failing to close out a hazard.

e. Passage of hazards down the supply chain

When passing the mitigation of hazards down the supply chain [or along the life-cycle of a project] care should be taken to ensure that all parties involved in the issues are fully aware of the hazard identifications and other mitigating actions given to other parties. Mitigations should not be passed down to single parties without a clear mutual understanding of the singularity and ownership of such particular issues. When passing down hazard mitigation to more than one party, a management process is required in order to optimise the combined hazard mitigation. It is recommended that a "Project Safety Certification Committee" is established to oversee hazard closeout in accordance with SMS best practice. It is however ultimately the responsibility of the operator to accept this to be the case prior to commencing operations.

f. Recognition of all system interrelationships

Many of the system design factors are interrelated. This needs to be recognised and managed in an integrated manner during all stages of the design or modification of a tramway.

Interfaces should be identified and managed from an early stage in the project using defined procedures within the project management system.

g. Safety Verification

The Railways and Other Guided Transport Systems (Safety) Regulations 2006<sup>2A</sup> (ROGS) came into force in two stages in April and October 2006. These Regulations removed the requirement for new and modified works to receive 'approval' from the Railway Inspectorate before being brought into use. Dutyholders are required to have in place an overarching safety management system that includes processes for controlling risks from new and modified works. In some cases where works are both of a type new to the system in question and which are capable of creating significant risks then a specific process termed 'safety verification' must be applied. Further guidance on the regulations<sup>21</sup> and specifically on the application of safety verification in tramways<sup>22</sup> is published by ORR.

In some cases, the specific enabling legislation for a tram system may contain provisions that require 'approval' for certain aspects of the tramway to be obtained before being brought into use.

## DEFINITION OF TRAMWAY

- 1.11 For the purposes of this guidance, 'tramway' means a system of transport used wholly or mainly for the carriage of passengers, which employs parallel rails which provide support and guidance for vehicles carried on flanged wheels, and in respect of which:
- (a) the rails are laid wholly or partly along a road or in any other place to which the public have access; and
  - (b) on any part of the system, the permitted maximum speed of operation of the vehicles is limited to that which enables the driver of any such vehicle to stop it within the distance he can see to be clear ahead (in this document, referred to as 'operation by line-of-sight').
- 1.12 Different parts of a tramway may fall into one of several broad types:
- (i) 'integrated on-street' tramways where the part of the highway occupied by the rails may also be used by other vehicles or by pedestrians,
  - (ii) 'tram gates', where only trams (and buses if permitted) travel along a short length of road that precedes an integrated on-street system,
  - (iii) 'segregated on-street' tramways or 'tram-only streets' where the part of the highway occupied by rails may be crossed by pedestrians, but is not normally shared with other road users, or
  - (iv) 'off-street' tramways where the alignment of the track is wholly separate from the highway.

## OPERATION BY LINE-OF-SIGHT

- 1.13 Tramways use line-of-sight operation. In this mode, a tram should be able to stop, before a reasonably visible stationary obstruction ahead, from the intended speed of operation using the service brake.

## SCOPE

- 1.14 This document provides guidance on the design, construction and operation of on-street tramways. For avoidance of doubt, the guidance also extends to tramways in the following circumstances:
- (a) aspects of off-street tramways where sections of track intersect with the highway, or change to or from on-street tramways; and

- (b) off-street tramways, which are governed by the requirements of other parts of the tramway system that are on-street.
- 1.15 Guidance on historic and replica tramways is provided in Appendix C - Heritage tramways.

## TRAMWAYS AND ROAD TRAFFIC LAW

- 1.16 On-street tramway vehicles are 'tramcars' for the purposes of road traffic legislation. In some instances, they are included in the definition of motor vehicles. The Tramcars and Trolley Vehicles (Modification of Enactments) Regulations 1992<sup>6</sup> specifies the sections of the Road Traffic Regulation Act 1984<sup>7</sup> and the Road Traffic Act 1988<sup>8</sup> which do not apply, or apply with modifications, to trams.
- 1.17 Trams are not subject to the Road Vehicles (Construction and Use) Regulations 1986<sup>9A</sup>, including those parts that refer to passenger-carrying vehicles (PCV's), or to any of the lighting requirements, unless these are included in any Act or Order authorising the construction of the tramway or in any specific statutory instrument.
- 1.18 Refer to Appendix H for further detailed information.

## STREET WORKS PROTECTION ARRANGEMENTS

- 1.19 General requirements as to the carrying out of street works and reinstatement are imposed by the New Roads and Street Works Act 1991<sup>10</sup>. The methods of protecting some types of work sites on the street are described in a Code of Practice issued under that Act: *Safety at Street Works and Road Works*<sup>11</sup> and in the Traffic Signs Manual.

## OTHER REGULATIONS AND STANDARDS

- 1.20 Works, plant or equipment may be subject to other specific Regulations, for example, the Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010<sup>12</sup> and The Electricity Safety, Quality and Continuity Regulations 2002<sup>13</sup> (as amended). In implementing the guidance in this document, compliance with all other relevant Regulations must be considered and specific reference is made to the more significant Regulations.
- 1.21 Similarly, any material or article used in the provision of works, plant or equipment may need to comply with a specific standard. The guidance in this document does not make reference to these numerous standards; however, an indication is provided where standards may be appropriate.
- 1.22 Any reference in this guidance to any material or article complying with a specific standard would normally be satisfied by compliance with any relevant standard recognised in any member state of the European Union (EU), providing that the standard in question offers levels of safety, suitability and fitness for purpose equivalent to those offered by the standard referred to in this guidance.
- 1.23 Trams on highway are subject to relevant road and traffic signage legislation. Where a deviation or derogation from the Road Traffic Signs Regulations and General Directions

2016<sup>16</sup> (TSRGD) is required then this must be obtained from the Secretary of State (or his agents).

## STRUCTURE OF THE GUIDANCE

- 1.24 The guidance is laid out, as far as is practicable, in a logical sequence that follows the main elements of the tramway system.
- 1.25 A 'Note' is used to provide additional information that is relevant to the paragraph(s) of guidance that precede it.

## TERMINOLOGY

- 1.26 Throughout the document the verbs listed below are used with the following specific meanings:
- (a) *should* - the primary verb for statements of guidance;
  - (b) *may* - where the guidance suggests options;
  - (c) *must* - only used where there is a legal requirement for the measures described to be employed. A reference to the relevant Act or Regulations will be provided;
  - (d) *is (are) required* - having decided upon a particular option or arrangement, some consequential choices stem from that first decision. This expression is used to indicate those consequential choices and where firmer guidance is considered appropriate.

### Tram

- 1.27 In this document, tramcars and any other rail vehicles that operate on tramways are referred to hereafter as 'trams'. 'Tram' includes one or more trams coupled together, and includes non-passenger-carrying vehicles.

### Highway

- 1.28 In this document, 'highway' or 'road' is used to mean any, or any combination of, the following:
- (a) carriageway;
  - (b) bridleway;
  - (c) cycle track;
  - (d) footpath;
  - (e) footway;
  - (f) land on the verge of a carriageway or between two carriageways; and

(g) any other place to which the public has access (including access only on making a payment).

1.29 The terms used here are more precisely defined in the Highways Act 1980<sup>14</sup> for England, Wales and Northern Ireland or for Scotland, in the Roads (Scotland) Act 1984<sup>15</sup>.

1.30 In this guidance the term 'Highway Authority' should be taken to include Roads Authority or Local Traffic Authority.

## 2 TRAMWAY CLEARANCES

- 2.1 This chapter provides guidance on the clearances within the tramway system, and also between the tramway and other parts of the highway. For information on electrical clearances refer to the guidance in Chapter 6 of this document.
- 2.2 Adequate lateral clearances should be provided, to allow trams to pass one another on adjacent tracks, or between trams and other road vehicles on adjacent carriageways. Additional clearances between trams and fixed structures should be provided to allow for the presence of people.
- 2.3 These clearances should be developed from the kinematic envelopes for the trams and take into account additional allowances for pedestrians and road vehicles.
- 2.4 Where a system uses a variety of trams, the effects of different kinematic envelopes needs to be considered.
- Note: If a high-sided vehicle is on a cambered road adjacent to a tramway, the clearance between the top of the vehicle and the higher parts of a tram could be less than the clearance at ground level.

### DEFINITION OF SWEEP ENVELOPE

- 2.5 The definition of the swept envelope (SE) is based upon a combination of the static envelope and the dynamic envelope.
- Note: Previous guidance has used the term Developed Kinematic Envelope, DKE, rather than Swept Envelope. The terms are mutually interchangeable and represent the same practical effects. Use of this term 'SE' will help to give better consistency with European practice.

### Static envelope

- 2.6 The static envelope is that formed by the maximum cross-sectional dimensions of trams to be used on the tramway and, where applicable, their loads when at rest on straight and level track. It should take into account allowances for tolerances in the manufacture of the trams and the effects on the suspension of tram loading and loads arising from the wind and other weather.
- It should not include driving mirrors where these are designed to deflect as with other road vehicles. However, clearances to fixed highway obstructions will still need to be considered.

### Dynamic envelope

- 2.7 The dynamic envelope is the static envelope enlarged to allow for the maximum possible displacement of the tram in motion, with respect to the rails on straight track. It should take into account tram suspension characteristics, and allowances for tolerances in the maintenance of trams including wear. The effects of end-throw and centre-throw of trams on curved track are not included, and are disregarded in the development of the dynamic envelope.

## Kinematic envelope

- 2.8 The kinematic envelope is the dynamic envelope enlarged to allow for the permitted tolerances in track gauge, alignment, level and cross-level and the dynamic and static effects of track wear. The kinematic envelope is speed dependent.

## Swept envelope

- 2.9 The kinematic envelope is developed to take into account all the possible effects of curvature, including super elevation of the track, and end and centre throw of the tram. It too is speed dependent, but is unique to the particular location at a given speed. This is referred to as the swept envelope. This is abbreviated to SE in this document.
- 2.10 Over-generous methods of calculation of the SE should be avoided, as they may mislead other road users as to which parts of the highway are safely accessible to them, and may create unnecessary design constraints.
- 2.11 The effects of high centre of gravity in low-floor trams and of independently rotating wheel sets may also need to be considered.
- 2.12 The enlarged SE of a tram in a credible degraded mode (such as suspension failure) should not exceed the normal SE plus the clearance to any fixed object or the established SE of a tram on an adjacent track. This should allow a tram to be recovered, albeit at reduced speed, without it coming into contact with structures or other passing trams.

## CLEARANCES BETWEEN TRAMS

- 2.13 The clearances between the SEs of two adjacent trams should be not less than:
- (a) without centre traction poles - 100 mm;
  - (b) with traction poles between the two SEs - 600 mm (but at least 100 mm from the face of the nearest side of a pole to each SE).

Note: These clearances are minimum clearances up to 2100 mm above ground level. At heights above 2100 mm, reduced clearances may be acceptable.

## CLEARANCES BETWEEN TRAMS AND STRUCTURES

- 2.14 The clearances between a SE and other highway features or fixed structures should be as follows:
- (a) to the edge of a traffic lane - 200 mm;
  - (b) to an isolated obstruction in the centre of the carriageway or on a side reservation - 100 mm;
  - (c) to a kerb - 300 mm (where pedestrians are excluded);
  - (d) to a continuous obstruction in the centre of the carriageway or on a side reservation - 600 mm.

- Note 1: These clearances are minimum clearances up to 2100 mm above ground level and where circumstances permit, greater clearances are encouraged. At heights above 2100 mm reduced clearances may be acceptable.
- Note 2: 'Side reservation' means a section of segregated on-street tramway located alongside a carriageway.
- Note 3: 'continuous obstruction' in this context implies an obstruction larger than a lamp column, bollard, traction pole, litter bin etc. to distinguish from longer obstructions such as walls or lengths of guard railing.
- Note 4: Adequate clearances should be maintained between the SE and any structure or pole, taking account of pedestrian movement.

## CLEARANCES ON HIGHWAYS

- 2.15 Lanes used by trams and other large vehicles, such as buses, coaches and heavy goods vehicles, should normally be 3650 mm wide for a two-lane carriageway. Lane widths that are shared between trams and other road vehicles will probably be dictated by the needs of the latter. A minimum lane width should be 3250 mm unless agreed with the Highway Authority. The overall layout within constricted urban areas may benefit from a detailed assessment of lane widths actually required depending on the classes of traffic that are to use each lane e.g. buses only, but taxis may be allowed to use bus lanes.
- Note 1: The Road Vehicles (Construction and Use) (Amendment) (No. 6) Regulations 1995<sup>9</sup> permit vehicles up to 2550 mm wide, and mirrors can be outside this. Therefore, the effective overall width of such a vehicle can be as much as 3000 mm. This is of particular relevance for lanes adjacent to those used by trams.
- Note 2: The widths of the lanes used by trams are based on a tram having an overall width of 2650 mm. Where narrower trams are used, the recommended lane widths for sole use by trams may be reduced accordingly. Conversely where wider trams are used, the recommended lane widths might need to be increased accordingly.

## 3 INTEGRATING THE TRAMWAY

- 3.1 This chapter provides guidance on the general design, layout and integration of the tramway with the highway.
- 3.2 Where the tramway is in a highway shared with other road users, its design and construction should allow it to be used by those other road users.
- 3.3 Where the tramway runs along the highway, crosses it, or is otherwise close to it, provisions to promote compatibility between trams and other road users should be incorporated into the highway design.
- 3.4 The operating arrangements for normal conditions and for emergency situations should be clearly defined for the type of infrastructure over which trams are operating. These should include appropriate audible and visible warnings, and evacuation and control procedures in case of emergencies. Provisions must be made during any road or tramway maintenance operations for the safe movement of pedestrians and other highway users.
- 3.5 In areas of integrated on-street tramways trams may run in a lane with other road vehicles where they will be subject to normal road traffic regulation orders and speed orders. In areas of segregated on-street tramways trams may run in a space immediately adjacent to traffic lanes, in either side reservation or in central reservation, where road traffic regulation or speed orders may not apply. In areas where trams are segregated from other traffic lanes, in central or side reserves, normal highway signage and lineage is not necessarily used as these are tram only areas. As a consequence, it is important that measures are taken to prevent other vehicles entering these areas, e.g. by the provision of tram gates.
- Note: Traffic Regulation Orders may exclude most vehicles but permit, for example, access for frontages or road sweepers.
- 3.6 Particular attention should be paid to the design of road junctions, and locations where the form of tramway alignment changes (e.g. from side to central reservation, or from integrated to segregated on-street tramway).

### ALIGNMENT CONSIDERATIONS

- 3.7 The alignment of the tramway should take into consideration:
- (a) the road layout, e.g. intersections, roundabouts etc.;
  - (b) pedestrian footways and crossings;
  - (c) cyclists and cycle lanes;
  - (d) the needs of frontagers for access and property maintenance;
  - (e) public utilities, and access requirements if it is identified that this cannot be undertaken with the tramway in (normal) operation;
  - (f) clearances on the highway (see Chapter 3);

- (g) the permitted minimum radii of horizontal and vertical curvature, the combinations thereof and the other engineering constraints for the tramway and its trams;
- (h) the location and design of tramstops (see Chapter 5);
- (i) the location of overhead electric traction equipment and other fixed structures (see Chapter 6); and
- (j) drainage.

## ROAD INTERSECTIONS

- 3.8 In the design and operation of an on-street tramway it is particularly important to recognise that the behaviour of other road users will influence the safety of the tramway. The design and operation may need to take into account likely deliberate actions and errors of judgement by other road users.

### Tramway intersections with other roads

- 3.9 At-grade intersections of tramways with other roads are road traffic junctions. The arrangements for controlling the tramway and other road traffic at an intersection should be co-ordinated. At intersections with minor roads, the tramway should be regarded as if it were the major road even if the relative volume of traffic suggests otherwise.

Note: The degree of signing or signalling may require permitted enhancements in accordance with the Traffic Signs Manual<sup>24</sup>.

- 3.10 The design of junctions should take account of good practice and recommendations on visibility splays in highway design guidance. Information can be found in documents such as the Design Manual for Roads and Bridges, or the Department for Transport Manual for Streets.
- 3.11 The maximum permitted approach speed of trams to intersections may have to be limited to negotiate the junction safely. The approach speed to an intersection should enable a tram to stop safely if the intersection is obstructed. The place from which the intersection first comes clearly into view and then remains in view for the tram driver should be identified so that the available braking distance can be established. The permitted maximum speed should be based on this distance and normal service braking rates.
- 3.12 Where a tram is being integrated into an existing highway and the maximum prescribed indivisibility splay cannot be achieved, speeds lower than the geometric speed may be required.
- 3.13 The visibility splay for a tram should be calculated from the driver's fixed seat position to a set-back measured from the SE, and not from the kerb line.
- 3.14 It is helpful if the view of the intersection includes the *Stop* or *Give Way* positions on the other approaches. This aids judgement as to the likely movements of other vehicles.
- 3.15 Where a segregated on-street tramway runs immediately alongside a carriageway or in a central reservation between carriageways, and it intersects another road, the intersection should be signalled or signed.

- 3.16 At each location there should be an assessment of the risks to road traffic turning across the tramway; this should aim to highlight issues such as OHLE poles adjacent to crossings that could trap a road vehicle in the event of a collision with a tram, also identify the potential for signage to be mounted on poles with frangible bases.
- 3.17 Where a segregated on-street section of tramway runs parallel to, but some distance from, one side of a road, and a side road crosses the tramway tracks before joining the main road, signalling the road junction to include the tramway can often not be justified on current road traffic criteria. Nevertheless, some warning of a tram approaching from behind may be necessary for vehicles on the main road if there is insufficient room on the side road between the road intersection and the *Give Way* or *Stop* line at the tramway crossing. Passive signs may be used, but may not have sufficient impact where the traffic flow on the tramway is light. In such circumstances, revisions to the highway layout or traffic management measures should be considered.
- 3.18 The road traffic light signals and signs required for the protection of at-grade crossings on tramways are prescribed in the TSRGD.<sup>16</sup> Such signals should be controlled by a traffic signal controller, approved for tramway use by the Highways Agency. The detailed arrangements should be agreed with the Highway Authority.
- 3.19 Road junctions and intersections with on-street tramways should be treated in a way similar to a normal road layout. This should comply with the appropriate advice from the Department for Transport as set out in the 'Manual for Streets'<sup>23</sup>. Signals should also be provided where a turning road vehicle may momentarily encroach on an adjacent tram due to end or centre throw.
- 3.20 Signs giving warning of the presence of trams should be provided and details of these are in the TSRGD.<sup>16</sup>
- 3.21 Where road traffic light signals are provided, the tram should have a level of precedence agreed with the Highway Authority.

### Off-street tramway intersections with the road

- 3.22 Intersections between a road and an off-street tramway should be treated as if they were intersections between a minor road on which the road traffic is travelling, and a major road on which the tram is travelling and has priority, regardless of the volumes of road and tram traffic.
- 3.23 Conventional three-aspect signals for road vehicles and the tramway equivalent for trams should be used as described in Chapter 7 "Control of Movement".
- 3.24 A non-signalled intersection between an off-street tramway and a road should be signed as if the tramway were the 'major' road. *Stop* or *Give Way* signs should be provided on the road approaches for road traffic, with the 'Tram' sub-plate applied as appropriate. If necessary, the relevant warning sign and speed restriction sign should be provided on the tramway approaches.
- 3.25 Visibility from the minor road carrying the road traffic should comply with the appropriate advice from the Department for Transport.

## PEDESTRIAN FOOTWAYS AND CROSSINGS

- 3.26 In streets which have high densities of pedestrians, the pedestrians should be encouraged to use defined crossing points over the tram track. The crossings should have dropped kerbs and appropriate tactile marking. These crossings should be designed so that they are obviously the safest crossing point.
- 3.27 Where safe pedestrian routes are defined, there should be clearly recognised features to aid identification which may include the type of paving, signing, pedestrian signals, dropped kerbs, pedestrian guard rails or planters.
- 3.28 Crossing points on a tramway should be co-ordinated with the crossing points of any shared or adjacent carriageways. On off-street tramways, the preferred arrangement is to separate entirely the crossing points for any road and for the tramway, but if not separate, the arrangements for pedestrian crossings of on-street tramways should be used.
- 3.29 All designated crossings of tram tracks should be designed with the needs of mobility- and visually-impaired people in mind.
- 3.30 Standard TSRGD pedestrian signals should be used at places where the normal passive signing at pedestrian and other foot crossings is inadequate. The need for signalling will depend on factors such as visibility and tram and pedestrian traffic flow.
- 3.31 Where the platforms or tramstops lie in the centre of the road, and if those boarding or alighting from a tram have to cross one or more lanes of road traffic to reach or leave the designated access point for the tramstop or platform, those crossing points should be treated as pedestrian crossings.
- Note: Careful consideration should be given to both visibility of pedestrians by tram drivers and visibility of approaching trams by pedestrians.

### Crossing layouts

- 3.32 Where reasonably practicable, the part of the crossing over the tram track should not be in-line with any other separately-signalled pedestrian crossing or separate zebra crossings.
- 3.33 Fencing or pedestrian guard rails to highway design principles should be provided where necessary, to guide pedestrians to face oncoming trams before they cross the track, or to direct their attention to pedestrian crossing lights.
- 3.34 Part or all of such pedestrian crossings may be unsignalled if the circumstances at the site allow. For example, if the visibility along the tram tracks is good and the volume of tram traffic low, it may be possible to dispense with pedestrian signals when other circumstances (such as a high volume of adjacent road traffic) would dictate that the road crossing would be signalled. At other places it may be necessary to provide pedestrian signals across the tramway, but a zebra crossing may be sufficient across the road.

### Pedestrian crossings linked with tramway signals

- 3.35 Where the tramway crossing cannot be separated in any way from the crossing of the remainder of the highway, positive indications which are visual, audible and, where practicable, tactile, should be given under the same conditions which apply at a traffic-signalled junction with a pedestrian phase or a signalled pedestrian crossing.

- 3.36 If the crossings are staggered, and it is appropriate, audible equipment to the appropriate specification issued by the Department for Transport may be suitable.

### Pedestrian crossings with signals linked to approaching trams

- 3.37 Where the tramway crossing can be separated from the remainder of the highway crossing by the provision of refuges, or where the pedestrian crossing movement is parallel to the road over tram tracks only, i.e. where an off-street or segregated on-street tramway crosses or enters a road, only the warning of the approach of a tram should be given (no tram - no warning). The warning should be:
- (a) visual. For consistency with highway practice, a conventional red/green man pedestrian signal should be used where there are signals controlling tram or road traffic at the location concerned.
  - (b) Audible warnings should only be provided at crossings where this would be consistent with highway practice for such locations.
- 3.38 The design of any tactile surfaces should follow Department for Transport guidance<sup>25</sup>.

### CYCLE/TRAMWAY INTERFACE

- 3.39 If cycles and trams are to share the same highway alignment then there should be appropriate facilities for cycles to make crossing movements and to traverse tramstops. If this is not possible then alternative cycle routes should be used. Alternative cycle routes can be achieved either by placing a separate cycle lane adjacent to the footway, by providing an alternative direct route or by providing a one-way cycle lane within the carriageway.
- 3.40 Where there are discontinuities in cycle lanes due to the presence of tramstops, experience shows that there is likely to be misuse, with cyclists following their desire lines even where this leads them to cross rails at shallow angles. Kerbside cycling refuges may be appropriate on long, steep routes and on the approach to tramstops.
- 3.41 Particular care should be taken to avoid pinch points with cycle lanes along the route, and where roadside platforms are provided, careful consideration of the impact on cyclists is necessary.
- 3.42 Where cycle lanes cannot be provided, the clearance between rail and kerb should be a minimum of 1000 mm, and consideration should be given to the removal of obstacles from that area, e.g. by the provision of drainage incorporated into the kerbs. This clearance is intended to provide a clear route for cyclists in the absence of trams and, combined with the removal of obstacles from that area, reduces the likelihood of sudden movements by cyclists towards the tramway. It is not intended to provide clearances for trams to pass cyclists.
- 3.43 One-way cycle lanes should be clearly marked and signed as such; vehicle parking and loading prohibitions will be required. Wider cycle lanes within the carriageway to permit two-way cycling should be avoided.
- 3.44 To avoid the risks from unauthorised parking of vehicles fouling the SE, the width of the cycle lane (between the kerb and the nearest edge of the line shown in the appropriate diagram of the TSRGD<sup>16</sup> should not be greater than 1000 mm and the edge of the line nearest to the tram track should be at least 200 mm from the SE (see Figure 1).

- 3.45 Where it is necessary for cycle lanes to cross tram tracks, these intersections should be, as far as possible, at right angles to the tracks. Where the achieved crossing angle is less than 60°, consideration should be given to alternative crossing layouts and other measures that mitigate the risks faced by cyclists. These could include additional road markings to show the recommended routes across junctions for cyclists.
- Note 1: In addition to the local Highway Authority, local cycling groups may provide useful information in relation to local cycle routes and relative user levels in addition to feedback on the most effective cycle route solutions for the tramway route under development.
- Note 2: General guidance on cycle issues is found in DfT Local Transport Note 2/08 "Cycle Infrastructure Design"<sup>26</sup>.

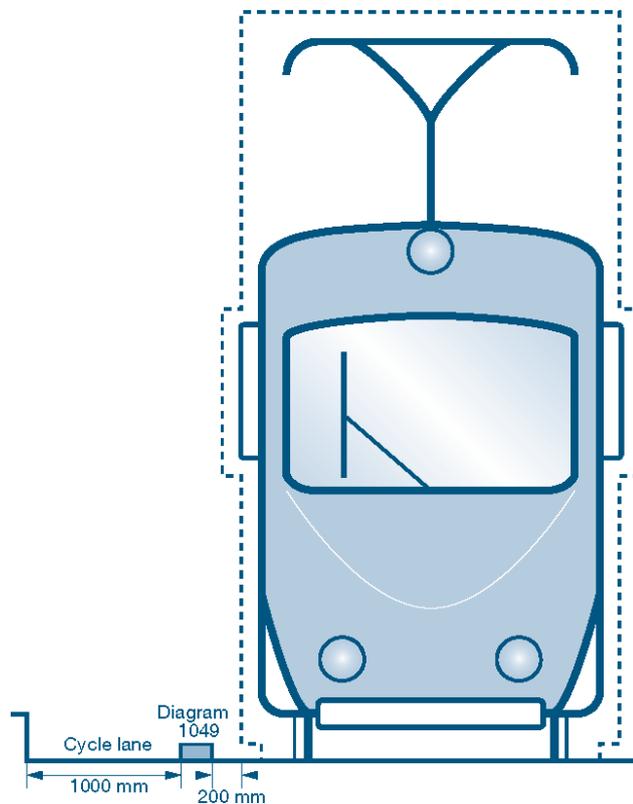


Figure 1: Clearances between tramway and cycle lane

## FRONTAGERS

- 3.46 The needs of premises fronting the tramway, including access, should be carefully assessed.
- 3.47 It may be necessary to provide dedicated loading/unloading and private parking bays to avoid the tram track becoming obstructed by vehicles.

- 3.48 Obstructing a tram track can normally be made an offence under the powers authorising the construction and operation of the tramway or by means of relevant by-laws.
- 3.49 Where the tramway crosses entrances to or exits from premises, it should not be necessary to erect warning signs at each such location. Road traffic light signals may be necessary at busy locations or where sight lines are inadequate.
- 3.50 If the place concerned is likely to attract drivers unfamiliar with the area (e.g. a factory), warning signs may be required.

## PUBLIC UTILITIES

- 3.51 Public utilities in or under the highway should, where possible, be accessible while trams are operating. Any access covers should have their nearest edge at least 500 mm from the edge of the SE. Where pipes and cables have to pass under the track, they should be ducted or sleeved before the tracks are laid, to facilitate maintenance or renewal.

## CHANGES BETWEEN SEGREGATED AND INTEGRATED ON-STREET TRAMWAYS AND OFF-STREET TRAMWAYS

- 3.52 Where a tramway joins, leaves or runs alongside a carriageway, it should be identified by appropriate signing, carriageway markings or traffic signals, in accordance with the TSRGD.<sup>16</sup>
- 3.53 Access to the off-street or segregated on-street sections of tramways by vehicles other than trams should be deterred by traffic signs, which may be supplemented by traffic regulation orders, by-laws etc.
- 3.54 Suitable treatment of the road surface leading to a wholly segregated section of track, e.g. ballast, flexible or frangible bollards between the tram tracks (potentially with a lower than normal clearance to the tram being permissible) or isolated cobbles set into the surface, would help to encourage compliance with the signs.

## TRAMWAY PATH

- 3.55 The tramway path is the area reserved for a moving tram in its environment. It is derived from the SE by adding the minimum appropriate clearance. It therefore depends upon the SE and upon the nature of the operational environment and the structures and features within it.
- 3.56 It is important that at an early stage a determination is made of a trams SE at various speeds, this is particularly relevant for low speed areas such as through platforms to ensure that over-cautious clearances are not adopted.
- 3.57 The path of an on-street tramway should be marked where it is not apparent from the carriageway or kerbs, and where it would be useful either to tram drivers or other road users to do so. Where such marking is necessary, it should be consistent with the prescribed markings shown in the TSRGD.

- Note 1: Such definition may be achieved by the use of colour, texture or differences of levels to enhance visibility.
- Note 2: If yellow dot markings are to be continued through any yellow box markings at junctions, this marking may require an amendment to the yellow box markings.
- 3.58 If more than one type of tram is to be used on a system, the tramway path at any point should be determined by the characteristics of the tram type that has the widest SE at that point.
- 3.59 Where two tracks are parallel to each other or converge, they should be enclosed within a single tramway path.
- 3.60 On segregated on-street sections, the boundaries of such sections should be adequately delineated and access to the track by other road vehicles, except at designated crossings, discouraged.
- 3.61 Kerbs may be required to separate a segregated on-street track from an adjacent carriageway unless vehicle barriers are installed, for example, to separate road vehicles from oncoming trams or to protect against collision of road vehicles with isolated lineside structures.

## PEDESTRIAN PROTECTION ARRANGEMENTS

- 3.62 Pedestrian guard rails may be used to direct pedestrians to safe crossing points. These guard rails should be appropriately set back to avoid creating trapping points.
- 3.63 Fencing should be provided at places on the tramway where there is a significant risk to pedestrian safety. Access to the track, except at designated crossings, should be discouraged.
- 3.64 Appropriate forms of deterrent paving may be used to discourage both pedestrian and vehicular access.
- 3.65 In areas to which pedestrians have access, street furniture, adjacent infrastructure, access for tramway infrastructure maintenance and tram operating speeds should be designed to reflect the requirements for line-of-sight operation.

Note: Further guidance on pedestrian issues is given in Appendix F

## 4 THE INFRASTRUCTURE

- 4.1 This chapter provides guidance on the infrastructure of the tramway system including the track, bridges, tunnels and infrastructure identification.

### THE TRACK

#### Running rails

- 4.2 Steel running rails should conform to the appropriate European Standards such as: (BS EN 14811 or BS EN 13674). The rail section(s) and materials, and wheel profile(s) should be carefully selected so as to be mutually compatible in terms of derailment prevention, ride, noise, wear and adhesion.

Note 1: Consideration will need to be given to adhesion levels achievable with new rails. Generally these levels improve with use.

Note 2: Magnetic properties of the rail will affect the performance of electromagnetic track brakes.

- 4.3 Grooved rails should have sufficient and suitable drainage provided at appropriate intervals and locations (such as areas of ponding, bottom of gradients), and when laid in the highway, connected to surface water drainage systems. The drains should be capable of being easily cleaned to allow removal of sand and other debris. The provision of drainage slots should not render the rail incapable of providing sufficient support or guidance for trams.

Note: The effect of the presence of rail grooves on highway drainage may be significant.

- 4.4 Where rails are laid in a carriageway that is used by rubber-tyred vehicles travelling in the same general direction as the rails, the effect that the steel rail and any flexible filling will have upon the skid resistance of the carriageway surface should be considered, particularly when vehicles move across the carriageway and their tyres cross over the rails at shallow angles. The track should be located within the carriageway so that, so far as is reasonably practicable, it does not coincide with the path normally taken by the wheels of rubber-tyred vehicles.

Note: Additional warnings of the risk of skidding may need to be given to motorists. Rubber-tyred vehicles may skid when accelerating, as well as when braking or cornering.

- 4.5 The carriageway incorporating the tramway should be engineered to present a surface which:

- (a) can support the normal loads of vehicles using the carriageway; and
- (b) has a seal to minimise the ingress of water at the interface between rail and adjacent road surfaces, where such ingress could cause damage to the highway surface.

- 4.6 Where flexible filling material is used, that material should, so far as reasonably practicable, have a skid resistance comparable with normal road surface material.

- 4.7 So far as is technically feasible, when first laid, the head of the rail should be level with the adjacent road surface.

## TRACK GEOMETRY

- 4.8 The maximum horizontal and vertical curvature, the maximum gradient, the maximum track twist on a tramway, and combinations thereof, should be established taking account of the physical constraints of the route, the capability of the tram, and the effects of speed, curvature and gradient on the passengers.
- 4.9 The horizontal curvature of sections of ballasted Vignole trackform should be designed with the highest radius possible and the consequence of flange climb or overspeed derailment mitigated. The mitigation should consider as a minimum the following:
- Advance warning signs and speed limit warnings as defined in TSRGD<sup>16</sup>;
  - Avoidance of lineside equipment boxes, drainage inspection covers etc. in the vicinity of curves;
  - Provision of automatic speed control.

Note: If geometric limits are set on the infrastructure that are too severe then these may create restrictions on the types of trams that can operate over the route.

- 4.10 Where circumstances permit, super elevation should be provided on the tram track, and the cross section of the highway should accommodate this.

Note: Other matters to be considered include whether surface water drainage can be directed away from the grooves in the rails by providing a cross-fall, and whether the surface between the rails (the four-foot) has to be cambered.

## TRAMWAY POINTS IN THE HIGHWAY

- 4.11 Points should not be located where the movement of the blades would cause a hazard to other road users or where road vehicles could damage the points. The moving blades of the points should not normally be located:
- (a) at places in the street where there are concentrations of pedestrians, such as at formally identified crossings;
  - (b) where there would be a particular danger to cyclists or motorcyclists; or
  - (c) in busy traffic, or where traffic lanes cross or merge with a tram lane, particularly where this is also aggravated by a turning movement.

Note 1: Pre-sorting points, with interlaced track or double-headed rails or other techniques, may be used where practicable to achieve this objective.

- Note 2: Where points have to be located at the places identified above, special precautions may be necessary to minimise the risk (see Chapter 7 and Appendix B).
- 4.12 Where a point indicator is the primary means used to allow a tram to approach facing points at a speed higher than that which would allow the driver to observe the lie of the points and stop in advance of an incorrectly set route or misaligned point blade, the point indicator and point detection circuits should be designed to meet inherently failsafe criteria.
- 4.13 There should be an additional indication for out of correspondence condition which should be a horizontal bar. See Appendix E for recommended point indication diagrams. (*This appendix will be added in the next version of this document*)
- 4.14 If point blades are misaligned or an incorrect route is set, a tram that cannot proceed should not obstruct other trams (other than a following tram) or traffic. Where the points are some distance beyond the road junction, an appropriate arrangement is shown in Appendix B.
- 4.15 Where points are located in off-street sections of the tramway, provision should be made to deter access to those areas where the moveable portion of the points would cause a hazard to the public.

## BRIDGES AND VIADUCTS

### Bridges carrying the tramway

- 4.16 Bridges or viaducts carrying tramways should be designed using appropriate methods and loading assumptions. Designers who choose to follow the Eurocode process should note that the standard load models in EN 1991-2 are all for mainline railway cases and are unlikely to be suitable for the modification. If a standard EN 1991-2 load case is used then a suitably justified use of a reduced factor  $\alpha$  will be necessary.
- 4.17 Adequate derailment containment should be provided on all bridges and structures and elsewhere where the consequences of derailment would result in a significant hazard.

### Bridges over the tramway

- 4.18 Bridge parapets should deny access to the live overhead electrical traction power system.
- 4.19 Bridges and supporting structures over the tramway should be capable of resisting credible impact forces from derailed trams. Designers should be able to demonstrate that they have used credible impact criteria in developing the design.

## TUNNELS

- 4.20 lighting in underpasses and tunnels should be provided when either side is street-lit. This is in addition to the provision of lighting on an emergency basis for evacuation, which may also assist maintenance.
- 4.21 If the tunnel is shared with other traffic of any kind then it should meet current highway design standards.

- 4.22 Where the tram is the only user of the tunnel to the exclusion of other road or rail users then the risk profile is likely to be lower, and tunnel design based on risk assessment of the tramway hazards should reflect this.
- 4.23 Where former railway tunnels are used and the trams have doors on both sides, the available space should be used to provide one generous-width centre walkway if it is not possible to provide adequate side walkways.
- Note: Where the size of a former railway tunnel does not allow a walkway to be provided, then the track may be used as a walkway as long as:
- (a) there is sufficient clearance for the tram doors to open and allow passenger egress;
  - (b) the track provides an acceptable walking surface;
  - (c) the tunnel is illuminated; and
  - (d) the tramway operates on line-of-sight through the tunnel.

## ACCESS CONTROL

- 4.24 A tramway generally has no restriction on access. However, where special risks occur, appropriate deterrent measures should be provided.
- 4.25 Particular attention needs to be given to the protection of the electric traction system from unauthorised persons. Such protective measures should be designed with the needs of the environment in mind (see Chapter 6).
- 4.26 The design of the tracks, paving, overhead line equipment and other infrastructure associated with the tramway should take account of the needs of pedestrians and other highway users, and make appropriate provisions for their safety.
- 4.27 While the tramway is normally unfenced, some fencing or other barrier may be necessary to segregate or direct pedestrians away from it at particular locations.
- 4.28 Special consideration should be given to the needs of mobility-impaired people, whether on foot or in wheelchairs, or using pushchairs.
- 4.29 Where a need has been established for a segregated tramway, deterrents to access should be provided to discourage trespass by both pedestrians and road vehicles.

## IDENTIFICATION OF THE INFRASTRUCTURE

- 4.30 A means of identifying any location along the tramway should be provided, for example, by numbering the overhead line supports. All bridges and other fixed structures, as appropriate, should be uniquely and conspicuously identified. Any system of identification should be consistent with that of the highway or roads authority.

## TERMINATING TRACKS

4.31 Where tram track terminates, arrangements should be made for a tram that overruns the normal limit of operations to be brought to a halt or contained safely. The arrangements may include sand drags, soft macadam surfacing over the rails, energy-absorbing architectural features such as large planters, or other appropriate measures. Selection of the arrangements for a location should be on the basis of tram kinetic energy, the risks arising from an overrun, and suitability for the surrounding environment. The means chosen should discourage pedestrians from lingering in an overrun area.

Note The provision of buffer stops could increase risk if used without proper consideration of energy absorption rates.

## 5 TRAMSTOPS

The term 'tramstop' includes stops with a raised platform above pavement level and those with platforms at pavement level.

### TRAMSTOP LOCATION

- 5.2 The needs of passengers, pedestrians and other road users should be reflected in the design of tramstops and associated pedestrian routes. Design factors include:
- (a) sightlines;
  - (b) gradients and curvature;
  - (c) lighting; and
  - (d) pedestrian desire lines.
- 5.3 Tramstops should be sited so that:
- (a) people who cross to the tramstop have adequate visibility of approaching trams and road traffic;
  - (b) tram drivers have adequate visibility of the tramstop;
  - (c) tram drivers have adequate visibility of people at or approaching the tramstop; and
  - (d) other road vehicle drivers have adequate visibility of pedestrians approaching or leaving a tramstop.
- 5.4 If visibility is poor, then crossings equipped with pedestrian signals may be considered.
- 5.5 Particular attention should be given to the design of tramstops and platform edges to minimise risks to pedestrians and other road users.
- 5.6 When tramstops are located on gradients, consideration should be given to the difficulties that might be created for those who are mobility impaired.

### TRAMSTOP PLATFORMS

- 5.7 Platforms may form part of the footway or other public areas accessible to pedestrians.
- 5.8 Platforms should be provided with a tactile surface and a platform edge marking strip and these should follow Department for Transport guidance<sup>25</sup>. Platform surfacing should provide contrast to the edge marking and a suitable level of friction.
- 5.9 Platform length should be sufficient to match the passenger door arrangements of the longest tram or normal combination of trams using the part of the system on which the tramstop is located. The length of the platform should include an allowance for inaccurate stopping.

## PLATFORM HEIGHT

- 5.10 Platform heights of 300mm are becoming common for low level platforms, and this may be the most appropriate choice for any new systems.
- 5.11 Where platforms are provided and the height difference between the footway and the platform is more than 400 mm, the non-tramway edge may need to be fenced. Continuous steps may be provided instead of a fence and the appropriate tactile markings should be used.
- 5.12 Differences in height between tram floor and platforms must not exceed 50 mm at doors which are intended to be used by mobility-impaired passengers<sup>12</sup>. Where such access is provided only at some doors, adequate signage should be provided to indicate the door or doors which provide it. To ensure compliance throughout the life of the system, adequate wear and maintenance tolerances should be considered in the design.

Note: Mobility-impaired people are a very much wider group than wheelchair users. For example, people with prams and pushchairs have the same need for level access.

## PLATFORM WIDTH

- 5.13 Platform width should give adequate unobstructed space for passengers boarding and alighting and should take into account pedestrian movements along the platform and the likely accumulations of waiting passengers. Consideration should be given to congestion likely to be caused adjacent to ticket vending machines and beneath shelters.
- 5.14 The minimum width between the tramway edge of the platform and any structure on the platform, except for the roofs of shelters, should not be less than 1500 mm.
- 5.15 An island platform should normally be at least 3000 mm wide, but may be narrower for low platforms.

Note: An island platform is one that lies directly between two tramway tracks. A platform between a tramway track and another carriageway lane not used by trams is a side platform.

## PLATFORM CLEARANCES

### Between platforms and trams

- 5.16 Horizontal clearance between platforms and door thresholds must not exceed 75 mm at doors which are intended to be used by mobility-impaired passengers.<sup>12</sup> Where such access is provided only at some doors, adequate signage should be provided to indicate the door or doors that provide it. To ensure compliance throughout the life of the system, adequate wear and maintenance tolerances should be considered in the design.

Note 1: The dimension of 75 mm is the maximum that must be maintained over the life of the system and it is recommended that at installation a figure of 40 mm is achieved to help ensure compliance with the Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010<sup>12</sup> over the life of the system.

Note 2: The amounts by which the static vehicle profile (see Chapter 2) will be increased to form the

kinematic envelope or the SE are speed dependent, therefore the gap is also speed dependent; constraining this increase by the platform edge may require the imposition of a speed limit through the tramstop.

- 5.17 No shelter, sign or other structure on a platform should encroach within 450 mm of the edge of a carriageway used by other road vehicles.
- 5.18 Where a side platform has road traffic adjacent to the non-tramway side a fence or barrier should be provided if normal highway design standards would require it.

### Vertical clearance

- 5.19 There should be clear headroom of at least 2300 mm. This applies to shelters, signs and all other structures on platforms.
- 5.20 Shelters, signs and other structures on the platforms should be designed to prevent access to overhead electric traction equipment.

### LIGHTING AT TRAMSTOPS

- 5.21 Tramstops should be adequately and uniformly illuminated during the hours of darkness to a level commensurate with the surrounding area and as required by CCTV. Illumination may be provided by adjacent carriageway lighting.

### ACCESS TO TRAMSTOPS

- 5.22 A safe and convenient access to tramstops should be provided for all, including mobility-impaired people.

Note: See Appendix F for guidance on crossings.

- 5.23 The design of the infrastructure adjacent to platforms and pedestrian crossings at tramstops should be such as to minimise injury to a person struck by a tram. The surrounding surface should be at a level relative to the rail that allows the tram's pedestrian underrun protection to operate effectively; this may be either by ballasting to rail level or other flush surfacing. This surfacing should also extend on the approach and departure to a tramstop for a suitable distance based on the tram braking performance and likely tram speed in the location.
- 5.24 Where access to a tramstop is by ramp from an adjacent road bridge, the length of the ramp will, if the slope is 1 in 20 (5%), be in the order of 100 m where the road is over the tramway and 160 m where it is under it. Intermediate flat landings will increase these ramp lengths by 20 m to 30 m. The total length of such an access may be considered to be excessive by the more elderly or mobility-impaired people and lifts may have to be provided.

## 6 ELECTRIC TRACTION SYSTEMS

- 6.1 Trams should usually be supplied with electric traction power from overhead line systems at a voltage consistent with BS EN 50163.
- 6.2 Exposed live conductor rails or similar systems should not be used on on-street sections. Use of alternative traction supply systems should be compliant with the Electricity at Work regulations 1989 and subject to risk assessment.
- 6.3 The physical design of overhead electric traction power supply systems for tramways should be compatible with the requirements and capabilities of the current collection equipment of tramcars. The application of mainline railway design criteria should be avoided.

### OVERHEAD LINE EQUIPMENT

- 6.4 Structures supporting an overhead electric traction power supply system should be positioned so that they neither significantly obstruct or endanger users of the highway, nor are unduly exposed to damage from an errant road vehicle or tram.
- 6.5 Electric traction supply poles with cantilever arms, or a system of span wires between traction poles or building attachments, may be used to support the overhead line equipment.

Note 1: The general requirements for clearances to electric traction supply poles are given in Chapter 3.

Note 2: Where footways are a minimum width (normally 1800 mm) the Highway Authority may require the poles to be located beyond the back of the footway.

- 6.6 All electric traction poles should be resistant to climbing.
- 6.7 If tension weights are used in public places, they should be provided with an arrestment device in the event of a broken wire. In public areas tension weight assemblies should be either shrouded or within the support column.
- 6.8 Structures supporting the overhead line equipment and not bonded to the traction return (IEC 913 & BS EN 50122) should be at least double insulated from live components. The primary insulation should be as close as possible to the live conductors.

Note: The risk of insulation degradation, leading to hazardous potential differences, may be reduced to an acceptable level by the use of multiple insulators or lengths of continuous insulation in the contact wire support system of the overhead line equipment.

### Security of overhead line in the event of collapse or loss of any one support

- 6.9 The design of the overhead line supports should aim to minimise the vulnerability of each support to damage. The loss of any one support (e.g. as a result of a fire loosening a building fixing or of a pole being struck and damaged by a road vehicle) may release tension in the overhead line system but the design should allow other supports to prevent live equipment from sagging below 5200 mm above the highway. Off highway, it may sag lower provided that it remains out of reach of pedestrians. Connections between the pole and the contact wire should be mechanically weaker than the contact wire system itself to ensure that if a pole is

damaged, the connection will break before the live equipment is dragged down.

## Use of electric traction power supply poles for street lighting or other electrical equipment

- 6.10 Where electric traction poles are used to support the street lighting system or other electrical equipment, precautions should be taken so that even under fault conditions, one power system cannot adversely affect the other

Note: Precautions may include double insulation in respect of the different electrical systems, and specially designed earthing systems.

- 6.11 Street lighting or other electrical equipment should be designed and installed so that it can be maintained safely without affecting normal operation of the tramway system.

## MANAGEMENT AND SAFE OPERATION OF POWER SUPPLY

- 6.12 The design of the electric traction power supply system should be compliant with BS EN 50122 parts 1, 2 and 3.

- 6.13 Isolating switches should be provided to give effective and efficient means of control of the power supply system under both normal and emergency conditions. Such switches should be protected from casual interference by unauthorised people and located so as not to cause a hazard. It is preferable for isolators to be located in secure trackside cabinets in positions protected from errant highway vehicles. Should it be necessary to mount isolators on traction supply columns, consideration should be given to protecting people from accessible live parts and ensuring a safe means of manual operation.

Note: Factors such as the proximity of buildings and the need for access for such matters as window cleaning may dictate the location of isolators.

- 6.14 Suitable protection arrangements should be provided so that, either in emergency or as part of a planned isolation, normally live equipment can be bonded to the traction return system. Such arrangements should be capable of use without exposing staff to risks from road or tram traffic and should not be capable of being interfered with by traffic or the public.

- 6.15 The electric traction supply feeding system should be capable of discriminating between fault currents and normal system load currents. The protection equipment should be able to detect all credible faults, for example, a short circuit at the remote end of a section being fed from the traction substation.

- 6.16 High-speed dc feeder circuit breakers should be provided that are capable of automatically disconnecting all power feeds to a short circuit in the traction system. Automatic re-close should not normally be used.

## Sectioning

- 6.17 The electric traction system conductors should be sectioned electrically and provision should be made to enable the electric traction supply to be disconnected. Where necessary, means should be provided to permit the equipment to be earthed or otherwise made safe.

Note: Care should be taken to locate section insulators in positions that do not create operational constraints, for example immediately after leaving a tramstop, leaving tight curves, or within

highway junctions.

## Central control facilities

- 6.18 The tramway operational control room should have provision for the safe and efficient management of the electric traction power supply system. Where the traffic control is located separately from the electric traction power supply control, communication facilities should be provided between the two (see Chapter 7).
- 6.19 There should be a monitoring system that clearly shows the actual position or status of all monitored switches, isolators, circuit breakers or other devices controlling the power supply. This system should have provision to record all status indications, alarms and operator actions.
- 6.20 Arrangements for control of the traction supply should be such that under all normal or failure conditions of the control system, a need for the emergency discharge of that supply at a particular location can be met within the response time required by the emergency services.
- 6.21 Sufficient information should be permanently displayed, or otherwise immediately available for display in the electric traction supply control facility, to enable the controller to:
- (a) relate, with sufficient accuracy, the electrical distribution system to the geography of the tramway; and
  - (b) make safe the area affected by an incident in terms of tramway operation and electrical supply.

## Avoidance of dangerous touch potentials to adjacent structures

- 6.22 Where it is possible to touch equipment at the return and earth potentials simultaneously, the hazard should be assessed to ensure that dangerous touch potentials are mitigated in other ways. Reference should be made to BS EN 50122-1.

Note: Unbonded structures and other conductive equipment alongside the tramway will normally be at the 'mother' earth potential of the locality. The rails and body of a tram may be at a different potential from local earth, particularly at sites remote from feeder stations and under fault current conditions.

- 6.23 Where equipment has to be connected to a different earthing system, precautions should be taken to prevent danger to people who could touch both systems simultaneously.

## Use of running rails as return conductors

- 6.24 Where the running rails are used for the return of electric traction current:
- (a) the along-track resistance should be designed and maintained to be as low as reasonably practicable; and
  - (b) the rails should be nominally insulated from earth and not deliberately earthed at any point; but
  - (c) the rails within the confines of maintenance depots should be earthed.

## Minimisation of leakage of stray current to earth

- 6.25 The design of the electric traction supply system should ensure that leakage of stray current is normally minimised. The spacing of electrical sub-stations is important and minimising the return resistance by the use of adequate rail section or additional return conductors should be

considered. Proposals that may create higher voltages in areas considered to be less accessible should be discussed with the Inspectorate at the design stage.

Refer to Appendix G for further advice on the management of stray currents.

Note 1: Leakage of direct current may give rise to the risk of galvanic corrosion of structures and apparatus.

Note 2: Direct currents in the earth may lead to dangerous malfunction of equipment (such as interference with track circuits).

Note 3: To avoid excessive leakage current, the depot traction supply may require a separate traction substation that is normally not connected to the main tramway traction feeding system.

## ELECTRICAL CLEARANCES

6.26 The appropriate clearances for tramway systems are defined in BS EN 50121-1.

### Height

6.27 The height of the contact wire or any other live part of the overhead electric traction supply system must not be less than 5800 mm above the surface of any carriageway at the maximum temperature of the wire.<sup>13</sup> Any proposal to use a lower position (for example, because of an existing bridge) would require express statutory authority or an exemption from the Secretary of State.

Note: Snow and ice loading may reduce the height of the contact wire or other live parts above the carriageway.

6.28 At other places accessible to the public, the position of the contact wire or any other uninsulated live part of the overhead electric traction supply system must be not less than 5200 mm above the ground or from a surface on which a person might reasonably stand, at the maximum temperature of the wire.<sup>13</sup> Any proposal to use a lower position (for example, because of an existing bridge) would require express statutory authority or an exemption from the Secretary of State.

6.29 Where the headroom below the contact wire is reduced, the 'safe height' should be indicated on road traffic signs. Both advance warning signs shown in diagrams 779 and 780.1A of the TSRGD<sup>16</sup> and, at the obstruction, the signs shown in diagrams 779 and 780A, should be provided. The indicated safe height for voltages up to 750 V dc should be at least 460 mm less than the actual headroom unless height gauges are installed, in which case the indicated safe height should be at least 380 mm less than the actual headroom.

### Arrangements for overhead electric traction power supply systems on department for transport high load routes

6.30 Special arrangements should be provided where a Department for Transport high load route intersects a tramway where diversion of the route is not possible, such as a means of lifting the overhead line equipment for the passage of a high load.

## 7 CONTROL OF MOVEMENT

- 7.1 This chapter, together with Appendix B, provides guidance on the control of tram movements on a tramway.
- 7.2 The objectives are to control the movement of trams, prevent collisions and prevent possible derailment on points and crossings, and at other high risk locations.
- 7.3 Line-of-sight driving should be used on all tramways. A tram should be able to stop before a reasonably visible stationary obstruction ahead (including a signal displaying a Stop aspect or points indicator displaying an inappropriate aspect for the intended, or expected, route), from the intended speed of operation, by using the service brake. Relevant considerations may include:
- (a) the available sighting distance;
  - (b) the intended speed of operation;
  - (c) the braking performance of the tram, taking into account the gradient and tram brake equipment response time;
  - (d) the effectiveness of the tram headlamps, if it is intended to operate in darkness in unlit areas, or the effectiveness of any illumination of the track;
  - (e) the expected driver reaction time, which will depend upon what other actions the driver is expected to be carrying out at the location;
  - (f) the visibility and clarity of signals and points indicators;
  - (g) the topology of the surrounding area including side roads/walkways; or
  - (h) surrounding amenities, such as playing fields, schools, residential care homes;
  - (i) the geometry of the tramway alignment;
  - (j) the provision of any form of active warning system.

### BI-DIRECTIONAL SINGLE LINE SECTIONS

- 7.4 Where the visibility has been assessed as being adequate from one end of the single line to the other, such that the driver of a tram can be relied upon to assess whether a tram in the opposing direction has entered, or is about to enter, the single line, there is no requirement for signalling to be provided. In this case a rule regarding precedence of occupation of the section is appropriate, reinforced by signs.
- 7.5 Where the distance exceeds the driver's forward visibility, or geometry or structures intervene, then signalling controls should follow highway principles for directionality, reinforced where necessary by indicators that a tram has entered an occupied section from the opposite direction, colloquially known as SPAS (Signal Passed At Stop) indicators.
- 7.6 The operation of trams in these sections should always remain as line of sight and drivers should be prepared to stop on seeing an approaching tram.
- 7.7 Such systems are not required to have a level of safety integrity commensurate with railway signalling principles.
- 7.8 Railway signalling principles may also be used to provide a higher level of safety integrity if higher speeds of operation are required.

## INTEGRATION OF THE TRAMWAY AND HIGHWAY

- 7.9 The design and integration of the tramway and highway should take account of the following factors that could affect the safe operation of the tramway
- (a) actual pedestrian desire lines and cycle crossing points;
  - (b) design of pedestrian routes so as to encourage pedestrians to face towards any oncoming tram before crossing the track;
  - (c) design and location of parking bays, equipment cabinets, overhead line poles, vegetation and other street furniture and features, so as to avoid places of concealment for pedestrians;
  - (d) provision of barriers between places of concealment and the SE;
  - (e) design of access routes to and from tramstops so that passengers are discouraged from crossing the track at places other than designated crossing points;
  - (f) the safe and efficient passage of other highway vehicles;
  - (g) intervisibility between approaching trams and vehicles emerging onto the tramway;
  - (h) the creation of one-way streets to prevent vehicles emerging from junctions where the sight lines are particularly poor;
  - (i) speed restrictions, on both trams and other highway traffic;
  - (j) audible warning by approaching trams;
  - (k) measures to deter pedestrian access to some areas;
  - (l) warning signs for those approaching the tramway;
  - (m) elimination of features likely to distract tram drivers or divide their attention;
  - (n) the turning radii of vehicles manoeuvring in the vicinity of the tramway path;
  - (o) levels of illumination of tramway junctions with highways should be consistent with normal highway design practice.

Note: Reference should be made to the appropriate chapters of the Department for Transport Traffic Signs Manual<sup>24</sup>.

- 7.10 Conflicting road and tram movements at road intersections and places where a tramway crosses a carriageway should (where necessary) be controlled by highway signalling.
- 7.11 Part-time traffic signals may be employed to allow the use of emergency crossovers and other infrequently required tramway routes on the highway. The appropriate signing for part-time traffic signals on the highway as given in the TSRGD<sup>16</sup> should be provided. This may need to be supplemented to give more information to other road users (e.g. 'tram reversing').
- 7.12 Where it is necessary to control the movement of trams during roadworks, consideration should be given to adapting portable signals to show tram aspects.

## CONNECTIONS BETWEEN TRAMWAYS AND RAILWAYS

- 7.13 Connections between a tramway system and railway system should be suitably managed. If railway vehicles need to operate over a tramway their compatibility needs to be ensured and the operation appropriately managed. Similarly, if a tram needs to operate over a railway line the requirements of the railway undertakings will need to be met. Apart from the times when movements have been properly arranged through robust controls then connections must remain secured out of use. Connections between systems should only be provided where an operational need has been established.

## LOCATION OF TRAM SIGNALS

- 7.14 On the highway, the layout and positioning of tram signals, and the associated staging and phasing at intersections, should follow current highway traffic engineering principles. Particular attention should be paid to the requirements of turning traffic in the design, location and staging of traffic signals. Consideration should be given to the visibility of tramway signals such that signals are visible to tram drivers held at stop lines irrespective of the location of other highway vehicles.

Note: Staggered stop lines may assist with ensuring the visibility of tram signals. Tram signal heads may be placed on either side of the track to optimise visibility from the driver's cab.

- 7.15 All signs and signals on the highway must be agreed with the Highway Authority.
- 7.16 Where the tramway track layout allows for the reversal of trams in the highway in a way that would result in the tram moving in the opposite direction to other road traffic, road traffic signals to stop the other road traffic while the tram reverses are required.

## TRAM DETECTION

- 7.17 Detection systems should be configured so that the failure of an individual detector does not compromise the safe operation of a road junction or pedestrian crossing.

The form of detection for trams may be different from those used for other vehicles on the highway.

- 7.19 If each driving position of a tram is separately identified for route calling and route releasing, then suitable arrangements should be provided to ensure only one driving position is active at any one time under normal operating conditions.

## POINT CONTROL, DETECTION AND INDICATION

- 7.20 Power operated points on a tramway are normally set by a demand from the tram on approach. The points should then throw only when the tram driver is sufficiently close to them to determine that no person will be affected by the moving parts, but in enough time for the tram driver to determine the lie of the points before reaching them. If the points are not established to be clear of persons then the tram driver must not allow the demand for the points to throw to be made (either by operating a control or moving to a position where the driver knows demand would be initiated).
- 7.21 Where points have the facility to be manually operated by the use of a lever or other such means, access to and operation of such points should not present a risk of personal injury. Where manual points are regularly used as part of normal service then the stopping position for the tram should not lead to hazards for other highway users and should allow the tram driver to leave the tram and operate the points in safety.
- 7.22 Where point indication is necessary then this should be independent of the signalling control system and should be dependent only on the detection of point blades and any locking arrangements. Detection should be of both the lie of the point blades and the correct application of the locking mechanism, including spring points.

- 7.23 Where a road traffic signal is permitting the tram to proceed in only a specifically indicated direction then it is the responsibility of the tram driver to ensure the correct corresponding lie of any points.
- 7.24 Off-highway a signal can be interlocked with and dependent on the lie of points and this may help to reduce operational risk.
- 7.25 On a highway, a demand from a tram should in all circumstances be capable of being made to road traffic controller independently of the lie of the relevant points.

Note: This is to ensure that the tram will always get a proceed at a road traffic junction where it is not legal to pass a signal at stop. Passing a signal at stop would normally only be possible under the control of a person holding an authority granted by the Chief Constable.

- 7.26 The switch blades (or their equivalent) of any points used in the facing direction should be positively held in position during the passage of a tram. Mechanisms that allow the points to be 'trailed' may be used.

Note: Where spring force or hydraulic pressure is used to achieve this, a speed restriction through the points may be required.

- 7.27 Points must be locked such that once set for a particular tram and an appropriate indication given to that tram, the points cannot be moved until the whole of that tram has passed over those points.
- 7.28 An indication of the lie of facing or non-trailable power-operated trailing points that are used regularly by passenger-carrying trams should be given to the tram driver by a visual indicator positioned close to the points.

Note: Operators may find it useful to have indications of out of correspondence points transmitted to a central location.

- 7.29 Indication is not required for points in depots or for emergency trailing crossovers which become facing only when used, provided that the tram driver can observe the position of the point blades from the driving position before driving over them.
- 7.30 If the points are incorrectly set or are misaligned, the place where the tram should stop should be clearly marked. If this is not immediately before the points, the point indicator may be duplicated at the stopping point.

## REVERSAL AND 'WRONG DIRECTION' RUNNING

- 7.31 In general all vehicles on the highway must keep to the left side of the road, see Highways Act 1835, section 78.<sup>27</sup>
- 7.32 Wrong direction movements on the highway must only be made when necessary for safety or to permit trams to turn during emergency operation. The distance of wrong direction operation should be minimised and the driver must be in the leading cab. There is no requirement to have such moves authorised by a police officer, but drivers of trams should take appropriate care. The Road Vehicles (Construction and Use) Regulations 1986, regulation 106<sup>9A</sup>.
- 7.33 When wrong direction operation may be required for an extended period, operators should come to an agreement with the relevant authorities over the most appropriate arrangements for the safe control of traffic.

## DESIGN AND CONSTRUCTION OF TRAMWAY POINTS, SIGNALS AND OTHER INDICATIONS

- 7.34 Careful choice of track components for points and crossings on a tramway should be made to ensure compatibility with tramway point mechanisms and equipment. In normal circumstances point mechanisms should be trailable. Mechanisms that are not trailable can present a significant derailment hazard to a tram if run-through.
- 7.44 Where point position indicators are used these should ideally conform to the format set out in Appendix E (Note this Appendix will be added to the next version of this document)
- 7.45 A tram signal should be provided at all road traffic signalled installations for each direction from which a tram may approach.
- 7.46 Two or more trams should not normally operate through a signalled highway junction consecutively, in the same direction, and within the same phase. Any proposal to do so should be based on two successive tram proceed phases within the same stage of the junction signalling.
- 7.47 Traffic signals applicable to tramways must comply with the TSRGD.<sup>16</sup> It defines those signs and signals that a tram driver must obey. Further guidance on signs is given in the Traffic Signs Manual<sup>24</sup>.
- 7.48 The prescribed tram signals for on-street tramways should ordinarily be used throughout systems to ensure consistency.
- 7.49 Consideration should be given to the provision of 'pre-start' or 'demand received' indications. This could be displayed either in the tram cab or at a suitable location on or near the relevant signal.
- 7.50 Primary tram signals should normally be located on the left-hand side of the track. They may be located on the right-hand side of on-street tramways (i.e. between pairs of tracks), subject to the clearance requirements being met.

## TRAMWAY AND ROAD TRAFFIC SIGNS

- 7.51 Signs for other road user's consequent upon the introduction of a tramway are prescribed in the TSRGD.<sup>16</sup> Signs that are not prescribed in these regulations should be specifically authorised by the Department for Transport. Further guidance on signs is given in the Traffic Signs Manual<sup>24</sup>.

Note: Only a prescribed sign can be legally enforced and only prescribed signs can legally be placed on the highway. The use of non-prescribed signs is not only unlawful but also of little practical use and could expose the tramway operator to legal proceedings.

- 7.52 A proliferation of signs should be avoided.
- 7.53 Signs applicable to tram drivers only should be mounted so as to be conspicuous to drivers of trams but presenting as little distraction to other road users as possible, e.g. on electric traction supply poles. Details of these signs are in Appendix A - Tramway signs for tram drivers.

Off highway there is no requirement to use prescribed highway signage though it is strongly advised that signs for tram drivers follow the prescribed signs.

- 7.55 For other signs consideration should be made to using some of those set out in The Health and Safety (Safety Signs and Signals) Regulations 1996<sup>28</sup>.

## SPEED LIMITS

- 7.56 Prescribed retro-reflective lineside signs shown in diagram 976 in the TSRGD,<sup>16</sup> indicating the maximum permitted speed, should be shown throughout a tramway. All signs should be similarly mounted and located at the tram drivers eye level. These signs would normally be located wherever:

- (a) the maximum permitted speed on a section of tramway changes; or
- (b) the maximum permitted speed of a tramway located in the carriageway differs from the limit for other road vehicles.

Note: In certain situations, generic speed restrictions would normally be applied at specific locations (e.g. through tramstops) and these may be provided for by the application of operational procedures, rather than individual signs for each restriction.

- 7.57 The maximum permitted speed of a tram on a carriageway shared with other road traffic should be approximately the same as, or lower than that for other highway traffic.
- 7.58 The maximum permitted speed of a tram on a segregated on-street section may be higher than that for other road traffic provided that the presence of the tramway is clearly indicated to other road users. The higher speed should be agreed with the Police and the Highway Authority. An order under section 84 of the Road Traffic Regulation Act 1984<sup>7</sup> may be required.

## CONTROL OF TRAM SIGNALS

- 7.59 Where tram signals are associated with ordinary road traffic signals on on-street tramways, they should be controlled by the local road traffic light signal controller with appropriate tramway functionality.
- 7.60 The control hierarchy should be such that whatever additional tramway controls are superimposed upon the local controller, it should be able to function on its own, including the processing of tram demands, if the transmission link to a central controller fails.
- 7.61 The local road traffic light signal controller should not be involved with determining route information for the tram, but should be presented with the appropriate demand being received from the tram detection equipment. In certain circumstances, it may be necessary for an interface unit to be interposed between the controller and the tram detection equipment. This arrangement should similarly be able to function on its own if the link to any tramway supervisory or control system fails. The fundamental system may be developed further to encompass higher order traffic control systems.
- 7.62 Wherever the control of the tram signals is through a normal road traffic light signal controller, the detection of the lie of the points on a running line should be shown through a separate point indicator.

- 7.63 The design of the control system should be such that intersections can be safely controlled, allowing such precedence for trams as may be agreed with the Highway Authority, as described in Appendix B - Road and tram traffic signalling integration.
- 7.64 In fixed-time systems, the tram phases should run irrespective of the presence of a tram. For demand-dependent systems, tram signal phases should run in conjunction with parallel and complementary phases for other road users.
- 7.65 Where tram movements conflict with other road traffic flows, separate stages or phases should be provided solely for tram movement. *Proceed* aspects for trams should not return to *Stop* before any parallel *Proceed* signal for other road vehicles. An allowance should be made to give the tram earlier warning of the impending *Stop*, and so reduce the risk of the tram overrunning the stop line and a longer all-red period (i.e. the inter-green period) may be required following the termination of the tram phase.
- 7.66 The design of a pedestrian crossing should ensure that, subject to a timeout in the event of an undue delay, the *Proceed* aspect for pedestrians (and the *Stop* aspect for a tram) cannot be given if an approaching tram is within its service braking distance of the crossing.

## TRAMWAY CONTROL ROOM

- 7.67 The tramway operations control room and electrical control room should normally be combined.
- 7.68 The design of the tramway control room should provide a working environment that minimises distraction and fatigue, to avoid the risk of error by the staff responsible for the control of operations. A human factors study should be carried out at the design stage or when there is a significant change to the control room or systems. All information necessary to control the system safely should be continuously displayed. The integrity of controls and indications should be appropriate to the extent to which safety depends upon their correct operation. Both normal and degraded modes of operation should be taken into consideration when assessing the risks and the level of integrity required. The control room equipment essential for the safe operation should be protected from the consequences of electrical supply failure at the control room. Any loss of power or changeover to battery supplies should not cause a loss of integrity in the ability to control the system.
- 7.69 Display screens capable of showing the track layout and positions of tramstops should be provided. Display screens for the electrical supply systems should be provided that are capable of showing the locations of feeding points, and the actual position and status of circuit-breakers and section isolators. If any diagram or diagrams respond to the position of trams, the lie of points or switches, position of circuit breakers or aspect of tram signals, such information should be clearly displayed. Switching between displays in the course of an operation is not acceptable if this gives rise to a consequent need to remember the status of relevant items. A fixed line diagram or diagrams should also be provided to enable operations to continue in the event that the display screen equipment is unavailable.
- 7.70 There should be a high integrity recordable telephone line for use between the local emergency services control room(s) and the tramway control room. Tramway control room staff should be made aware of any incoming calls on such a line, even if other communications systems share the same equipment. A similar line should be provided to the controlling signal-box of any rail system that crosses or shares an alignment with the tramway. All such communication lines should continue to function if mains power is lost at the tramway control room.

- 7.71 Whenever control-room staff pass messages that are critical to safe operation, all messages should be recorded and the recordings kept for at least 24 hours. Where safety is dependent on communications between control-room staff, these communications should be similarly recorded.

### Radio communications systems

- 7.72 An adequate system of radio communication between the tramway operational control room and trams should be provided. A system allowing selective calling and identification of individual trams, or groups of trams, should be provided if instructions that are critical to safe operation are to be passed by radio. The radio system should incorporate the facility for each of the emergency services and tramway personnel to use their own portable radios within their own command structure; this facility should be functional throughout any running tunnels, and within any access shafts and cross passages.
- 7.73 Voice communications between control and the tram driver should be kept separate from those between the tram driver and the passengers so as to prevent the latter from overhearing control messages.

# 8 TRAM DESIGN AND CONSTRUCTION

## GENERAL GUIDANCE

- 8.1 A tram should be designed so that it is safe for its users (passengers or members of staff) and does not endanger other users of the highway.
- 8.2 In general, a tram which operates on-street should conform to the current Road Vehicles (Construction and Use) Regulations 1986<sup>9A</sup> for road vehicles in so far as appropriate. Although not subject to the mandatory requirements for road vehicles, trams should nevertheless include features in their construction and performance that make them safe for use on the highway and in other places where they share the infrastructure with other users.

Note 1: The Road Vehicles Construction and Use Regulations 1986<sup>9A</sup> cover all aspects of highway vehicles including weights, dimensions, safety items and environmental standards. The regulations are updated progressively when the UK Government needs to update any rules on vehicle safety or operation.

Note 2: Much of this regulation derives from Directives of the European Union (EU), and these in turn derive largely from United Nations Economic Commission for Europe (UNECE) regulations, these are globally agreed standards.

Note 3: The website of the UK Vehicle Certification Agency (VCA) has a list that shows which of these UNECE regulations have been translated into EU Directives and which in turn are (or will be) implemented in the UK through amendments to the Construction and Use Regulations.

<http://www.vca.gov.uk/additional/files/legislation/information-notices/directives-published.pdf>.

- 8.3 The VCA website also has useful summary diagrams for buses and goods vehicles that show which Directives / Regulations apply to which aspects of those road vehicles.

[www.vca.gov.uk/vehicletype/bus-image.asp](http://www.vca.gov.uk/vehicletype/bus-image.asp) and [www.vca.gov.uk/vehicletype/goods-vehicle-image.asp](http://www.vca.gov.uk/vehicletype/goods-vehicle-image.asp)

## COMPATIBILITY

Relationship with road traffic light signal and point controllers

- 8.4 A tram to be used on the highway should be equipped with a system of communication to permit it to be detected by highway signal controllers so that the appropriate stage and phase can be called on the road traffic light signals. The system, or a similar one, should also be able to request a specific route at junctions and actuate the safe operation of the points.

## EXTERNAL LIGHTING

- 8.5 The external lighting of trams which run on-street should conform so far as practicable with the Road Vehicle Lighting Regulations 1989,<sup>17</sup> in so far as both the construction of the tram and the achievement of the following objectives will allow:

- (a) in the forward direction, it should uniquely identify the vehicle as a tram;
- (b) bi-directional trams should carry the full range of lights and reflectors for running in

- either direction; and
- (c) lights and reflectors on the sides of the tram should be similar to those required for large goods vehicles rather than those for passenger-carrying vehicles.

8.6 The following arrangements are considered to meet these objectives:

	FACING FORWARD	FACING REARWARD	ALONG THE SIDES
Headlights	Two white dippable and a third white dipped mounted centrally above them	-	-
Position lights	Two white	Two red	-
Outline marker lights	Two white	Two red	-
Side marker lights	-	-	At least three for a 30 m long tram - Amber
Direction indicators	Two amber	Two amber	Amber (combined with side marker lights)
Reflectors	Two amber (may be combined with direction indicators)	Two amber (may be combined with direction indicators)	At least three for a 30 m long tram, 1 m above road level - Amber
Brake lights	-	Two or two clusters - Red	-
Fog lights	-	Two high-intensity - Red	-

8.7 As an alternative to a third centrally mounted high level white light, the 'cyclops', a suitably large and well illuminated destination indicator may be able to perform the same function as long as it is always lit.

Note 1: Community Directive 76/756/EEC addresses overall road vehicle lighting installations and is implemented in the UK through the Vehicle Lighting Regulations 1989 (as amended).

Note 2: Specific Community Directives address the individual components of the lighting installations. The list on the VCA website: <http://www.vca.gov.uk/additional/files/legislation/information-notices/directives-published.pdf> defines the main EC Directive numbers that apply to each subsystem.

Note 3: The EC's "EUR-Lex" legislative database contains the text of the Directives where the detailed technical requirements for the lighting subsystems may be found. This information can also be obtained from the original UN ECE Regulation documents.

Note 4: The website of the UN ECE ([www.unece.org](http://www.unece.org)) has the underlying technical agreements. Selecting 'Our work' then 'Transport' then under 'Areas of Work' selecting 'Vehicle Regulations' will bring up a web page where the original regulations can be accessed directly.

### Lamp positions

8.8 Lamps should be positioned as close as practicable to the positions prescribed within the Road Vehicle Lighting Regulations 1989.<sup>17</sup> Due allowance should be made for the construction and shape of the ends of the tram in permitting variations from the specified heights and distances

from the sides. The following guidelines are generally considered to offer a suitable arrangement:

- (a) all the lamps, except the centrally-mounted headlight and the side-mounted lights, should be placed as close as possible to the side of the tram, preferably at a distance of not greater than 400 mm;
- (b) front and rear position lamps and direction indicators should be approximately 1500 mm from the ground;
- (c) the end outline marker lamps should not be below the top of the windscreen at either end; and
- (d) the main pair of headlamps should be placed between 500 mm and 1200 mm from ground level and the central headlamp, above the windscreen.

Note: Trams should comply as far as possible with the requirements placed on PCV and Goods vehicles. A comparison with the original texts of the relevant parts of the EC / UN documents for each subsystem may help to illustrate why the figures used in UK Regulations have evolved.

#### 8.9 While running on-street:

- (a) all the headlamps, the position lights, end outline lamps and the side marker lights should be lit. The other lamps should be lit as the occasion demands;
- (b) all the white lamps and none of the red lamps should show forward in the direction of travel and vice versa to the rear;
- (c) the front, rear and side direction indicators should all flash together. If combined side marker lights and side direction indicators are provided, the indicators should be substantially brighter than the marker lights;
- (d) the normal road vehicle configuration for hazard warning lights should apply; and
- (e) for safety purposes, it should be possible to leave the hazard warning lights on with the driver's key removed.

#### 8.10 On systems that are exclusively line-of-sight off-street tramways, the following lamps should be provided:

- (a) three headlamps, front position lights and rear position lights;
- (b) brake lights; and
- (c) higher-intensity rear fog lamps (which may be used in place of the rear position light, but care should be taken not to override the visibility of the brake lights).

#### 8.11 The side marker lamps required for other sections of tramway need not be lit on the off-street sections. It is not necessary for the direction indicators to operate on off-street sections unless required to do so by the operating requirements of the system.

#### 8.12 Where different arrangements apply for on-street tramways and off-street tramways, a single selector switch should be provided in each cab to change the configuration of the lights when changing from one type to the other.

#### 8.13 The light output of the various lamps and size of reflectors should conform as near as practicable to those specified in the Road Vehicle Lighting Regulations 1989<sup>17</sup> The following points should be noted:

- (a) care should be taken not to oversize the side marker lamps;
- (b) external 'door open' lights may be provided, but these should be designed so as to give no confusion with the lights required to be shown when the tram is in motion; and
- (c) a tram should not display a red light or reflector at the front.

- 8.14 Generally the Directives (as amended) provide for the use of Light Emitting Diode light sources instead of filament lamp sources.
- 8.15 In the event of failure or loss of the low voltage supplies from the auxiliary converter or generator (as appropriate to electric or diesel powered trams) the tram's on-board batteries should be capable of maintaining the external lighting, including the dipped beam headlamps. This should allow sufficient time for the tram to be driven to a place where it can safely be removed from service if appropriate, or to allow time for it to be recovered by another vehicle.
- 8.16 The adequacy of light output should take account of the environments within which the tram will operate. For example, when running on unlit reserved sections of tramway.

## DRIVING MIRRORS AND REAR-VIEW CCTV

- 8.17 Except on trams used solely on off-street tramways, mirrors or other devices should be provided to give the tram driver a rearward facing view along both body sides when the tram is in motion. Such mirrors or devices should be included within the SE.
- 8.18 At tram stops, the tram driver should be able to clearly observe passengers boarding and alighting, to confirm that before starting the tram, no passenger has been trapped by a closed door and that all pedestrians are adequately clear of the tram.
- 8.19 Whilst setting off and in motion, the tram driver should be able to observe traffic on either side of the tram, particularly in regard to under- or overtaking vehicles, before commencing a turn off the main carriageway or when joining the carriageway.
- 8.20 The images presented to the driver should not be unduly affected by darkness, low angled sun, or prevailing weather conditions (e.g. rain in dark conditions).
- 8.21 Consideration should also be given to providing drivers with visibility of any external parts of the tram (e.g. the rear end) which may be susceptible to 'surfing' activity.
- 8.22 Where either CCTV or mirrors are used for rear viewing then consideration should be given to the ergonomic issues that arise in the cab layout. The CCTV displays or mirrors should be placed so that they are easily visible to the driver from his normal position, without the need to unduly divert his attention from the road ahead. There should be no significant loss of view alongside the tramcar between what can be seen directly from the cab and through CCTV/Mirror (i.e. no blind spot). From within the cab the driver should be able to adjust the position or angle of any rear view mirrors, or the image quality of any CCTV displays.
- 8.23 The height of the mirrors or CCTV cameras relative to pedestrians, and in particular those standing on tramstop platforms, should be considered carefully so as to obtain the best compromise between visibility to the tram driver and the risks of pedestrians standing close to the platform edge being struck by them.

Note: For CCTV systems, some guidance may be derived from the EC Directive 2003/97/EC.

## AUDIBLE WARNINGS

- 8.24 Trams should be fitted with an adequate audible warning device at the driving ends. The warning emitted should be in keeping with the environment in which the tram runs. The warning should be loud enough to indicate the approach of a tram without causing injury or undue alarm to those in the proximity.
- 8.25 The sound level and audible frequency of the warning device should be such that it will be audible to staff or pedestrians on the track at the service braking distance of the approaching tram.
- 8.26 The warning device should have two levels of sound where trams run both on-street and off-street:
- (a) the lesser level, for use on-street to alert people of the tram's presence, should produce a sound that is distinctive compared with that emitted by other road vehicles; and
  - (b) the greater sound level, for use in emergencies and off-street.
- 8.27 For on-street use the warning might be provided by using a single stroke gong which can be rung at different rates depending upon how rapidly the operating pedal or button is depressed.
- 8.28 For off-street use and emergencies on street a horn similar to those on buses or cars would be considered suitable for this function.

Note: Some additional guidance can be taken from Annex I to EC Directive 70/388/EEC.

## PEDESTRIAN PROTECTION AND OBSTACLE DEFLECTION

- 8.29 Collision protection should be provided for pedestrians as follows:
- (a) the tram ends and sides should be continuously skirted. The bodywork and skirting should be designed to deflect people who may come into contact with the tram and stop them from passing beneath;
  - (b) there should be a guard in front of the leading wheels designed to prevent people or objects being run over by the tram, with adequate clear space to prevent crush injuries; and
  - (c) the guard should be positioned as close to the highway surface and to the wheels as is reasonably practicable. It may have a deflecting lower edge of pliable material to close the gap to the surface of the highway.
- 8.30 Effective obstacle deflection equipment should be provided to reduce the risk of derailment. This equipment may be attached to the running gear or to the tram underframe. Such protection is in addition to that provided in relation to pedestrian collision although the same equipment can serve both purposes.
- 8.31 Consideration should be given to installing systems that provide additional warnings to the driver of potential hazards within the forward path of the tram such as camera based obstacle detection.

## STRUCTURAL INTEGRITY

### Underframe and body

- 8.32 The underframe and body, including any articulation joint, should be designed to:
- (a) have sufficient mechanical strength to withstand the anticipated loads in normal use;
  - (b) mitigate against the effects of a collision with another tram, road vehicle or buffer stops in a way which minimises injury to passengers, staff and other road users; and
  - (c) have adequate jacking points, with their positions clearly identified on the outside of the tram and accessible for use by the emergency services.
- 8.33 Reference should be made to: EN 12663-1 classes P-iv or P-v as appropriate; and EN15227 in regard to crashworthiness. Class P-v may be considered generally appropriate for tramway operations using, normally, single trams under line of sight operation at speeds up to 80 km/h. Class P-iv may be considered more appropriate to operations at speeds greater than 80 km/h and/or where a substantial proportion of operation is undertaken under fully signalled conditions on fully segregated alignments.
- 8.34 Consideration should also be given where possible, to mitigating the effects of body side collisions from other road vehicles.

## WINDOWS

- 8.35 Windscreens and other forward-facing windows should be able to resist impact from projectiles or other objects. Other tram windows should conform to the current standards for passenger-carrying vehicles on the highway.

Note: Further guidance may be found by reference to EC Directive 92/22/EEC.

- 8.36 It should not be possible or necessary for people to lean out of windows.
- 8.37 Cab windows should not open in such a manner as would allow the tram driver to extend any part of the body, including the head, beyond the kinematic envelope while the tram is moving, unless full clearances exist throughout the tramway system.

## COUPLERS

- 8.38 Couplers and drawgear may be one of two different types:
- (a) for regular service use. They should be fitted if the operation of the tram system demands it; or
  - (b) for emergency use only in all other cases.
- 8.39 Any coupler fitted to a tram operating on an on-street tramway should be designed to fold away or otherwise be retracted when not in use. The extended position of the coupler should be included within the kinematic envelope.
- 8.40 On trams fitted with couplers, adequate fenders or protective covers are required to mitigate damage to other vehicles in the event of an accident. The end of any folded or retracted

coupler, or any fixed coupler (if permitted), should be within the bodywork and protrude as little as possible beyond the fenders. Any sharp edges or points should be covered and provided with suitable fenders.

- 8.41 Couplers should be designed to withstand the loads for which they are intended. Intended loads should consider also any instantaneous 'snatch' loads that might occur when a rescue tram has to pull away with a 'dead' tram.
- 8.42 Service loads might also have to consider situations where trams being rescued have some brakes still applied.
- 8.43 The coupler should be designed to accept at least the load imposed when hauling or propelling a 'dead' tram anywhere on the system.
- 8.44 Consideration should be given to coupler failure and subsequent mitigation to prevent uncontrolled movement or run-away.

## INTERIORS

### Driver's cab

- 8.45 The cab should be designed on ergonomic principles. All the controls and indications needed while driving should be convenient to use and located so as to minimise the risk of error.
- 8.46 The interior layout of the cab should be designed to prevent portable objects being placed where they would obscure the tram driver's visibility or interfere with the controls. There should be stowage provided for the driver's personal effects, and a convenient location for any timetables, documentation or notices to which drivers may need to refer frequently.
- 8.47 The design of the driver's cab should offer optimum internal and external visibility for the driver.
- 8.48 Consideration should be given to the driver's access to and egress from the cab. If the cab does not have an external door, an external saloon door located immediately behind the cab should be provided. Such a saloon door should be provided with separate internal and external controls for the use of staff. Where access and egress is only possible via the passenger saloon, a removable or breakable cab side window should be fitted for emergency egress. Consideration should also be given to an emergency roof exit.
- 8.49 Any door between the cab and the passenger saloon should be either sliding or open into the cab in order to avoid the problems of blockage by passengers and/or their baggage.
- 8.50 Tram signals, signs, passengers waiting at tramstops and other road traffic should be clearly visible from the cab under all credible operating conditions. Suitable means of obscuring the sun and for preventing distraction as a result of reflected light from cab instruments or saloon lighting should be provided.
- 8.51 An internal mirror or other devices may be provided to enable the tram driver to observe passengers within the tram saloon.
- 8.52 The cab should afford sufficient heating, cooling and ventilation to allow the driver to remain comfortable under all credible operating conditions. The driver should be able to control the temperature in the cab. Where the driver will be required to change ends, the system should ensure that the cab the driver changes to offers the same comfort level.
- 8.53 On double-ended trams, where the driver will be required to change ends, the cab ventilation

and/or heating systems should be capable of being left operational in the unoccupied cab to ensure a suitable working environment is maintained for the next time that the driver needs to change ends.

## DRIVING CONTROLS AND INDICATIONS

- 8.54 The driving controls and indications available to the tram driver should enable the tram to be operated safely. The controls for (or displays of) any signalling system should not detract from this.
- 8.55 The driver's controls should be laid out with consideration for ergonomic issues and to minimise the risk of incorrect operation. It is suggested that a human factors study is undertaken to verify this.
- 8.56 It should be possible to easily recognise or read the displays on the driver's desk under all credible lighting conditions. If necessary, the brightness of illuminated displays should be capable of adjustment by the driver.
- 8.57 Recognised standard motor vehicle markings should where appropriate be used for controls, indications and icons.
- 8.58 Illuminated displays and controls should be positioned such that they are not reflected in the windscreen or cab side windows such that the driver's ability to see ahead and to either side would be impaired.

Note: DIN 5566-3 may be of assistance for ergonomic matters.

- 8.59 Consideration should be given to the position of the driver. The driver should normally be located in the centre of the cab or to the right of centre. The seat should have sufficient adjustment such that the tram driver can observe the nearside footway.

Note: Some guidance is given in EC Directives 77/649/EC, 71/127/EC and 2003/97/EC.

- 8.60 The following should be provided:

- (a) Traction and brake controller;

It is recommended that the convention of "Forward for Power" and "Backwards for Stop" is used for UK tramway systems.

Movement of the Traction / Braking Controller (TBC) handle in the backward direction should result in a gradual increase in the braking effort, with full service braking reached at a decent position at a point short of the full travel of the TBC. Movement of the handle beyond this point should result in an Emergency 3 (Hazard brake) application being made. Moving the handle forward from Emergency 3 should revoke this hazard braking mode.

- (b) a Driver's Vigilance Device, designed so that it cannot be kept in the operating position other than by a vigilant tram driver;

It is recommended that instead of the term "Driver's Safety Device", that in accordance with EN 13452 the term "Driver's Vigilance Device" is used.

For clarity, the intent of EN 13452 is to mandate a 'dead-mans' function, not create a system of random driver acknowledgement.

- (c) an emergency brake button, in addition to (a);
- (d) an emergency 'pantograph down' button for pantograph systems, or equivalent button for different systems;

The emergency pantograph down button (or its equivalent) should be of a distinctively different colour to any control provided for the Emergency Brake. Once operated, release of this button should not allow the pantograph(s) to be raised until the normal pantograph raise/lower control has been operated.

The button controls for (c) and (d) should be different in shape to other button controls and should be mushroom-shaped. They should also be distinctively coloured. The emergency brake button should be red.

- (e) a speedometer, calibrated in km/h;

EC Directive 75/443/EEC gives further detail issues on speedometers.

- (f) a data recorder, having sufficient channels and capacity to record information pertinent to the investigation of accidents involving the tram and capable of being calibrated, downloaded and presented as evidence;
- (g) switches to operate the main tram traction power supply circuit-breakers; and
- (h) means to disable the controls at non-active driving positions so as to prevent interference with them.

8.61 If provided, it should not be possible to select Reverse without requiring it to be a conscious action on the part of the driver. This can generally be achieved by requiring the driver to use both hands, e.g. by the need to depress a push-button at the same time as turning the selector switch to the Reverse position.

8.62 Systems, Controls and Indications should also be considered to:

- (a) limit the speed generally or when operating in a particular mode, e.g. off-street;
- (b) protect against wheel slip when accelerating or wheel slide when braking;
- (c) operate sanding gear;
- (d) control the functions of the internal and external communication equipment to prevent mutual interference and cross-talk;
- (e) Provide additional warnings to the driver of hazards in front of the tram.

## DESIGN OF PASSENGER SALOON

8.63 The interior layout and fittings of trams should be designed to minimise injuries to passengers and tram crew.

8.64 The ratio of seating to standing passengers is a matter for the operator, but for planning purposes the density of standing passengers should not normally exceed 4 passengers/m<sup>2</sup> of available standing space.

8.65 Gross laden weight calculations and floor strength requirements should be based on a standing passenger density of 8 passengers/m<sup>2</sup> of available standing space.

- 8.66 Any internal steps and stairways must meet the requirements of the Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010.<sup>12</sup>
- 8.67 Interior lighting in trams should meet the lighting levels provided in other passenger-carrying vehicles. In common with these vehicles, additional lighting in doorways, steps and internal stairways should be considered.
- 8.68 Lower lighting levels are acceptable in the event of electric traction power being lost. The level of lighting should be sufficient to enable the tram to be evacuated. Emergency lighting should be provided to automatically illuminate upon loss of traction power and battery power.

## INTERIOR FITTINGS

- 8.69 Interior fittings of trams should be designed so as not to cause injury in normal operation and to minimise secondary injuries to passengers should the tram be involved in an accident. Interior fittings should include the following:
- (a) adequate grab-rails and stanchions of an appropriate size for mobility-impaired passengers, and for standing passengers and of a colour easily seen by the visually impaired;
  - (b) hanging straps, if fitted, should have limited movement and be secure under load;
  - (c) interior glass which conforms to current passenger-carrying vehicle standards and has protected exposed edges; and
  - (d) passenger-operated buttons (door opening, alarm, stopping request).
- 8.70 Facilities must be provided for mobility-impaired passengers in accordance with the Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010.<sup>12</sup>

## EMERGENCY EQUIPMENT

- 8.71 Equipment for emergency use should be carried on each tram. Suitable provision should be made for stowing emergency equipment so as to be reasonably accessible to the tram driver. The following should be carried:
- (a) a fire extinguisher;
  - (b) a position for a hand lamp sited so that in emergency, the lamp can be used as a temporary tail light; and
  - (c) a first-aid kit.

## ACCESS AND EGRESS

### Doors and door controls

- 8.72 Tram doors should be designed to operate safely.

Note: EN 14752 gives some guidance on the design of passenger doors and doorways. The requirements of the Rail Vehicle Accessibility Regulations or the Persons of Reduced Mobility TSI should also be considered where relevant.

- 8.73 Doors and associated areas should be designed so as to minimise the danger of trapping injury. They should be fitted with obstacle detection equipment and should not operate with excessive force. It should be possible to release limbs or other objects trapped by the doors without difficulty.
- 8.74 Facilities should be provided for passengers in accordance with the Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010.<sup>12</sup>
- 8.75 Where fitted, folding steps or sliding plates should be interlocked with the electric traction power controller and brakes to prevent movement of the tram when they are deployed.
- 8.76 When the tram is moving, external passenger doors should be secured in the closed position. It should not be possible for the tram to start unless all external passenger doors are closed and secured. In the event of doors or their control system moving from the 'closed' position while the tram is moving, traction power should be removed automatically and the brakes should be applied.
- 8.77 Passenger door controls and the method of operation should be clearly and unambiguously signed.
- 8.78 The door arrangements should enable passengers and tram crew to evacuate safely. It should be possible for passengers to open external doors once the tram is stationary. Door emergency releases should be operable to allow the opening of external and internal doors even if there is a failure of any tram equipment, power supply etc.

## Door controls

- 8.79 If passenger-operated door control buttons are provided, they:
- (a) must be compliant with the Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010;<sup>12</sup> and
  - (b) should only be enabled when the tram is correctly located at a tramstop and/or it is safe to disembark.
- 8.80 Emergency opening devices fitted inside the tram should be able to be used by the passengers without the help of the tram driver. The operation of these devices should be brought to the attention of the driver. It should not be possible to open the doors until the tram is at (or nearly at) a standstill.
- 8.81 There should be a means of releasing designated external doors from the outside in an emergency.
- 8.82 The design and labelling of internal and external door emergency releases should deter non-emergency use.
- 8.83 The tram driver should be able to easily identify which emergency door-opening device has been operated. After operation, the device should be able to be cancelled only by the driver or other members of the tramway staff.
- 8.84 If the external emergency release device is also intended to be used as a means of opening tram-crew access doors, it should be possible to reset it from both inside and outside the tram.

## COMMUNICATIONS

- 8.85 Alarm points should be provided so that in an emergency, it is possible for passengers to communicate to the tram crew, and for the crew (or, where required, the tramway system controller) to communicate to the passengers.
- 8.86 Where there are request stops, facilities for requesting the tram to stop should be provided and the use of this facility indicated both in the cab and in a prominent position in the passenger compartment. Such equipment must comply with the Rail Vehicle Accessibility (Non-Interoperable Rail System) Regulations 2010.<sup>12</sup>

## POWERED SYSTEMS

- 8.87 The electrical and other powered systems and equipment on trams should not endanger other systems or people in either normal operational, maintenance or failure modes. Consideration should be given to the location of equipment that the driver may need to access for resetting, to ensure neither the driver nor passengers are exposed to risk.
- 8.88 Safety-critical systems should be designed to fail to a safe mode, either by redundancy or before safety-critical levels are reached. Suitable alarms or interventions should be provided as necessary.
- 8.89 Preventative measures should be provided to guard against fire or a system overload under fault conditions, and to enable a tram to be either operated safely under emergency conditions in the event of failure, or to be recovered or otherwise removed from causing an obstruction on the highway, or both.
- 8.90 A battery should be provided which, in the event of failure of the electric traction power supply, can provide sufficient interior and exterior lighting (appropriate to the tram system) and other essential subsystems such as radio.
- 8.91 The power-supply system onboard the tram should provide an adequate, protected path for the return current and should be protected against the effects of accidents and unauthorised access to the live parts.
- 8.92 The power systems should be appropriately guarded against unauthorised access.

### Electric traction power supply

- 8.93 The design and construction of the collector for the electric traction power supply and associated isolators and protective devices should take into account the need to avoid hazard either to tram operating staff or to the public.

Note: EN 50206-2 gives additional guidance on pantographs for tramway use.

- 8.94 Over-current protection and isolation arrangements should be provided as close to the source as possible. The main traction power circuit breakers and line fuses should be roof-mounted for overhead electric traction systems. These may be below the underframe for conductor-rail systems.
- 8.95 Overhead systems should be fitted with roof-mounted lightning surge arrestors.
- 8.96 Sufficient and effective bonded paths to the tyres of the wheels from the superstructure should

be provided on any tram used on an electric tramway system or on an alignment shared with an electric railway. The return path, if this is through the rails, should be designed to ensure that conductivity remains sufficient through the wheels at all times.

## Isolating devices

8.97 The following means of isolating the tram from the traction supply should be provided:

- (a) a control by which the tram driver may isolate the power supply between the current collector(s) and the electrical equipment, without leaving the cab;
- (b) a control by which the tram driver may disengage the current collector(s) from the source without leaving the cab; and
- (c) a control by which the current collector(s) may be disengaged from the traction supply which is accessible from ground level outside the tram; its position should be marked.

8.99 In the case of trams powered or assisted by on-board energy sources, equivalent provisions to the same standard as required by the PCV Regulations should be provided to allow the energy source(s) to be shut down by the driver from within the tram. A similar facility should be provided, accessible from ground level, on the exterior of the tram. Its position(s) should be clearly marked.

8.100 Once operated, it should not be possible to reinstate the functionality of the tram's control systems simply by resetting isolation switches. Returning the tram to operational status should only be possible once the tram has been shut down and re-initialised using the normal cab controls.

8.101 Additionally, a means of isolating the battery should be provided which is accessible from ground level outside the tram; its position should be clearly marked. Other electrical circuits should also be protected by isolating switches and circuit breakers, which may be combined as appropriate.

8.102 Where there is a means of isolating the battery or other sources of stored energy, operation of this facility should not result in the immediate loss of communication between the tram driver and the system Controller. Neither should there be any loss of emergency lighting. This may be met by providing the on-board radio equipment with a local back up battery with sufficient capacity to ensure that the tram driver is able to communicate in an emergency, or ensuring that the driver has access to a separate independently powered means of communication

8.103 On trams that use overhead lines as the power source, it should be possible to raise and lower the current collector manually when the tram has discharged batteries. After raising the current collector manually, the tram should then be capable of being re-energised and charging the batteries using only the supply from the overhead line.

## Electrical equipment protection

8.104 Electric traction power cables should be routed so that they are protected from mechanical damage. In addition, the following precautions should be taken:

- (a) where the cable route passes through a fire barrier, adequate fire stopping should be provided; and
- (b) if the cable route passes through the passenger compartment, this should be by the shortest practicable route.

Consideration should also be given to protecting power cables against damage that could occur as a result of a collision.

- 8.105 The operating voltage of electrical equipment in areas accessible to passengers should not exceed 50 V.
- 8.106 Cubicles containing equipment at electric traction power supply voltage which have to be in the cab must be locked or appropriately secured. Warning notices must be displayed.<sup>18</sup>
- 8.107 Cubicles containing power control equipment that could emit toxic fumes if set on fire should not be ventilated into the passenger compartment.

## CONTROL SYSTEMS

### Traction power controller

- 8.108 The traction power control system should be of robust design, using safety-critical techniques in hardware and software systems to guard against unsafe conditions in failure modes.
- 8.109 Whatever traction control system is used, it should be designed so as to prevent:
- (a) the taking of power or release of the brakes when any external doors are detected as not closed, or when folding or sliding steps or ramps are deployed;
  - (b) the taking of power when the braking systems are not available;
  - (c) the enabling of controls, except the emergency brake, from more than one driving position at a time; and
  - (d) the movement of the tram in a direction opposite to that selected by the tram driver.

A combined traction and brake controller should be fitted.

- 8.110 Where a single microprocessor is used for safety-critical functions in the tram control system, it should be designed to appropriate safety-critical standards.
- 8.111 Jerk rates during starting and acceleration should not exceed those set in EN 13452.

### Brakes

- 8.112 Trams should be fitted with:
- (a) a continuous system for the control of the service brake, operable from the driving position in service on trams coupled in service conditions;
  - (b) a parking brake which is automatically applied when the tram is 'shut down'; and
  - (c) brakes that remain partially applied when the tram is brought to a standstill until the controller is operated to take power to move the tram.
- 8.113 Where the braking force applied through the wheels is insufficient to meet the required braking performance, an electromagnetic brake or brakes acting directly on the track should be fitted to achieve the required performance.
- 8.114 The braking system should be designed so that:
- (a) an assisting vehicle (another tram or a recovery vehicle) can operate the brakes on a failed tram if they are operable; and

- (b) if the brakes on a failed tram are inoperable, the brakes of the assisting vehicle should be such as to enable it to haul and to control the failed tram at slow speeds.

Note: Consideration should be given to the accessibility of brake release controls if a tram is standing in a platform area.

8.115 An irrevocable brake application should result from:

- (a) a lack of correspondence between vital control systems;
- (b) insufficient air pressure, hydraulic pressure or electrical supply to operate the service brakes or traction control system;
- (c) the loss of brake activating pressure;
- (d) the accidental parting of articulated or coupled trams; and
- (e) the unintended deployment of steps or boarding devices, or when an external passenger door is no longer detected as closed.

## Brake performance

8.116 For braking systems reference should be made to the guidance given in EN 13452.

8.117 EN 13452 defines the different levels of braking in a standardised terminology which may differ from that used by some UK operators. For clarity, this Guidance uses the terminology of EN 13452, for which the common UK equivalents are as follows:

- Service braking - being the normal mode of operation, generally using only the primary braking system, supplemented as necessary under heavy loads and/or at low speeds, by the mechanical braking system.
- Emergency 1 - Emergency braking (where the requirement is simply to bring the tram to a standstill by any means, irrespective of the position of the traction and brake controls). Once applied, the Emergency Brake should remain thus and be capable of release only once the tram has come to a standstill. The EN calls for this to be at service braking performance level, i.e. it is the brake mode that a tram system might apply if the door loop was broken or the driver was found to be incapacitated.
- Emergency 3 - Hazard braking (where the maximum braking effort is applied in order to bring the tram to a standstill in as short a distance as practicable. The Hazard brake is an "all or nothing" brake, and should be revocable by the action of the driver deselecting it.
- Emergency 4 - A hazard brake of the same performance as emergency 3, but applied by the driver by use of an emergency button and therefore irrevocable until the tram is at a standstill and a specific reset is undertaken.

8.118 The parking brake should be able to hold a fully laden tram, or to hold it (in any load condition) and another (unladen) tram with failed or isolated brakes on the steepest gradient on the system.

8.119 A brake application should occur automatically if a tram rolls back after stopping on an uphill gradient. The tram should stop within 500 mm under all loading conditions on the steepest gradient on the system.

8.120 Equipment should be provided to optimise traction and braking performance under credible

adhesion conditions. Such equipment is likely to include sanders and slip/slide regulation systems.

- 8.121 Assessment should be made that any magnetic track brakes are physically compatible with the infrastructure of the systems over which the tram is intended to operate and will, when operated, not result in any untoward operation of signalling or communications equipment as a result of transient electromagnetic effects. Consideration should be given to potentially reduce braking performance on rails formed from austenitic steels.

## FIRE SAFETY

In general, and unless otherwise specified, it is sufficient for any tram operating under Line of Sight principles to be designed to a fire standard which is equivalent to that required for buses, as set out in the PCV Regulations.

Circumstances in which a higher standard, such as EN 45545, would be appropriate would include:

- operation under absolute signal control (i.e. as a railway);
- operation of vehicles with floor heights similar to railway vehicles that restrict passenger evacuation;
- operation over bridges or through tunnels, where there are not easily accessible places of safety. Operation through a tunnel does not automatically call for a higher fire standard to be applied if either –
  - the tunnel is double tracked, provided with a suitable walkway (which may be at track level) and of a length short enough to allow escape to a place of safety from any smoke and fumes produced by the fire, or
  - the tunnel is designed and equipped to the same standards as are applicable to road tunnels.

## CAR BODY TWIST

Car Body Twist can be introduced by the track alignment design (defined here as Design Twist) or can develop as a result of deterioration of the designed geometry during and following installation. Design Twist results from cant gradients, the effect of combining horizontal curvature and longitudinal gradients (including those associated with vertical curvature) and the design of flange-running crossings. It should be noted that twist caused by the combination of horizontal curvature and vertical curvature does not result in a change in cant and therefore cannot be measured using traditional techniques based on measuring the change in cant over a fixed distance. The magnitude of twist resulting from deterioration of the installed track from that of the designed geometry is dependent upon the system installation and maintenance tolerances.

## APPENDIX A - TRAMWAY SIGNS FOR TRAM DRIVERS

This appendix provides guidance on the tramway signs that give instructions to tram drivers.

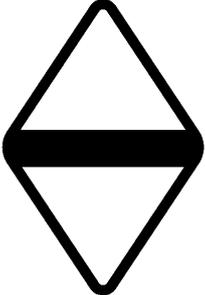
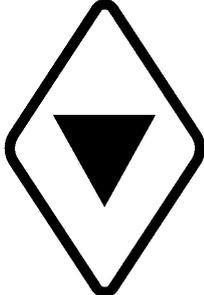
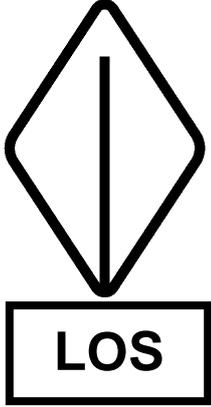
Note: The tramway signs have been designed so as to reduce the risk of their being confused with other road traffic signs.

The design and sizes of tramway signs must comply with the TSRGD<sup>16</sup>. The size should be selected so as to ensure the sign is clearly visible and legible. Signs should normally have black legends, symbols and borders on a white background. Signs should be positioned at a tram driver's eye level.

The tramway signs should be used consistently throughout a tramway system and should be consistent with those used by tramways operating on the highway.

Figure 8 shows a 'Stop' sign, Figure 9 a 'Give Way' sign, and Figure 10 indicates the maximum permitted tram speed, and Figure 11 shows an instruction sign. The instruction sign should be used with a separate plate mounted below it conveying the specific instruction applicable.

Should a tramway wish to use signs other than those illustrated below, they should discuss their proposals with ORR.

			
<p>Figure 8: To indicate to tram traffic the requirement to stop, and not to proceed until it is safe to do so</p>	<p>Figure 9: To indicate to tram traffic the requirement to give way to other trams or other road vehicle traffic</p>	<p>Figure 10: To indicate the maximum permissible speed of tram operation until amended by another speed variation instruction</p>	<p>Figure 11: To indicate to tram traffic the requirement to observe the instruction conveyed by the accompanying plate. The plate conveys a specific instruction to the tram driver. Permitted variants include: other letters, or text conveying other meanings</p>

# APPENDIX B - ROAD AND TRAM TRAFFIC SIGNALLING INTEGRATION

This appendix provides guidance on the integration of tram signalling with road traffic light signalling. To give the appropriate priority to trams, the tram phase (when demanded) may need to run before any parallel or similarly compatible phase for other road users is initiated. The tram phases should terminate at the same time as any parallel stage or phase for other road vehicles. The following examples illustrate ways in which detectors may be positioned. Figure 12 indicates typical tram detector positions.

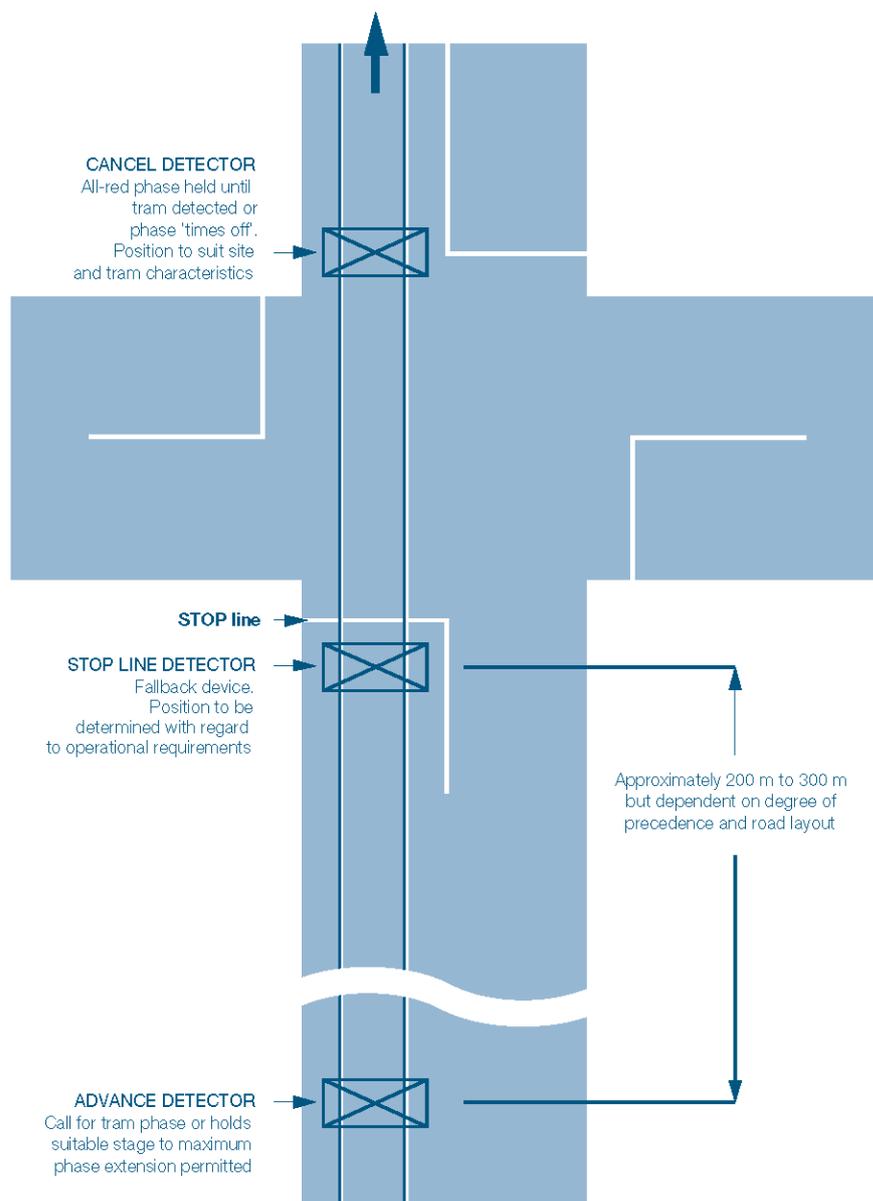


Figure 12: Tram detector positions

## CONTROLLED INTERSECTIONS

Tram detectors should be provided where road traffic light control systems employ some degree of demand dependency. The detector's function is to register a demand in the road traffic light controller to call up the tram phase in the next appropriate stage in the sequence.

Tram selective detectors should respond only to trams. Selective detectors may also pass information for tramway operational purposes.

A stop line detector should be provided. It should register a tram demand if none is already present. If the tram *Proceed* signal is already present, departure from the stop line detector may initiate a red period. A cancel detector should be provided on the downstream side of the stop line to enable the red period to be terminated before the end of the maximum period once a tram has cleared the intersection.

The minimum provision should be a 'stop line detector' and a 'cancel detector'.

An advanced detector may be provided further upstream of the stop line detector on the tram approach to secure a tram *Proceed* indication without requiring the tram to stop at the stop line. The advanced detector may then be used to prioritise the tram phase if required, including making provision for the passage of a tram in the opposite direction on a parallel track.

Note: The maximum degree of priority that can be given will depend on the distance of the advanced detector from the stop line, tram running speeds, and the staging and timing arrangements for the intersection.

Further advanced detectors may be necessary to allow the tram the maximum precedence, to permit it to run unimpeded through the intersection, or to improve junction capacity for other road users.

Note: The distance between the outermost of these detectors and the intersection will be governed by the maximum permitted speed of the trams and the maximum attainable speed, whichever is less, and the time taken for the signal controller to change to the appropriate stage, the objective being for the *Proceed* aspect to be shown before or just as the tram reaches an overall service braking distance (including reaction time) from the stop line.

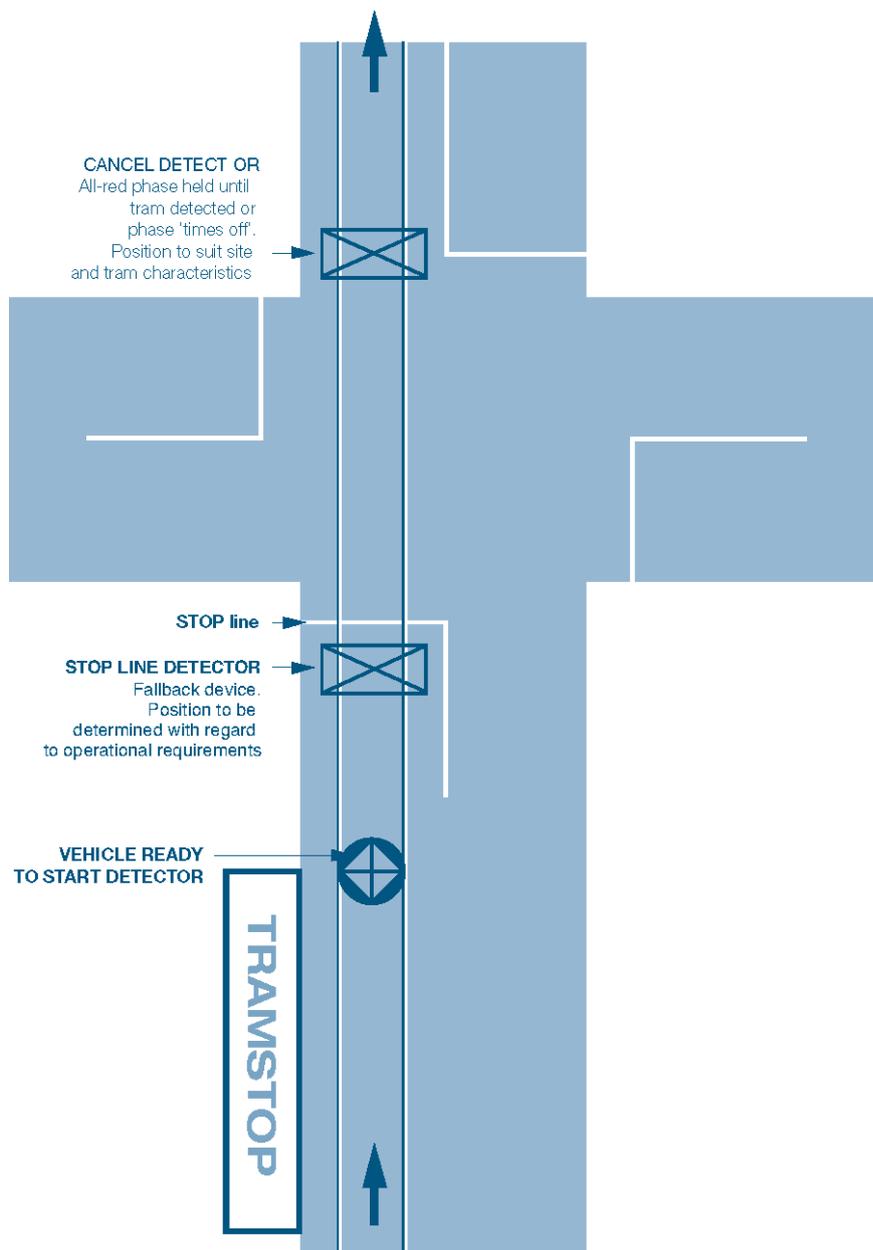
The signal aspect "cluster" defined in diagram 3013.5 of the TSRGD<sup>16</sup> should be displayed for a period commensurate with the service braking performance and approach speed of trams. A shorter period, commensurate with the emergency braking performance, may be used if the signalling design ensures that a signal will only return to *Stop* as a tram is approaching under exceptional conditions (for example an emergency services vehicle hurry call or a fault). However, the period should be consistently applied throughout each individual system.

Note: The nominal time for this aspect to be displayed is normally five seconds, but may be varied between systems according to local geographic, climatic and traffic conditions, which may affect the braking performance of the trams.

## PRIORITIES AT CONTROLLED INTERSECTIONS

'Hurry call' signals for emergency service vehicles should override all other demands.

Where a tramstop is located between where the advanced detector would be positioned and an intersection, a 'tram ready to start' (TRTS) detector should be provided so that the tram driver can initiate the tram phase when the tram is ready to depart from the tramstop. Figure 13 shows a tramstop with a TRTS detector.



Where a tramstop is so close to the intersection that the TRTS detector would be located with or very close to the stop line detector, then the TRTS detector should replace and also assume the role of the stop line detector.

If the last detector before a junction is a TRTS detector but the tram can move forward from this detector to the stop line at the junction, means should be provided for a tram phase

demand if the driver forgets to use the TRTS feature and moves forward off the detector.

## PEDESTRIAN CROSSINGS

A pedestrian crossing located at a signalled road intersection should be controlled by the road traffic light controller.

Where pedestrian crossings cross both the road and the on-street tram track in one continuous crossing, the tram signal aspects shown should be harmonised with the road traffic red and green aspects.

A hold detector should always be installed to prevent the tram signal changing to stop after the tram is within its service braking distance (although the hold detector may be subject to a timeout if the tram is unduly delayed).

## ROAD TRAFFIC LIGHT CONTROLLERS

Communication is required between the road traffic signal controller and any tram detectors. The road traffic signal controller should analyse the information from these tram detectors to determine when to call and cancel the tram phases. Tram route information for the intersection may be supplied directly by the detectors or from a tramway traffic control facility.

Note: It may also be necessary to provide an interface unit between the road traffic light controller and the tram detection equipment.

In situations where points are located more than a maximum tram length downstream of an intersection, information regarding the lie of the points will not be provided to the tram signal, but the proposed route may be indicated in the *Proceed* aspect. This situation is illustrated in Figure 14.

Where the tram turnout lies within a tram length of an intersection, the points should be located on the approach to the intersection to avoid a tram stopping on the intersection awaiting the points being set and a *Proceed* aspect being given. This situation is illustrated in Figure 15.

Local point indicators should be provided adjacent to the point ends. Only these indicators, and not the tram signal, should show the lie of the points.

The routing of trams and the detection and control of point mechanisms should be wholly contained within the tramway control system.

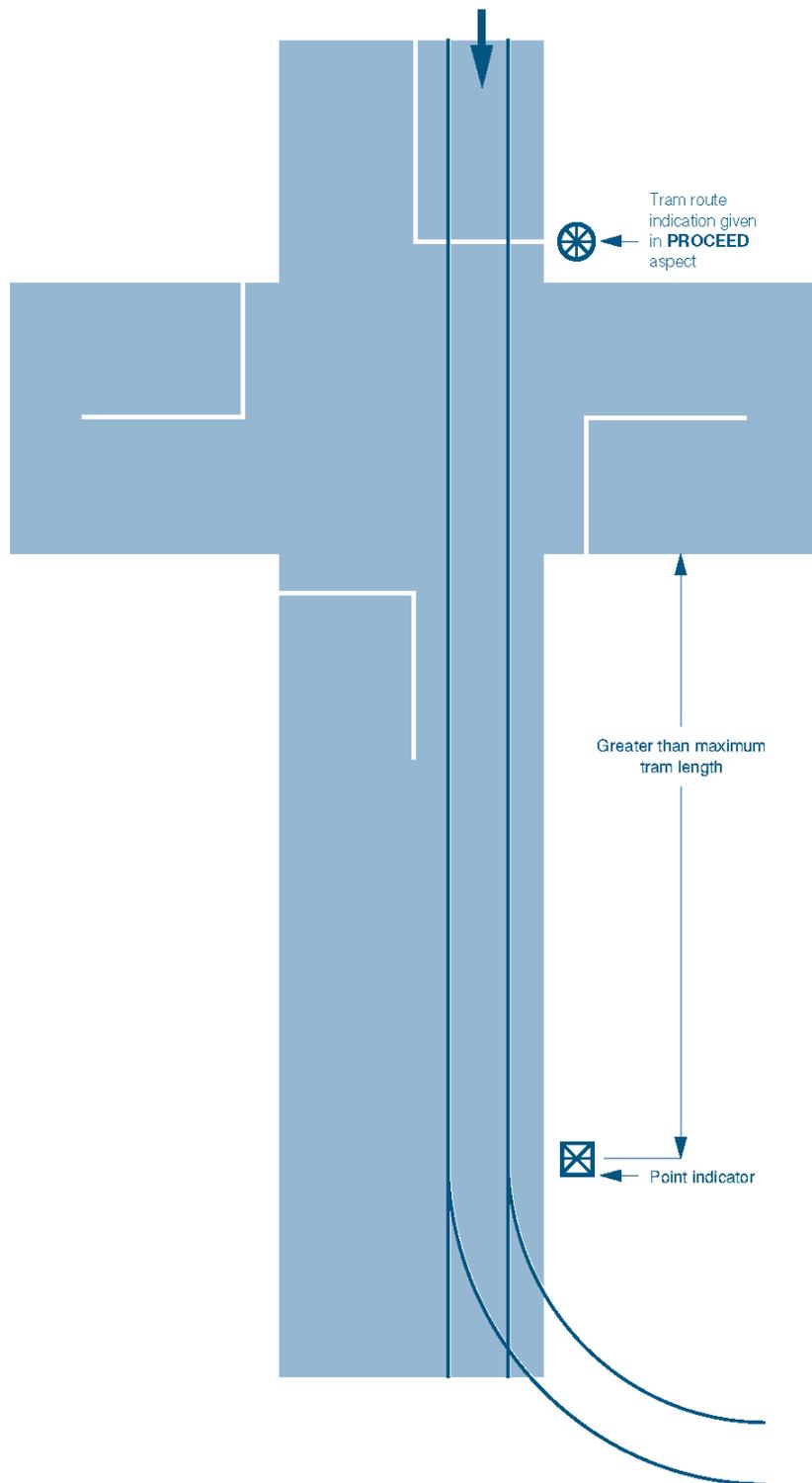


Figure 14: Tram junctions with points after road intersection

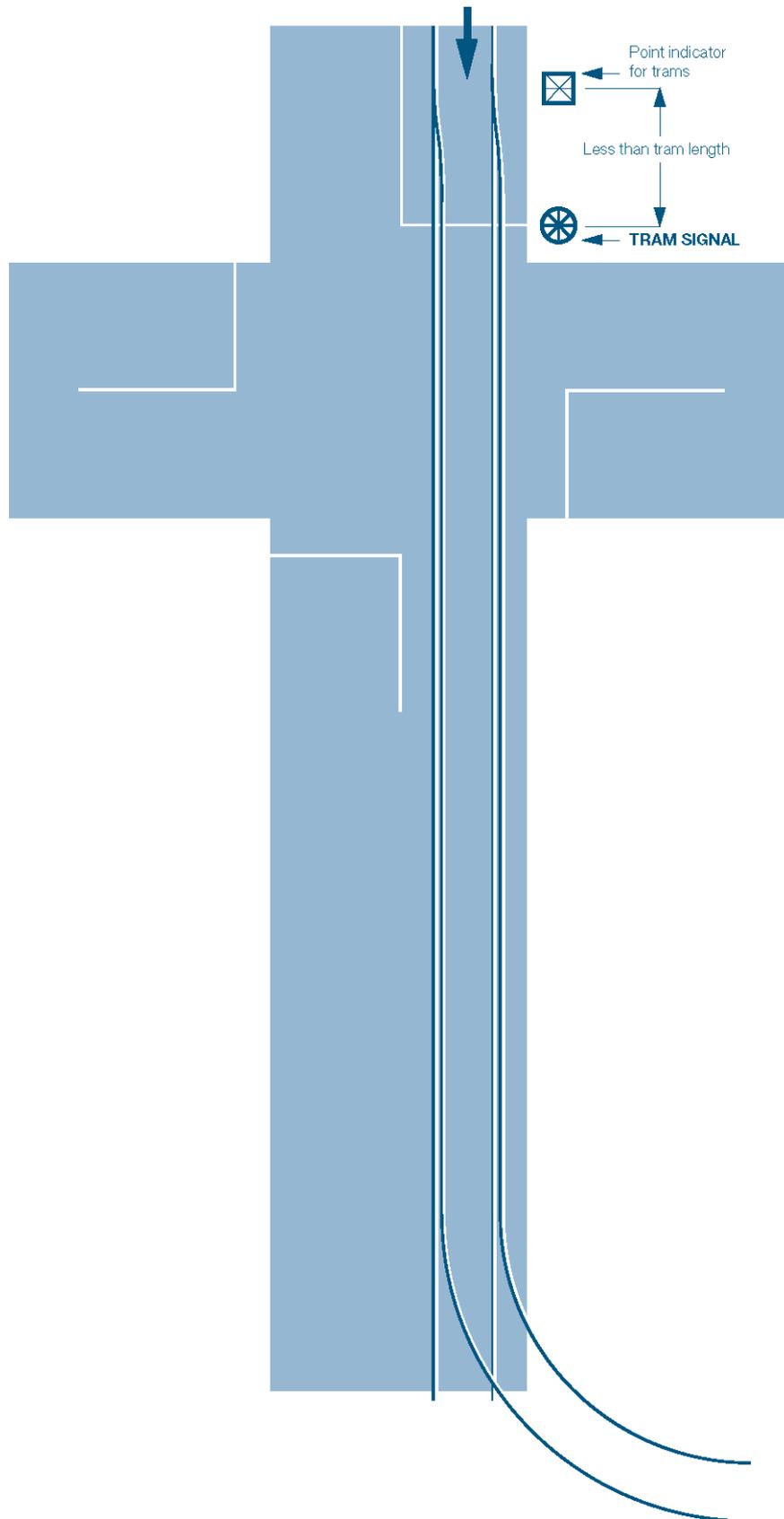


Figure 15: Tram junctions with points before road intersection

## URBAN TRAFFIC CONTROL SYSTEMS

The tram signal system may be interfaced with an urban traffic control system (UTC). The interface will depend on the individual UTC used. However, suitable tram detector arrangements in keeping with those described above are required for all types of UTC.

Traffic signal controllers should comply with the requirements of Highways Agency document TR 2500 'Specification for traffic system controller'.

## EQUIPMENT MONITORING

The road traffic light controller should monitor the failure of lamps in the tram signal.

The road traffic light controller should be designed to monitor tram detectors to ensure they are functioning correctly and do not cause any conflicting aspect to be shown.

Where tramway systems operate within a UTC area, the road traffic light signals will be monitored regularly; in addition, monitoring of the tram signal lamps is required. To prevent a misleading tram signal aspect being shown in a combined, single-unit array, having individual lamps or clusters of light emitting diodes (LEDs), a minimum of three out of the five lamps or clusters should be lit. Where the aspect is provided by a fibre optic or LED display giving the appearance of a continuous band, the monitoring system should reveal the condition that less than 60% of the band is visible or the light output of the band has fallen below 60% of the normal. In either case, provision should be made for the control room or UTC to be alerted. Highways Agency document TR 2514 "Performance Specification for Light Signals for the Control of Tramcars" sets out requirements for signal performance.

Where tram systems operate outside UTC areas, or in towns and cities without UTC, a monitoring system that complies with the current Department for Transport specifications should be provided.

The default mode during a detector failure should provide the following facilities unless an agreed equivalent system is installed:

- (a) the failure of an advanced detector should not register a demand for a tram phase;
- (b) the failure of a stop line detector should register a permanent demand for a tram; and
- (c) the failure of a cancel detector should cause the all-red period to run to the maximum time permitted (sufficient to allow a tram to clear the intersection in accordance with current traffic management practice).

An alternative means of registering a tram demand is required in the event of failure of a detector, such as a TRTS detector which doubles as a stop line detector. Alternatives may be:

- (a) the creation of a plausible demand (see Note 1);
- (b) recognition of a stop line detector registering a permanent demand (see Note 2);
- (c) a key-operated override switch located at the local traffic controller or adjacent to the signal (see Note 3); or
- (d) remote input from the UTC system (see Note 4).

Note 1: If any detector fails where other detectors are available for inputting plausible demands, they may be used to call up a tram phase.

Note 2: Where a road traffic light controller can recognise that a stop line detector is registering a permanent demand, e.g. by reference to inputs from other detectors, the demand may be downgraded to a non-priority demand. Where this is not possible, a tram phase should have a maximum time allotted to it, following which it should be shut down and the tram phase thereafter appear automatically at a fixed time within each cycle, either running concurrently with other appropriate phases or separately.

Note 3: A key-operated override switch may be provided to enable a tram input command to a road traffic light controller if any of the tramway equipment upstream of and including the tramway interface unit should fail.

Note 4: A facility for the tramway control room or the local urban traffic control centre to insert a tram demand via the UTC equipment may be used to assist trams which are unable to indicate their presence to the local road traffic signal equipment.

## APPROVAL

All equipment:

- (a) used to control road traffic on the highway;
- (b) connected to a road traffic light controller; or
- (c) housed with the road traffic light controller;

Must be approved before being put into service. Further information regarding approval procedures can be obtained from the Highways Agency documents TR 2500 and TRG 0600, and also in document TD 07/07 of the Design Manual for Roads and Bridges. For traffic light controllers this approval extends to the content of all instructions stored in, or executable by the controller and not simply the hardware.

Systems employing radio techniques must be approved by the Secretary of State.<sup>19</sup>

## APPENDIX C - HERITAGE TRAMWAYS

This appendix provides guidance on heritage tramways, the use of historic trams on new or existing tramways, and the design and use of replicas of historic trams.

Some heritage tramways possess works, plant and equipment (including trams) which do not meet the terms of the guidance in this document in all respects. Where such works, plant and equipment have been in use over a sustained period, and these disparities have been countered by suitable operating practices and staff training, the guidance should not be taken as suggesting that these arrangements should be disturbed so long as the works, plant and equipment continue to be used with these safeguards.

The guidance in the main part of this document should be followed whenever it is reasonably practicable to do so. This particularly applies to matters of electrical safety and to clearances between trams and structures.

In this appendix:

- (a) open-top tram means a single-deck tram without a roof, or a double-deck tram without a roof over all or part of the upper deck;
- (b) open-sided tram means a tram having open sides giving direct access to the seats (a 'toastrack' tram or 'combination' tram) or a tram having side windows capable of being stowed to a substantial extent within its body sides or roof (a 'semi-convertible' tram).

### TRAMWAY CLEARANCES

It may not be practicable to establish a precise kinematic envelope for each tram on a heritage system. However, it should be possible to establish a generous tramway path to cover all trams used or likely to be used on the tramway.

On tramways that operate open-sided trams, the clearances given in Chapter 3 should be increased so that there is at least 830 mm between the SE and any structure, including poles. This clearance may be reduced when restraining bars are fitted to the sides of such trams.

On tramways that operate open-top trams, the clearance to the underside of a structure over the tramway from the floor of the open deck should not be less than 2000 mm. This clearance should be increased to 2750 mm if there are overhead electrical conductors.

### THE INFRASTRUCTURE

#### Track

The weight of rail should be appropriate to the maximum axle loading and permitted speed. Section 45 of the TWA 1992<sup>5</sup> enables directions to be given as to the axle loadings and speeds.

On ballasted track, the ballast should be level with the top of the rail to allow any drop-down lifeguards to function efficiently. This may be unnecessary if the line is fenced or other means of deterring unauthorised access to the track are in place.

### Electric traction system

The minimum wire height above the floor of the upper deck of any open-top tram should not be less than 2750 mm. Where this is not practicable, any special precautions and operating instructions should be discussed with the ORR.

## CONTROL OF MOVEMENT

Indicators to show the lie of any facing points may not be required. If they are not provided, the operating procedures should require each driver to confirm the correct setting of the switch blade or blades before passing over the points.

A simple form of access control, instead of an interlocked signalling system, may be used on lines with single-line working. The method to be adopted should be discussed with the Inspectorate.

## ROLLING STOCK

A tram may employ horses, internal or external combustion engines, cables, or electricity to provide traction power. Guidance on electric traction power is given in Chapter 8.

The external lighting requirements for trams given in Chapter 8 may be relaxed. As a minimum, one or more headlamps and a tail lamp should be provided. Where reasonably practicable, trams (other than horse-drawn trams) operating in roads with other types of road traffic should be fitted with brake lights even though they may not have been originally so fitted.

The braking performance of heritage trams may be less than that given in the guidance in Chapter 8, providing the speed of operation and the operating rules of the system are appropriate to the actual braking performance.

The guidance on brakes, lifeguards and lighting may not be appropriate to horse-drawn trams.

Drop-down lifeguard trays actuated by movable gates at the end and sides of the leading end of a tram may be used instead of a fixed lifeguard.

Coupled trams should have compatible buffing and drawgear, and braking systems. They should have comparable end-loading strengths.

This guidance may be set aside if it becomes necessary to recover a failed tram in non-passenger service.

Heritage trams are not required to comply with the guidance in Chapter 8 governing fire-safety, except that suitable fire extinguishers should be carried.

## Open-top trams

On open-top trams, adequate clearance should be provided between the upper deck floor or any place where a person could reasonably be expected to stand, and any exposed live electrical equipment. This clearance and other arrangements made to protect against risks from an overhead power supply conductor, and any special operating instructions, should be discussed with the Inspectorate.

On open-top trams, adequate safeguards should be in place to minimise the risk of people being struck by the overhead power supply collector of any such tram as a result of the de-wirement or rotation of the collector or of any part of it becoming detached.

Edge protection commensurate with the height above ground should be built into the tram to protect against falls.

Note: The Heritage Railway Association has produced additional guidance on horse trams.

## APPENDIX D - NON-PASSENGER-CARRYING VEHICLES USED ON TRAMWAYS

This appendix gives guidance on non-passenger carrying or works trams.

Non-passenger-carrying trams should follow the design principles detailed in this guidance where practicable or appropriate. However, where such trams are infrequently used or unpowered or are self-propelled works trams, some features may be difficult to achieve or may be considered unnecessary.

Vehicles used for tramway maintenance may be exempt from some of the operational provisions for passenger-carrying trams. The degree of exemption will depend on:

- (a) the type of tramway system;
- (b) when the vehicles are used, i.e. in or out of service hours; and
- (c) whether the vehicles are self-propelled or not.

Works trams and other similar vehicles should follow (unless specifically excluded below) the guidance given in Chapter 8 for:

- (a) underframe and body;
- (b) driver's cab;
- (c) mirrors;
- (d) external lights and audible warning devices; and
- (e) braking performance.

Works trams are not required to follow the guidance for couplers, which may be non-folding and need not be fitted with fenders or protective covers. Additional operational control measures may be required to minimise risk to pedestrians and other vehicles.

Unpowered works vehicles are not required to follow the guidance for:

- (a) underrun protection;
- (b) skirts; and
- (c) lighting and audible warnings; but
- (d) must carry side marker lights.

Unpowered works vehicles used at the extreme leading end of a works train should carry the appropriate forward lighting and be equipped with a position from which a member of the staff can safely operate the emergency brakes and an audible warning device. Vehicles at the rear of a train should carry the appropriate rear lights. End outline marker lights are not required unless the top of the vehicle body is more than 2500 mm above rail level.

Powered non-passenger-carrying vehicles used exclusively within possessions may not need to comply with the lighting requirements described in Chapter 8.

## APPENDIX F – Pedestrian Issues

This appendix gives additional guidance on the integration of tramways into pedestrian environments

Design of alignment to accommodate tram in a pedestrian friendly manner:

The alignment of the track should be considered carefully with potential pedestrian access to minimise the risk of serious injury. This is particularly relevant on vertical curves or where there are tight clearances for example in case a large overhang at the tram ends could lead to injuries. The radius of all horizontal and vertical curves should be reviewed in conjunction with the tram characteristics.

Recognising limitations of available trams is an essential interface identification requirement in relation to the local topography

At the project planning stage, the parameters and limitations of available trams being considered should be taken into account.

Track geometry impact on pedestrian safety

Consideration should be given to the following at the design stage:

- Effects of alignment on tram spatial positions relative to the road;
- Hogs, sags, curves horizontal (reference pedestrian desire lines) and vertical;
- Pedestrian protection from underrun;
- Gap between tram and road, position of wheels ref. tram body;
- Clearances to pedestrians etc., assessment of risks in presenting false security to pedestrians.
- Positioning of the alignment to maximise available space for pedestrian use, taking account of parking, loading, footfall etc.
- Consideration of consequences of derailment and how this interacts with the pedestrian environment.

Desire lines

Consideration should be given at an early stage of the infrastructure design to pedestrian movements around and across the tramway system. Desire lines may need to be modified to reduce risks to pedestrians. Desire lines may be affected by some of the sighting hazards listed below.

The design of the tramstops and pedestrian access should, as far as possible, minimise the desire to cross the track at places other than designated crossing points. Particular care should be taken at tramstops where trams may possibly only be required to stop when requested.

The walking or ground surface should be finished flush with the rail head within a tramstop area and at least within 1m of a crossing point. Passengers should be encouraged to use defined crossing points.

Warning signs shall be placed such that pedestrians are clearly warned of the dangers and footpaths designed to direct passengers to designated crossing points.

## Sighting hazards

The tramway should be designed to minimise the number of visual obstructions so that tram drivers and pedestrians can easily see each other, particularly considering the following issues:

- Road junctions
- Vehicle inter-visibility
- Vehicle parking
- Bus stops
- Landscaping/trees
- OHLE and lighting poles
- Light to dark transitions
- Lighting levels
- Street furniture
- Tunnels/underpasses

## Major buildings, schools and other institutions or facilities

The design of a tramway should take account of associated pedestrian movements and of pedestrians not giving the presence of trams their full attention.

## Pedestrian management

Active and passive guidance measures should be considered in the design as necessary depending upon location and may need to take into account event management. Within the tramway there may be areas requiring pedestrian access, areas where pedestrians should be discouraged from walking (resulting from any risk assessment such as within a tramstop, for example) and areas where pedestrians are prohibited (such as next to a railway line). Methods of pedestrian control should be coherent throughout the system and include:

- Provision and delineation of pedestrian crossings;
- Signage;
- Active deterrents such as barriers, paving, planting etc. Where deterrents are provided to separate pedestrians and trams the deterrents should not also introduce potential trapping hazards with the tram body (side or front) or underside. Passive deterrents such as marking the tramway path should be considered.
- Defined walkways on bridges, viaducts and other restricted areas.

## Junction design

Adequate provision should be given to pedestrian crossing phases at signalled junctions. Wider area impacts on road traffic and pedestrian flows should be considered at an early stage of design development and subsequently during detailed junction design.

Non-signalled junctions should conform to necessary visibility requirements for both pedestrians and vehicle drivers. These should be in conformance with the Department for Transport requirements given in the publication "Manual for Streets" 2007.

## Pedestrian crossings

Where the demand dependent nature of tramway signalling could impact upon the available time allocated for pedestrians to cross, and the intensity of tramway traffic is well below the criteria normally applied to justify signal controlled crossings, it is found that pedestrians generally ignore signalled crossings. To reduce risk in these circumstances un-signalled crossings should be used except where the *mutual visibility of all road users* is inadequate. Exceptions to this guidance are as follows:

- where the crossings are common to other traffic sharing the lane or on adjacent lanes with no separation or
- where the crossings form part of a fully signalled junction and separation of the tramway crossing is not practicable or
- exceptionally, where tram and pedestrian flows are very high.

Uncontrolled pedestrian crossings with normal passive signing should be the default option even where other signalling is present unless such signing proves inadequate. However, consideration should be given to users that might need to take advantage of signalling them across the tramway, especially if it is provided for other roads at the junction.

Note: In the absence of a tramway, practice varies between local authorities in terms of signalling provision at road junctions and pedestrian crossings and whilst some prefer not to signal, others opt for more signalling. In both cases, the reasoning seems to focus on practical experience of accident rates which perhaps vary regionally for each type of junction. Some tramways extend beyond a single local authority boundary causing additional complication.

Every effort should be made to achieve consistency along tramways and as far as possible, between tramway systems to avoid confusion to both tram drivers and pedestrians alike. Such things as crossing layout, tactile colouring and texture, signage and guard rail configurations (when considered as best practice should be) cascaded forward from one system to the next.

## Operational issues

### Sighting

Sighting studies should be carried out at an early stage and should continue throughout the development of the design. When carrying out sighting studies, potential maintenance issues e.g. soft landscaping design, should be considered.

The positioning of driver information signage and potential for driver distractions should be considered at an early stage.

Operators' SMSs should provide for dealing with temporary works external to the tramway e.g. road works, scaffolding etc.

Issues raised as part of sighting studies should be incorporated into the hazard log, in order to maintain the validity of the safety acceptance process.

## Speed

Aspiration for run-time should be realistic taking account of all practical operating limitations.

Both geometric and operational speed limits need to be considered in parallel.

Operating speeds in pedestrian areas should consider random or unplanned movement of pedestrians.

## Tram underrun

On defined pedestrian areas where the walking surface is flush with the track, consideration should be given to ensure that, wherever possible, pedestrians are deflected away from the front of a tram rather than being drawn into the gap between the body and the track.

There should be a means of preventing pedestrians from either being crushed between the road and the tram underfloor or from going under the tram wheels at all areas identified in the risk assessment. For the purpose of the following paragraph this will be referred to as "underrun protection". Fast moving protection systems such as "drop down guards" should not be used.

The gap between the road surface and the underrun protection is dependent upon the tram layout and geometry in relation the alignment. This should be studied as a part of the project design. The presence of vertical curves may result in an unavoidable large gap between the body and the track at the front of the tram. In situations where this occurs, pedestrians should be discouraged from being in the area of greatest risk. In these circumstances the hazard should be mitigated by other considerations such as, for example, reduced tram speed.

## Surfing

In order to prevent "surfing" the design of the tram should avoid the possibility of providing sufficient external hand or foot-holds.

## Deflection on impact

The outside of the trams should be designed to deflect pedestrians away from the path of the tram wherever possible.

## Protruding parts of tram

The outside of the tram should minimize protrusions that could become entangled with pedestrian's clothing or cause injury.

## Heritage tramcars, under run protection devices

This section should be read as an extension of Appendix C

Heritage tramcars may operate either on dedicated heritage systems or on systems that are normally operated by modern tramcars.

Heritage tramcars are traditionally fitted with a variety of under run protection devices and in the case of some early or very slow speed tramcars no frontal under run protection is provided.

Under run protection devices on electric tramcars may include drop down 'gate and tray' systems, sprung tray systems, 'providence' lifeguards or a solid blade system, this is an indicative list as there were also experimental systems in use on 1<sup>st</sup> generation tramways. In addition bogie tramcars may be equipped with side protection between the bogies.

Steam tram engines are fitted with skirting to not exceed a gap of 100mm (4 inches) from the road surface but from 1890 'life protectors' were an additional requirement.

Cable tramcars and horse drawn tramcars, which operate at very slow speed, not exceeding 12 kph (7mph) are not necessarily fitted with under run protection but some may be fitted with small 'plough' blades or brushes to remove debris from in front of the wheels. Certain works cars or tramway maintenance vehicles are not fitted with under run protection by the very nature of their usage, e.g. snowploughs.

Tramcars that are equipped with a heritage pedestrian under run protection system should not exceed 40 kph (25 mph).

## APPENDIX G – Stray Currents

This appendix gives guidance on the management of stray current.

### Introduction

The power circuit of any direct current supplied electric tramway can be considered as consisting of four fundamental elements:

- The substations, from which the direct current at the designated nominal voltage for the line is supplied (Nominal voltages should be to BS EN 50163 “Supply Voltages for Traction Systems” unless the system already uses an alternative voltage)
- The positive conductor (i.e. the overhead line) connecting the supply to the trams
- The load, i.e. the trams
- The negative conductor (i.e. the rails), through which the current is returned to the substations

The flow of electrical current through a conductor will result in a voltage drop along its length, proportional to the resistance of the conductor.

The consequence of this is that parts of the rails will be at a different voltage than that of other objects buried in the earth, such as metallic pipes and cables belonging to other Statutory Undertakers such as Utility Companies.

This voltage will be dependent on the location and power flow within the system and may be positive or negative with respect to local earth. As there will be some resistance to earth the voltage distribution along the track at any instant in time will average zero with some parts positive and some parts negative. This distribution will vary depending upon the operating conditions and vehicle locations and whether the vehicles are motoring or braking (but negative voltages are not caused specifically by regenerative operation.)

Because the earth is a less than perfect insulator, the potential difference between the rails and nearby buried conductors will result in some of the traction return current “leaking” to earth and some of this total leakage returning to the substation, in part, via those buried conductors. The extent to which this will occur depends upon the relative total resistance of the many possible return paths, via the rails and via other conductors and the ground.

The consequence of stray current is that where it leaves a buried metal object, electrolytic corrosion will occur, frequently in highly localised areas and potentially leading to loss of material. For any significant loss of material to occur there needs to be current flow over time.

This is clearly undesirable in the case of metallic pipes carrying gas and water, as leakage and/or rupture has obvious safety and/or operational risks to both the tramway and the general public. In the case of cables, particularly the older lead sheathed types, such loss occurs even more rapidly and can lead to breakdown of the (now) unprotected inner insulation of the cable.

## The legal position

In the early days of tramway electrification, damage to apparatus was a significant issue to the various Statutory Undertakers who sought to prevent the tramway operators from allowing any current to return via the earth. This resulted in a court judgment (National Telephone Company versus Baker, 1893) which ruled that the earth was not exclusively for the use of the Statutory Undertakers, and that the tramway companies were as entitled to use it as much as they were, providing that they did not exceed reasonable limits. These were expressed in terms of maximum voltage drop in the running rails and promulgated via a series of recommendations published over time by the Board of Trade and the Ministry of Transport.

Importantly, it established the principle that some leakage current is inevitable, and that provided measures are taken to maintain it within reasonable limits, its existence has to be accepted by the Utility Companies and others who elect to bury their apparatus in the ground.

Such recommendations are now in the form of European Standards which are referenced below.

## Overall Stray Current Management Policy

Stray Current Management has to form an integral part of an overall Electromagnetic Compatibility Policy for a tramway. It should be compatible with the design of the tramway for earthing, bonding and lightning protection.

The electrical design of tramways should, as far as practicable and consistent with overall safety, be optimised in order that the potential to generate stray currents will be kept to the minimum practical throughout the life of the system.

This Stray Current Management Strategy sets out to assist a tramway to demonstrate, mitigate and manage the stray current risk where this is still considered to be potentially significant during electrical design optimisation.

## Information Exchange and Co-operation

It is in the interest of the tramway promoter (this may be the operator or maintainer) that this will be best achieved by co-operation and information exchange between all of the parties involved leading to agreement.

Information exchange and co-operation with all potential stakeholders should be carried out during the planning, design and construction stages. This can continue throughout the operation of the system when significant changes to the tramway are planned. In this way, possible effects, suitable precautions and remedies can be assessed. It is also important that the existence of stray currents from other non-tramway sources, (not restricted to other electric railways), is identified.

## Stray Current Working Party

It is recommended that tramways set up a Stray Current Working Party (SCWP) for each project. It is hoped that all Statutory Undertakers particularly the Utility Companies who have any concerns that their apparatus may be affected by stray currents would wish to be

involved and contribute to this working party. The tramway should determine the membership and propose terms of reference /constitution for the Stray Current Working Party. It would be hoped that this can be agreed by the members on a simple majority basis. The outline issues to be considered should be:

- To agree the establishment of a schedule of susceptible assets. It should be both understood that such assets must both be metallic and close to the tramway rails, and capable of forming an effective path between different parts of the tramway. Continental experience is that provided the measures described in the sections below are achieved, then buried metallic apparatus over 1m away from the rails in any direction will not be susceptible to stray currents.
- Cognisance should also be taken of any ongoing programmes to which the Utility Companies are committed to replacement of apparatus currently metallic with plastic or similar thus reducing the range and extent of susceptible apparatus.
- To scrutinise the project for the electrical system design and stray current management of the system
- To agree the level of testing of measures to mitigate stray current during the construction phase of the system.
- To agree the level monitoring of change in these measures during the operation phase of the system.
- To review results of testing during construction
- To review issues as they arise during the operation phase of the system.
- The frequency of meetings should be by agreement. It will be expected that the need will vary throughout the life of the project. However once tramway operations are established it would be expected that meetings will only be required where specific issues require to be reported or discussed.

It would be expected that, where appropriate, other Statutory Undertakers such as Network Rail and TfL may wish to deal with individual tramway projects in a broader forum which considers other interface issues (such as EMC) as well as stray currents. The tramway should accommodate this approach.

## Appropriate Standards

The base standard is BS EN 50122-2 (Protective provisions against the effects of stray currents caused by d.c. traction systems). The principles may also be applied to existing electrified systems where it is necessary to consider the effects of stray currents.

This standard gives comprehensive advice on the design of systems as well as recommended requirements. The design and management of tramway electrification should meet the requirements of this European standard.

Linked with this standard is BS EN 50122-1 (Protective provisions relating to electrical safety and earthing).

It is important to note that the protective provisions against electric shock in this second standard will take precedence over provisions against the effects of stray currents where safety of staff, or protection of the public, are concerned.

BS EN 50162 (Protection against corrosion by stray current from direct current systems) should also be considered during the design process this standard assists with the identification and measurement of potential corrosion from stray currents should they still

be considered a risk. The stray current design and management of the tramway should take account of this standard where it is appropriate and following consultation with the SCWP.

Other standards may be referred to as appropriate. Overall the tramway will be designed, constructed and operated to comply with appropriate legislation in force at the time.

## Electrical Design of the System

### Fundamental Principle of Stray Current Design and Management

It is not possible to obtain infinite resistance between the tracks and surrounding earth for the full length of the alignment, and certainly not for the life of the tramway and under varying weather conditions.

It is possible to limit the risk of stray current, but not to remove it entirely. The design and ongoing management strategy will be to ensure that as far as is reasonably practicable, the level of stray current is minimised.

### Designing to Keep Stray Current Low

For reasons based upon sound experience with early tramway electrification schemes it is the established convention to determine the insulated overhead conductor as the positive pole of the supply, with the running rails as the negative return.

From any point in the system the return current has the possibility of returning to the negative busbar of the substation by:

- The designated return path (primarily the rails but may include cables as well) or,
- Via the earth (i.e. as stray current)

The extent to which each path is chosen is governed by:

- $\text{Current} = \text{Voltage difference} / \text{Electrical Resistance in circuit}$

Which means that keeping stray current to a minimum a primary design objective of the electrical power supply system should be to:

- Keep the Rail to Local Earth *voltage* low
- Keep the Rail to Local Earth *resistance* high

### Designing to ensure that Rail to Local Earth Voltage Remains Low

The tramway will be supplied with electricity suitably transformed and rectified from the local electricity network supplier through substations located along the route. The local Rail to Local Earth Voltage at any point depends on the overall electrical resistance between that point and the sub-station. Tramways should achieve a low value of resistance in the following manner:

- Frequent feeding points from the traction supply along the alignment thus reducing the distance that return current has to travel. For each feeder point:
  - A robust incoming supply at each feeder point should be provided to the extent that this can be arranged with the local electricity network supplier. Ideally this should be from a ring main rather than a spur connection. This will keep emergency feeding due to the outage of a feeder point to a minimum.
  - It is usual to specify dual end feeding to each electrical section on the tramway; i.e. each section will be fed from the two adjacent sub-stations. This will reduce the

effective distance return current has to travel. Care should be taken to ensure that the open circuit voltages of the two feeding transformers are as equal as possible (by use of the secondary tapping adjustment) in order to ensure that the traction load is shared.

- It is also desirable to provide single feeding points at the midpoint of each section, with coupling switches as necessary to allow for a loss of local supply.
- At the extremities of the line the final section may be single end fed, but the overall length of the electrical section should be lower to compensate.
- The system should be designed so that the permitted accessible voltage is achieved with any one feeder point out of service.
- Welding by an approved process of all continuous lengths of rails in order that the electrical resistance of the rail is not increased by more than the level specified in BS EN 50122-2.
- Where welding of adjacent rail lengths is not possible then the rails will be connected by low resistance track bonds. Incorporating sufficient redundancy in bonding should be considered.
- A similar arrangement shall apply at special track installations such as points, crossings, and breather switches/expansion joints. It may be desirable for parallel return conductors to be installed across the length of special work to facilitate maintenance of the return path during maintenance operations.
- Frequent cross bonding between rails should be provided. In particular this is to give several parallel paths for return current all at equal potential, making maximum availability of return conductor capacity and additionally giving a level of redundancy in event of a failed bond, or rail discontinuity. The bonding shall encompass:
  - Between both rails of each individual track. Experience has shown that a bond separation of around 200m is appropriate.
  - All four rails on double track. Experience has shown that a bond separation of around 400m is appropriate for these bonds. Simulation/modelling will help to determine the appropriate separation for a particular system.
  - The actual appropriate intervals for each type of bond should be established at the design phase of the tramway.
- The majority of tram projects are "drive on sight" tramways and it should not be necessary to employ traditional heavy rail signalling track circuits requiring impedance bonds or insulated joints unless there are particular site or alignment conditions which require it.
- Rail sections should be chosen to give the maximum cross sectional area in order to minimise electrical resistance. Cognisance should be taken of the fact that wear to the rail will cause an increase in resistance over time up to the point that the rail is renewed. The calculations that determine the maximum accessible voltage should take into account the renewal limit of wear.
- Consideration will be given to providing parallel negative low resistance return cables should the project specific power supply studies show them to be required at any point of the alignment. Where it is not practical for other reasons to use a larger rail section or for example an isolated section of single track within a feeder section.

## Designing to ensure Rail to Local Earth Resistance Remains High

Tramways should seek to achieve this by ensuring a high level of insulation from earth of the running rails and the whole return circuit. The design and method of construction should be such that the overall conductance per unit length throughout the system will not exceed the values recommended in BS EN 50122-2 during routine operations throughout the life of the tramway.

It would be expected that the tramway as initially constructed will have conductance values several times better than the values given in the above standard. The inspection and maintenance regime adopted by the tramway should have intervention thresholds such that the track conductance values should never reach the values in the standard during normal operations at any time in the life of the tramway.

The tramway promoter and designer should determine and tabulate the conductance values for all track forms at all points of the route to which the system is being designed, and will be achieved immediately after construction. The intervention (and eventually renewal) thresholds to which the maintainer of the system will be required to achieve throughout should also be clearly stated.

The methods of achieving high levels of track insulation will vary according to the track form adopted. The following covers the basic principles for basic track forms:

On open formation where the running rails are laid above ground level as would be expected on a traditional railway formation.

- Sleepers typically of concrete.
- Insulated type rail pads between the rail-foot, the fastener and the sleeper which also meet the required rail toe loads and vibration/fretting performance.
- Ensure the ballast is:
  - not in contact with the rail as far as possible.
  - clean
  - well drained
- If grass or similar aesthetic feature is proposed it should be absolutely clear how contact between the medium proposed and the rails is to be prevented. This may include for the medium to be contained in separate containers located around the rails.
- In many locations the trams will regularly use sand to assist with adhesion. Build-up of sand deposits providing any direct path between rail and ballast should be routinely dealt with.
- At points and crossings ensure that there are no direct electrical paths between the rails and any electrical apparatus in the point machine, particularly the neutral and earth connections.
- All other rail-mounted conductive equipment will be insulated from earth. In particular the use of non-metallic connections to drain boxes is recommended.
- The exposed metal parts of all bonds or other connections to the rail should be kept as short as possible and clear of fasteners, sleepers or ballast or any other conductive structure connected to earth.

On slab track with rails proud of surface.

- Essentially the same issues as for ballasted track for rail pads, bonds and switches.
- Run-off and drainage should avoid standing water.
- Prevention of build-up of sand deposits is equally important.
- Measures will need to be considered to deal with any reinforcement material within the slab.
- On closed formation where the top of the running rail is level with the surrounding surface. Typical examples will be the highway and pedestrian areas. The points below relate only to electrical considerations.
- An insulating layer should be interposed between the rails and the surrounding structure. This can be achieved by the following means:
  - Using a rail coated with insulating material or
  - Surrounding the rail with a form of insulated "boot" or
  - Embedding the rail in an insulating medium or

- The use of insulating filler blocks on either side of the rail web.
- It may be acceptable to encapsulate the rail directly in concrete.
- If grass or similar aesthetic feature is proposed it should be clear how contact between the medium proposed and the rails is to be prevented.
- The choice and design of the insulating system should be consistent with:
- Noise and vibration attenuation policy, but must not compromise the insulation level. In considering the appropriate solution for a particular area there should be a clear understanding between the differing requirements for electrical insulation (essentially a thin layer) and noise and vibration (which would normally require a thicker layer which coincidentally provides electrical insulation).
- All proposed processes which require access to the rail to attend to defects or make new connections, and to undertake routine welding of rails in order to make good side and head wear.
- Particular attention should be paid to sealing the joint between the rail and the surface of the surrounding surface to minimise water penetration down the side of the rail. The method and materials chosen should take account of the extent to which the alignment at any point is shared or crossed by other forms of road traffic.
- Particular attention should be given to local insulation of the rail:
- At all rail welds, particularly if these are carried out after track installation.
- Where rail bonds or negative return cables are attached to the rails. There should be no exposed metal on either the rail, bonds or cables both at first installation and after maintenance.
- Attachment and insulation of tie-bars connecting both running rails if used.
- At any rail joints not capable of being welded. Continuity bonds should be provided at all such joints.
- Adequate drainage should be provided such that water runs off quickly and does not remain in the vicinity of the rails. Drainage should be cleaned regularly so that ponding does not occur except briefly under the most extreme conditions.
- Standing water should be avoided
- Rail grooves should be kept clean of debris (including sand deposited from the tramcars).
- At points and crossings ensure that there are no direct electrical paths between the rails and any electrical apparatus in the point machine.
- Any other rail-mounted equipment should be insulated from earth. This particularly relates to drain boxes and point machines.
- Measures will need to be taken to deal with any reinforcement material within the slab below and/or around the track.

## Safety Considerations

### Permissible Accessible Voltages

As described above high levels of insulation between rails and earth means that in general whilst the tram is operating there will be a potential difference between the rails and surrounding earth. Under fault conditions this potential difference can rise significantly to the extent that it could cause a danger.

There are limits to the permissible accessible voltages due to the traction return current and touch voltages due to currents under fault conditions set by BS EN 50122-1.

All tramway projects should meet these limits throughout the life of the system.

As the electrical system design is progressed and tram performance and service levels confirmed, each project should conduct a series of computer based power supply simulations. These will simulate accessible and touch voltages at representative points along the system under normal and emergency (i.e. with the designed level of feeder point outage) feeding, and under fault conditions. This will assist in determining whether or not additional measures are required to keep within the required limits. A reassessment should always be made when there is any significant increase in the level of service proposed or the introduction of new tramcars.

Any additional measures will relate to reducing further the return circuit resistance by for example the provision of additional return conductors. It will be appreciated that low accessible voltages under permanent conditions will also assist with the minimising of stray current.

Under fault conditions it may be necessary to connect the return circuit temporarily to earth until other protection measures (such as tripping to interrupt a short circuit current) become operative. This will be achieved by the provision of voltage limiting devices. Whilst this gives the risk of a short term increase in the local level of stray current, safety considerations take precedence. Such events should be both rare and of practically no consequence for third party apparatus.

## Voltage Limiting Devices

All Voltage Limiting Devices used shall meet the requirements of BS EN 50122-2 in terms of reset after operation. Ideally this should have the facility to be monitored through the SCADA system.

Experience has shown that there is a particular failure mode with some types of Voltage Limiting Devices. If they experience a high fault current or a large number of operational duty cycles due to short-term impermissible accessible voltages then they may fail in the short circuit mode. This then creates a direct path to earth for the traction return which could if undetected for some time lead to corrosion on other nearby metallic structures. Testing and maintenance procedures should take account of this failure mode.

For this reason hybrid switching types composing of a solid state control and separate DC contactor should be considered.

## Negative Earthing & Drainage Diodes

Initial practice with the UK's second generation tramways was to electrically connect all of the steel reinforcement in the track slab and connect this to the negative terminal of the d.c. rectifier via a diode. Although this was seen to offer a theoretical advantage by ensuring that the reinforcement should act as a collector mat such that any stray current can only return directly to the substation, experience has shown that this does not work in practice because the voltages that drive stray currents go both positive and negative in normal tram operation.

BS EN 50122-2 is written for a "floating" system and there should be no permanent connections between the negative bus-bar and earth, leaving the rails "floating" relative to Earth. As the resistance between the rails and the earth is not infinite, the rails will adopt an average potential close to that of the Earth.

It should be noted that the diodes have been removed in some of the earlier tramways with demonstrable improvement in stray current performance.

Where steel meshes or similar reinforcement are used as part of the track form for structural reasons or as a crack control measure then the tramway should review whether they should continue to be electrically connected. They should not be connected to the traction return circuit. Detailed specifications and design should be developed during the design of the track forms.

Provided that proper attention is paid to the return circuit resistance and insulation the special provision of a stray current mat should not be required. It should be noted that it is common practice amongst established tramway systems in mainland Europe to employ an un-reinforced concrete track slab.

Special requirements may apply to tunnels as described in BS EN 50122-2.

## Structures adjacent to the Tramway

The resistance between conductive structures adjacent to the tramway, which are not insulated from earth, and the track return system should be as high as possible. The only exception will be at depots which are dealt with below.

Where such structures fall within the zone that it would be possible for a person to be in contact, directly or indirectly, with both the structure and any conductive material connected to the track return then the requirements for accessible and touch voltages of BS EN 50122-1 should be met.

This will normally involve the use of voltage limiting devices.

## Special Arrangements for the Depot

For reasons of the safety of personnel working in the depot the traction return within the depot should be directly connected to earth. The depot should be fed from its own separate rectifier or power supply. The running rails within the depot should be separated from the main line by means of insulated rail joints. The layout of the depot should be planned to avoid any necessity for a tram to be stationary such that it will bridge these insulated rail joints. Operational procedures should support this.

All of the above will be in accordance with BS EN 50122-1 and BS EN 50122-2.

It should be noted that a depot site will normally comprise of an area within which maintenance activities will be undertaken normally within an enclosed structure, together with stabling areas. The tramway should consider whether the whole site or merely the maintenance area is to be subject to the above feeding arrangements. The decision will depend upon:

- The overall maintenance philosophy of the tramway; i.e. the extent to which maintenance is restricted to one particular area.
- The location of the depot site. Where for example it is contained entirely in an "all enclosed" urban development then it is likely the whole site will require to be considered.
- The effect of the current draw when the fleet is stabled but with much of the auxiliary load enabled. This will determine the maximum voltage drop along the tracks and thus

determine whether a direct connection between structural earth and the return circuit is tolerable.

## Other Railway Traction Systems

Care should be taken to ensure that there will be no direct conductive connection to track sections of other railway traction systems.

Special arrangements should be taken where conductive structures are adjacent to both systems (and in the case of Alternating Current traction systems are bonded directly to the tracks of the Alternating Current system). These arrangements will be agreed with the owners of each system and take account of the particular earthing and bonding arrangements on both systems. They should not compromise stray current levels on the tramway, except for extremely short periods under fault conditions.

## Cathodic Protection Measures

The overall design including the methods described in this section should ensure that there will be no consequences due to stray current for third party apparatus. Owners of third party apparatus may still wish to install specific cathodic protection measures on particular apparatus, as for example described in BS EN 12954. The tramway should not be expected to bear the costs of such work or take any consequences for the performance or monitoring of that apparatus in the future.

## Ongoing Monitoring and Control of Stray Currents

### Tests and Measurements

It is not practical to directly measure stray currents. The only practical measurement is a local potential difference between the traction return and "mother" earth.

It is sensible to take measurements of this potential difference in order to confirm that rail potentials stay within a consistent range relative to the design values and those measured at first installation. This information can then be used to calculate the track conductance along the route at any point in time thus allowing changes or trends to be identified and where necessary additional inspection and remedial actions instigated.

These measurements may be taken on a continuous or discontinuous basis. One of the procedures described in BS EN 50122-1 and its associated annexes should be adopted by all new tramway systems. Existing tramways should consider changing their present arrangements to those described in this standard.

The infrastructure maintainer should use this information continuously particularly that of any adverse trends to programme early inspection and remedial action. Intervention thresholds should be clearly defined and acted upon.

The tramway should be able to demonstrate that it is maintaining the return circuit insulation at the levels specified in their maintenance instructions. These ideally should be higher than those in the standard BS EN 50122-2.

Provided this is achieved and demonstrated then no other testing regime should be required.

It is for the Utility Companies to carry out any additional monitoring of their own apparatus as a part of their internal inspection and maintenance procedures. Any measurement and criteria for intervention due to measured stray-current interference for apparatus without cathodic protection should be in accordance with the procedures given in BS EN 50162.

In particular it should be noted that as return circuit insulation levels will always be high compared with soil resistivity changes in the latter locally over time will have insignificant effect.

The above should only apply to utility apparatus installed before the granting of the Transport & Works Act Order or equivalent legislation for any tramway project. It shall be the responsibility of the owner/installer of any new or modified apparatus to take full cognisance of the presence of the tramway and to design and install such that the apparatus is not susceptible to corrosion from stray current.

## Construction Phase

The tramway should recognise that the achievement of the agreed design standards for track insulation and bonding will require continuous attention to detail throughout the construction phase of the project. Procedures should be documented and in place which:

- Continuously review the practicality of the design for construction
- Provide rigorous quality control at all stages
- Carry out formal testing and recording at appropriate stages.

The detail of the above should be developed as the design and procurement proceeds and be incorporated into the overall project quality and test and commissioning documentation.

The above should be shared with the Stray Current Working Party during the design and construction phase.

## Maintenance during the Operational Period

The tramway should ensure that a regime of preventative and corrective maintenance of the system is in place throughout the operating period. Maintenance of return circuit insulation levels will form a key part of this. The majority of these actions are essentially good house-keeping activities such as:

- Monitoring of return circuit potentials, with reaction to changes.
- Keeping ballast clean and free of vegetation
- On grass tracks applying regular vegetation management to ensure no direct contact between the rail and the growing medium.
- Keeping drains clear.
- Cleaning sand deposits away from rails.
- Addressing highway surface failures promptly
- Checking bonds for soundness and that they are still in place (i.e. they have not been stolen)
- Checking cables for insulation damage.
- Checking protection devices for functionality.

## Renewals of Equipment

Over the operating life of the system equipment of both the tramway and third parties will require renewal. This may arise for several reasons;

- Life expiry.
- Obsolescence
- Damage

For all renewals it will be appropriate to consider the stray current implications of;

- The point at which renewal is judged necessary. For example the remaining cross sectional area of a rail may be considered more important than the physical state of the rail head.
- Service experience
- Changes in technology or materials

The quality of renewals or upgrades should be, as a minimum, consistent with the original construction. It would also be expected to take account of any changes in legislation or any appropriate European standards that may have been introduced or modified since the original construction.

In particular third parties should note that any renewal of their apparatus should take full cognisance of the presence of the tramway.

## Heritage and Museum Tramways

It is accepted that most current heritage and museum tramways will have been constructed to meet rules issued many years ago by the Ministry of Transport.

All tramway installations however have a duty to consider stray current implications. In doing so it should be remembered that for corrosion due to stray current to be an issue significant current must flow for some time.

Tramways should consider;

- The length of the return path to their feeding point(s) and its specific resistance.
- The maximum current draw to be expected from the tramcars to be operated on the line, taking into account operating speeds and likely loading.
- The operational periods of the line.
- The level of service to be provided during these operating periods.

They should also consider the likelihood of significant underground metallic services in close proximity to the alignment of the tramway.

Careful consideration of these points will allow a judgement to be taken as to whether any additional insulation of the traction return would be advisable at times of renewal or extension to the existing systems.

# APPENDIX H – Application of Highways Legislation to Tramways and Tramcars

*Note: This applies to England and there may be minor variations in relation to Scotland, Wales & Northern Ireland*

## SYSTEM SPECIFIC LEGISLATION

It is unlawful to install or use tramway apparatus in, under or over a highway without appropriate authority. Subject to minor exceptions such authority has to be secured by or under statute. In the recent past such statutory authority was obtained by means of a local Act of Parliament or by a Light Railway Order. Since 1993, the usual method of securing statutory authority has been by way of a Transport and Works Act order granted by the Secretary of State under Part I of the Transport and Works Act 1992 (TWA) and in Scotland since 2008 the Transport and Works Act (Scotland) 2007.

Based on the Transport and Works (Model Clauses for Railways and Tramways) Order 2006 (S.I. 2006/1954), TWA orders usually incorporate such clauses to authorise tramway promoters and operators to install rails in the street and to specify their relationship to adjacent road surfaces; to change alignments or substitute different trackwork; to construct and maintain works to control traffic on the tramway and works to alter the position of other utilities' apparatus; to alter the layout of streets, stop up streets, install level crossings and attach overhead supports to buildings; to remove obstructions from the tramway; to remove rails in the street in the case of discontinuance of the tramway; and to restore the road surface and to safeguard the rights of highway authorities to widen, divert or improve any highway along which the tramway is laid.

Article 45 of the model clauses authorises a tramway operator to make byelaws regulating the use and operation of, and travel on, its tramway, the maintenance of order on the tramway and its tramcars and the removal of obstructions (including vehicles without drivers) from the path of the tramway. Such byelaws require confirmation by the Secretary of State.

## STREET WORKS

### Overhead Electrical Equipment

The consent of the Secretary of State is required under section 37 of the Electricity Act 1989 for the installation and maintenance of electric lines above the highway, but such consent is not needed if the lines are part of the apparatus of a tramway installed under statutory authority (Overhead Lines (Exemption) Regulations 1992 (S.I. 1992/3074)).

Where an overhead electric line is located over a highway, the minimum height of such line is prescribed by the Electricity Safety, Quality and Continuity Regulations 2002 (S.I.2002/2665) as amended, with variations allowable in specific circumstances. Where such height requirements cannot be met (as, for example, in the case of a low bridge), an exemption is required from the Secretary of State.

## Other Street Works

Without statutory authority, tramway apparatus may only be placed or maintained in a street if a street works licence has been obtained from the relevant street authority pursuant to sections 49 and 50 of the New Roads and Street Works Act 1991 ("NRSWA").

If works intended to be carried out by a tramway operator constitute major transport works, there is an obligation on the part of the operator to agree with other street utilities the measures needed to be undertaken, the bodies to carry them out and the manner in which they are to be coordinated (section 84 of NRSWA). The relevant costs are to be apportioned between the tramway operator and the other utilities involved in prescribed proportions (Street Works (Sharing of Costs of Works) Regulations 1992 (S.I. 1992/1690)).

A street containing tramway apparatus may be designated by the relevant street authority as a street with special engineering difficulties. Tramway and other undertakers operating in such streets may be required to settle plans and sections of works to be executed in them (section 63 of NRSWA).

Undertakers proposing to execute street works that affect a tramway must give notice to the tramway operator of their intentions. An undertaker carrying out such works must comply with any reasonable requirements made by tramway operators for securing the safety of persons employed in connection with the works and ensuring that interference with the operation of the tramway by the works is kept to a minimum. The tramway operator is to be allowed reasonable time to formulate its requirements or make the necessary traffic arrangements.

These provisions do not affect the rights of undertakers to carry out emergency works, but notice of their intention to do so must be given to the tramway operator as soon as reasonably practicable (section 93 of NRSWA).

## Crossings of tramways

The Highways Act 1980 allows highway authorities or the Secretary of State to make Orders to extinguish or divert public rights of way that cross tramways. A tramway operator may apply for such an Order to be made (sections 118A and 119A of the Act).

An undertaker carrying out street works in a street which crosses a tramway on the level or which otherwise affect a tramway must comply with the reasonable requirements of the operator of the tramway as to the displaying of lights so as to avoid risk of confusion with any signal lights employed by the tramway or which might otherwise cause hindrance to the operation of the tramway (section 92 of NRSWA).

## New or Altered Works

The Railways and Other Guided Transport Systems (Safety) Regulations 2006 (S.I. 2006/1959) ("ROGS") as amended provides that no new or altered works to a tramway which would create or increase significant risk to safety are not to be carried out by the promoter or operator of the tramway without such works having first been verified in a prescribed manner by a competent person. In so far as the works relate to the tramway infrastructure for which the relevant highway authority is wholly or partly responsible, it is for that authority to establish the verification to the extent to which it has that responsibility and to appoint the competent person to undertake the verification.

## ROAD TRAFFIC

### Highway Act 1835

Tramcars are carriages for the purposes of section 78 of this Act and so must keep to the left, or near side, of any highway in which their rails are laid. But this requirement may be overridden by appropriate authority within a TWAO (for example, where a single-line of tramway is authorised to be operated in both directions, notwithstanding that the track is located in the centre or to one side of the highway). Such authority also generally allows for the reversal of tramcars at suitable points, where this is an inherent feature of their operation.

'wrong-line' running may be employed in emergencies, although it would obviously be advisable to liaise with the police authority if this were to be other than in isolated instances.

Special care and diligence must be exercised in the case of tramcar movements that are contrary to left-hand running.

### Public Passenger Vehicles Act 1981

Tramcars are not public passenger vehicles so that in general this Act does not apply to them, but some of its provisions have been applied by local legislation and the Secretary of State has power (so far not exercised) to apply certain provisions to regulate the conduct of inspectors, drivers and conductors, the conduct of passengers, the carriage of luggage and goods and the safe custody and re-delivery of lost property.

### Road Traffic Regulation Act 1984 ("RTRA")

This Act generally applies to tramcars, but by virtue of the Tramcars and Trolley Vehicles (Modification of Enactments) Regulations 1992 (S.I. 1992/1217) ("the Modification Regulations"), they are exempted from the following provisions of RTRA:

- Traffic regulation orders (section 1);
- Equivalent orders within Greater London (section 6);
- Experimental traffic orders (section 9); and
- Orders relating to one-way traffic on trunk roads (section 18).

The Modification Regulations also exempt tramcars from the effect of orders or notices imposing temporary prohibitions or restrictions on certain roads (section 14 of RTRA).

Under article 40(5) of the model clauses referred to above, tramcars are to be regarded as public service vehicles for the purposes of the duty imposed on local authorities by section 122(2)(c) of RTRA to facilitate the passage of public service vehicles and for securing the safety and convenience of their users.

### Road Traffic Act 1988 ("RTA")

This Act applies generally to tramcars, but the following provisions of the Act do not apply by virtue of the Modification Regulations:

- Using a vehicle in a dangerous condition or for a dangerous purpose (section 40A);
- Inspection of public passenger vehicles and goods vehicles (section 68);
- Prohibition of unfit vehicles (sections 69 to 73);
- Vehicles not to be sold in unroadworthy condition or as altered so as to be unroadworthy (section 75);
- Fitting and supply of defective or unsuitable vehicle parts (section 76);
- Testing condition of used vehicles at sale rooms or other premises (section 77);
- Weighing of motor vehicles (sections 78 and 79);
- Offences to do with reflectors and tail lamps (section 83);
- Method of calculating weight of motor vehicles and trailers (section 190); and
- Interpretation of statutory references to carriages (section 191).

The Modification Regulations also extend section 87 of RTA so as to make it necessary for the driver of a tramcar to possess a driving licence that authorises him or her to drive a motor vehicle in category B, within the meaning of the Motor Vehicles (Driving Licences) Regulations 1999 (S.I.1999/2864), with a saving for persons who were already driving tramcars during the year prior to 1 July 1992.

The Modification Regulations also exempt tramcars from the following subsidiary legislation made under the RTA:

- Motor Vehicles (Test) Regulations 1981 (S.I.1981/1694), which require the construction and condition of motor vehicles to be examined and for a test certificate to be issued on compliance;
- Road Vehicles (Construction and Use) Regulations 1986 (S.I.1986/1078), which impose general requirements governing the use of motor vehicles, their condition and equipment and the conditions under which they may be used; and
- Road Vehicles Lighting Regulations 1989 (S.I.1989/1786), which impose requirements as to the lighting of motor vehicles.

## Road Traffic Offenders Act 1988

This Act generally applies to tramcars, but power is conferred on the Secretary of State to disapply certain of its provisions (requiring warning of prosecution, etc., and provisions concerning driving licences), which provisions have so far not been exercised.

## Transport and Works Act 1992 (TWA)

Part II of this Act makes it a criminal offence for inspectors, drivers and conductors of tramcars and their supervisors to be unfit to carry out their duties through drink or drugs or after consuming so much alcohol that the proportion of it in the person's breath, blood or urine exceeds an amount prescribed by the Act. There are detailed supplementary provisions, most of which are analogous to the equivalent provisions for motor vehicles contained in sections 4 to 11 of RTA.

## TRAFFIC SIGNS, SIGNALS AND BARRIERS

### TWA

This Act enables a tramway operator to place or permit the placing of crossing signs and barriers on or near a private road or path near a tramway crossing. The Secretary of State may give directions to the tramway operator as to the placing of such signs or barriers (sections 52 to 54 of TWA). The nature of the signs and barriers are prescribed in the Private Crossings (Signs and Barriers) Regulations 1996 (S.I.1996/1786).

### Traffic Signs Regulations and General Directions 2016 (S.I.2016/362)

These Regulations and Directions are made under RTRA and RTA.

## REFERENCES

In all cases where reference is made to legislation, readers should check for any amendments that have subsequently been made to the text of the legislation.

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3. *Construction (Design and Management) Regulations 2015* SI 2015/51  
<http://www.legislation.gov.uk/uksi/2015/51/introduction/made>
5. *Transport and Works Act 1992 (c. 42)* The Stationery Office 1992 ISBN 0 10 544292  
<http://www.legislation.gov.uk/ukpga/1992/42/contents>
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<http://www.legislation.gov.uk/uksi/1995/3051/contents/made>
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<http://www.legislation.gov.uk/uksi/2016/362/contents>
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#### FURTHER INFORMATION

The majority of HSE publications can be downloaded free of charge from the website <http://books.hse.gov.uk>

The Stationery Office publications are available from: [www.tso.co.uk](http://www.tso.co.uk)

The majority of UK Public legislation is available as free downloads from the UK Government's legislation website [www.legislation.gov.uk](http://www.legislation.gov.uk).

# ACRONYMS AND ABBREVIATIONS

ALARP	As low as reasonably practicable
CCTV	Closed-Circuit Television
EU	European Union
ORR	Office of Rail Regulation
PCV	Passenger Carrying Vehicle
PRM	Persons of Reduced Mobility
RSP	Railway Safety Publication
RSPG	Railway Safety Principles and Guidance
RVAR	Rail Vehicle Accessibility Regulations
SCWP	Stray Current Working Party
SE	Swept Envelope
SPAS	Signal Passed At Stop
TBC	Traction / Braking Controller
TPWS	Train Protection and Warning System
UNECE	United Nations Economic Commission for Europe
VCA	Vehicle Certification Agency
UTC	Urban Traffic Control
LED	Light Emitting Diode
TRTS	Tram Ready To Start



