LRSSB - LRG - 18.0

LIGHT RAIL
Safety and Standards Board

Speed Management Systems Guidance

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DESCRIPTION:

THIS DOCUMENT PROVIDES GUIDANCE ON SPEED MANAGEMENT SYSTEMS

EXPLANATORY NOTE:

LRSSB is not a regulatory body and compliance with this guidance document is not mandatory. This document reflects good practice and is advisory only. Users are recommended to evaluate this guidance against their own arrangements in a structured and systematic way, noting that parts of this guidance may not be appropriate to their operations. It is recommended that this process of evaluation and any subsequent decision to adopt (or not adopt) elements of this guidance should be documented. Compliance with any or all of the contents herein, is entirely at an organisation's own discretion.

SOURCE / RELATED DOCUMENTS:

LRG 1.0 Tramway Principles and Guidance (TPG) (LRSSB)
LRG 6.0 Fatigue Management Guidance (LRSSB)
LRG 11.0 Medical Fitness Guidance (LRSSB)
LRG 17.0 Driver Inattention Systems Guidance (LRSSB)
Automatic Vehicle Speed Management System Trials. Issue 1 (May 2021) (Ian Rowe Associates)

RELATED TRAINING COURSES:	**RELATED LEGISLATION:**
N/A	Health & Safety at Work Act 1974 The Management of Health and Safety at Work Regulations 1999 Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS) (as amended) The Working Time Regulations 1998 Equality Act 2010

CHANGE NOTES:

Date of Issue	Issue No.	Revision No.	Reviewer	Details of Revision
27/06/2023	01	01	LRSSB	Amendments to text / format

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SPEED MANAGEMENT SYSTEMS GUIDANCE

CONTENTS

Revisions from Previous Issue:

New LRG document template and other 'new' formatting.

Appendix listed in the Contents Page.

Changes to Page 1: removal of the named preparer, reviewer and authorising person and insertion of an explanatory note in relation to the status of this guidance document.

Changes / additional items added to the Table A Terms and Table B Abbreviations (from existing text).

New Introduction Section added to be consistent with other LRG documentation.

Existing text from Forward and Introduction placed in a new Scope Section to be consistent with other LRG documentation.

Table 4.1 relocated to form Appendix A.

Numerous minor presentational, minor factual and typographical changes.

Text added to aid clarification where required / appropriate.

TERMS AND ABBREVIATIONS

Table A – Terms

Term	Definition
Duty Holder	Person in charge of infrastructure or operational activities at a particular time.
Line of Sight	Operating mode where a Light Rail vehicle should be able to stop before a reasonably visible stationary obstruction ahead at the intended speed of operation using the service brake.
Operating	Describes the action of driving' or 'being in control of' a Light Rail vehicle based on 'line-of-sight' operation. It includes anyone that is permitted to drive any rail-mounted vehicle over an area to which the public have, or can gain access to.
Safety Management System	A formal management system or framework to manage health and safety.

Table B – Abbreviations

Abbreviation	Definition
4G	Fourth Generation (of broadband cellular network technology)
ALARP	As Low As Reasonably Practical
AVSMS	Automatic Vehicle Speed Management Systems
DSD	Driver Safety Device
DVD	Driver Vigilance Device
EMC	Electromagnetic Compatibility
ESR	Emergency Speed Restriction
FMEA	Failure Mode and Effect Analysis
GPS	Global Positioning System
LRSSB	Light Rail Safety and Standards Board
PERCLOS	Percentage of Eye Closed
PSU	Power Source Unit
RAIB	Rail Accident Investigation Branch
ROGS	Railways and Other Guided Transport Systems (Safety) Regulations 2006 (as amended)
SIL	Safety Integrity Level
SMS	Safety Management System
SR	Speed Restrictions
TBC	Traction Brake Controller
TPG	Tramways Principles and Guidance
TSR	Temporary Speed Restriction
UK	United Kingdom

1. Introduction

1.1. This guidance supports the high level principles set out in LRG 1.0 Tramway Principles and Guidance (TPG) published by the Light Rail Safety and Standards Board (LRSSB).

1.2. This document provides guidance for Light Rail system (tramway) operators, owners and infrastructure managers on the selection of Automatic Vehicle Speed Management Systems (AVSMS) for Light Rail systems based on line of sight operations only. As with all guidance, this document is not prescriptive and is intended to give advice not to set a mandatory standard for the Light Rail sector, and it is based upon goal setting principles as good practice.

1.3. Much of this guidance is based on the experience gained from good practice from existing UK Light Rail systems and other related industries and published documents. It does not prescribe or endorse particular arrangements adopted by any existing UK Light Rail system and is intended to give guidance and advice.

1.4. This guidance is not intended to be applied retrospectively to existing Light Rail systems. However, owners and operators should consider and assess any implementation of this guidance and / or any subsequent revision to ensure continual improvement in reducing risks, so far as is reasonably practicable.

2. Scope

2.1 It is important to acknowledge that for Light Rail networks, the driver is the key risk mitigator in relation to incidents of overspeeding.

2.2 A suite of controls should be used to minimise the likelihood of overspeeding. These include the following:

- Route knowledge training for drivers;
- Implementation of step-down speeds;
- Signage; and
- Automatic Vehicle Speed Management Systems (AVSMS).

2.3 This guidance has been produced for the UK Light Rail sector following the RAIB report into the Sandilands accident in 2016[1], and includes and is informed by independent research carried out on behalf of LRSSB into systems available and their technical attributes[2].

2.4 In order to reduce the likelihood of a serious accident being incurred as a result of a vehicle overturn or derailment, LRSSB have published two guidance documents: LRG 17.0 Driver Inattention Systems Guidance and LRG 18.0 Speed Management Systems Guidance.

2.5 With regard to AVSMS, Recommendation 3 in the RAIB report explicitly states the following:

> *"UK tram operators, owners and infrastructure managers should work together to review, develop, and provide a programme for installing suitable measures to automatically reduce tram speeds if they approach higher risk locations at speeds which could result in derailment or overturning."*

2.6 This document relates to automatic vehicle speed management and covers the different approaches to AVSMS to deliver the minimum requirements to address this RAIB Recommendation and discusses additional benefits and considerations associated with AVSMS. This technological approach is intended to automatically regulate the speed of a vehicle if overspeed is detected.

2.7 This guidance is not intended to recommend any particular AVSMS or type of system that should be used, and does not cater for individual differences between UK Light Rail networks. Each duty holder should use this guidance to help identify an approach to AVSMS that will reduce risks on their network to as low as reasonably practical (ALARP) reflecting the particular characteristics of the vehicles, infrastructure and operational limitations.

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1 Overturning of a tram at Sandilands junction, Croydon (9 November 2016): https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/931905/R182017_201022_Sandilands_v2.2.pdf
2 Automatic Vehicle Speed Management System Trials. Issue 1 (May 2021) (Ian Rowe Associates): https://resources.lrssb.org/download/automatic-vehicle-speed-management-system-trials

2.8 It is important to note that no single approach provides a comprehensive solution to driver inattention and / or vehicle overspeed in isolation. However, the joint implementation of both systems acting in synergy delivers a significant reduction in risk.

3. Approach

3.1 This guidance has been informed by independent research and system trials conducted on behalf of LRSSB. The details of research and trials are available in the AVSMS Trials Report.

3.2 The AVSMSs currently available fall mainly into two distinct approaches with their own benefits and dis-benefits. The two approaches are as follows:

- Location-specific speed management using trackside-based technology (using beacons or balises); and
- Continuous speed management using GPS (global positioning system) / odometer-based systems.

3.3 This document describes the above approaches, the likely benefits and dis-benefits for both and lists considerations that should be taken into account when selecting an AVSMS.

Location Specific – Beacon / Balise Based Systems

3.4 The basic principle of this approach is that these systems rely on a physical beacon or balise mounted on the track which is read by a transponder or receiver mounted beneath each vehicle. This is connected to a processing unit that in turn is connected to the on-board vehicle speed monitoring equipment.

3.5 The beacon contains information about the controlled speed restriction. When the vehicle passes over the beacon, this information is read and compared with the current speed of the vehicle. If the vehicle speed is in excess of the permitted speed, the AVSMS produces an output. This can be used to produce a driver assistance warning for minor overspeed and / or automatically apply the vehicle brakes for greater overspeed occurrences.

Continuous – GPS / Odometer Based Systems

3.6 The basic principle of operation of this approach is that these systems provide constant monitoring of vehicle speed and current speed restriction. This is achieved by determining the current vehicle location based on the distance from the last verified anchor point, route and looking up the associated speed restriction from an on-board database, and comparing this against the current vehicle speed, then reacting if the vehicle speed is in excess of the permitted speed.

3.7 The reaction of the system can be driver assistance in nature (for example, audio alert, visual alert etc.) or may be connected to the vehicle braking system with the brakes being automatically applied.

3.8 The reaction may also be an audio / visual alert for minor overspeed occurrences with brake application for greater overspeed occurrences.

System Approach Benefits and Disbenefits

3.9 The high-level benefits and disbenefits of each approach as determined by the trials conducted on both AVSMS types are identified below. They should be considered for indication purposes only as specific AVSMS may have different attributes to those involved with the trials.

Location Specific

3.10 The benefits of a location specific approach include the following:

- Established approach used widely in Heavy Rail;
- Location-specific protection offered; and
- Capable of being linked with trackside signalling.

3.11 The disbenefits of a location specific approach include the following:

- System is limited to controlling only specified locations;
- May not be practical to implement temporary speed restrictions (TSRs) or emergency speed restrictions (ESRs);
- System may not be feasible for certain track sections (for example, embedded or unusual track forms);
- Implementation cost is dependent on number of locations covered;
- Some systems require power for beacons which may be impractical in some locations; and
- Requires staff to go trackside to test and maintain balises / beacons.

Continuous Monitoring

3.12 Commercial GPS is not highly accurate and is prone to loss of signal (tunnels, cuttings, proximity to tall buildings etc.). However, if the AVSMS uses GPS with supplementary information, such as wheel turn count, it is possible to achieve highly accurate vehicle location information.

3.13 The benefits of a continuous monitoring approach include the following:

- Every speed restriction on a system can be covered;
- Tolerances for overspeed can be defined for each speed restriction;
- High degree of flexibility, for instance TSRs and ESRs can be easily added and removed;
- Back office functionality can be very comprehensive and provides additional value-added features (for example, speed compliances by driver / location trends, real-time alerts of overspeed events for proactive management etc.);
- No equipment needs to be installed trackside therefore no additional cost incurred and no need for staff to go trackside; and
- System accuracy maximised by use of GPS and wheel turn counting for establishing location.

3.14 The disbenefits of a continuous monitoring approach include the following:

- Emerging technology, it is not well established;
- System accuracy that relies solely on GPS with no supplementary technology may not be accurate or reliable enough to adequately mitigate overspeed likelihood; and
- The amount of data captured can be significant and needs to be managed.

4. AVSMS Considerations

4.1 This section is intended to assist owners, operators and / or infrastructure managers of Light Rail networks in the selection of an AVSMS for their operations.

4.2 Appendix A lists questions that should be satisfied before selecting an AVSMS and an additional comment (where applicable) for each question. These comments have been informed by the AVSMS research and trials.

Safety Integrity Level (SIL)

4.3 Careful consideration should be given to the implications on SIL when fitting an AVSMS. This is generally applicable if the AVSMS automatically applies the vehicle brakes.

4.4 In general, if the AVSMS is integrated into the vehicle braking system, it will require a SIL rating equal to or greater than that of the vehicle braking system to maintain overall SIL.

4.5 However, if the AVSMS is not integrated into the vehicle braking system by use of ‘requesting brake application’ by an existing external mechanism (for example, using the brake loop input), then fitting such a system will not affect the SIL rating of the braking system. In this case the AVSMS does not need to be SIL rated.

4.6 However, it is recommended that even if the AVSMS does not need to be SIL rated, the quality and reliability should be carefully considered. This should be supported with a Failure Mode and Effect Analysis (FMEA).

4.7 In all cases, the selected system should include automatic self-check functionality with appropriate indication if errors are detected. Additional operational procedures may be required to assure continued reliability and AVSMS integrity.

4.8 If the AVSMS applies the vehicle brakes, consideration should be given to the risk of occurrences of ‘false positive’ brake applications, as severe braking can cause harm to passengers in the saloon due to falls.

5. Conclusions

5.1 The system trials for both types of AVSMS have shown a high efficacy of both approaches in management of overspeed occurrences of the type responsible for the accident at Sandilands.

5.2 Therefore, it is concluded that a well-implemented AVSMS utilising either approach may address Recommendation 3 of the RAIB Sandilands Report. However, each network should consider the technical capabilities of the various AVSMSs compatible with their infrastructure and vehicles which will deliver a control arrangement that reduces risks to ALARP.

5.3 From a safety perspective, every speed restriction on the route provides a mitigation of risk. Speed restrictions are set for reasons of compliance, for example, road speed limits, civil engineering (track curvature / cant) or operational safety (securement, stopping distances etc.), etc.

5.4 The location-based systems will only protect speed restrictions where the trackside equipment is fitted.

5.5 Most Light Rail networks have multiple speed restrictions along the route, so it may not be practical to protect all of these using the track-based equipment approach. In this case, a quantified risk assessment shall be used to protect the highest risk locations. This risk assessment should clearly and robustly assess risk across the whole network in order to demonstrate why certain locations are selected and the reasons that others are omitted.

5.6 With a continuous AVSMS, it may be possible and practical to impose a maximum speed profile along the whole route removing the necessity to rank risks mitigated by speed restrictions.

APPENDIX A: AVSMS Considerations

Research and Trial Comment		
Question	**Location Specific**	**Continuous**
System Functionality / Operation		
Does the system reliably monitor and control speed?	It may be necessary to install multiple trackside beacons as there may be read reliability issues when the vehicle passes over the beacon at higher speed.	High accuracy was maintained even when GPS signal was lost or wheel slip / slide experienced.
Can the system be implemented at all necessary locations?	It may not be possible to install beacons in embedded or unusual track forms.	All speed restrictions (SRs) were managed independent of location.
Can step-down speeds be implemented reliably?	To achieve this a beacon (or multiple beacons) may be required for each step-down speed.	Step-down speeds are managed as any other SRs.
Does the system allow speed restrictions to apply at a distance after the beacon position?	It may not be possible or convenient to install trackside equipment at the exact location of the SR. The system in the trial allowed implementation of SRs to be at a distance (programmable by location) from the position of the beacon.	As the continuous approach does not use trackside equipment there is no necessity for this type of requirement.
Is there a requirement for protection at diverging track junctions?	The AVSMS may not be able to manage two different SRs at a diverging junction. However, the AVSMS could be used to protect the junction by setting the SR for both routes at the lower operational SR of the two routes.	The AVSMS is able to manage different speeds at diverging junctions. However, this relies on the appropriate route being selected in the AVSMS. If an incorrect route is selected then the AVSMS would implement SRs based on wheel turns therefore failing to manage SR after the divergence. This could be corrected at the next tramstop where the GPS sample would detect incorrect position. As the AVSMS is not interlocked with the point's control, the junction could be protected by setting the SR for

		both routes at the lower operational SR of the two routes.

Research and Trial Comment		
Question	**Location Specific**	**Continuous**
How does the system manage minor overspeed occurrences?	The AVSMS in the trial provided indication of minor overspeed to the control room only.	Minor overspeed occurrences were communicated to the driver with audio and visual alerts. These were also sent to nominated recipients via SMS in real time.
How are system integrity errors indicated (how and to whom) and what procedure is required to manage these?	Each SR may require multiple beacons to manage step-down speeds. The system can detect any mis-reads in the sequence of expected beacons. These are reported to the control room. An internal maintenance procedure is used to address regular mis-read occurrences.	The AVSMS is dependent on GPS to eliminate cumulative errors for issues such as wheel slip. As the requirement for GPS is not constant (GPS is only required when the vehicle comes to a halt at a tramstop), accuracy was still maintained with a low GPS availability. Tyre wear was automatically compensated for in the AVSMS. Internal system errors detected are reported to the 'back office' utility (can be sent to Control Room / SMS recipient list).
Is management reporting of incidents of overspeed or brake applications required? If so, can the system deliver these in the required time / format?	Brake interventions are reported in real time to the Control Room.	All overspeed occurrences (minor and significant) are sent to the back office at the end of every trip. The AVSMS can be set to alarm automatically and send real-time SMS messages to appropriate recipients (for example, driver managers etc.).
What are the driver interfaces and how could this impact on driver task load?	Human factor issues should be considered. This should include: · The positioning and operation of cab equipment;	

	· Driver task load assessment (to ensure acceptability); and · Impact of additional alarms.	
Is the system susceptible to data integrity breaches (for example, 'hacking')?	Due to the nature of the track-based and vehicle-borne equipment, this risk is unlikely.	Assurance for data protection and data security should be sought.

Research and Trial Comment		
Question	**Location Specific**	**Continuous**
Rolling Stock		
Can the system automatically apply the brakes for occurrences of significant overspeed? If so, is there a requirement for braking to be revoked once permitted speed is reached? Should automatic braking apply the hazard brake or full service brake?	The AVSMS trialled automatically applied the brakes for significant overspeed occurrences. Both were non-revokable. Both AVSMS trialled applied the full service brake. It is recommended that the AVSMS is configured to use full service brake as opposed to hazard brake, as hazard brake application may result in passenger falls in the saloon. In addition, non-revokable brake application is recommended to reduce the likelihood of the driver becoming dependent on the AVSMS for speed control.	
Is there a need for different overspeed tolerances at different locations? If so, can these be defined and implemented in the system?	Each set of beacons would need to be programmed with different tolerances.	Tolerances for each SR could be set up in the topographical data file.
Will the connection of the AVSMS compromise the Safety Integrity Level of	See additional details on safety integrity level (SIL) below.	

any vehicle sub-systems (for example, braking)?		
What are the locations, size and space requirement for vehicle-borne equipment?	A single transponder was fitted to each vehicle in the most convenient location. The 'offset' distance from the ends of the vehicle was managed by the on-board software.	GPS antenna location is critical. The AVSMS required an antenna to be fitted above both cabs. A small processor unit was fitted in both cabs with a small touch screen to interface with the driver. Existing GPS antenna cannot normally be shared.
What the requirements are for power/cabling of vehicle-borne equipment?	The following connections were required for the AVSMS trialled: · 24V PSU; · Cab active signal; · Connection to braking system; · Appropriate ground / earth connection; and · Two independent speed probes.	The following connections were required for the AVSMS trialled: · 24V PSU connection; · Cab active signal; · Connection to braking system; · Appropriate ground / earth connection; and · Systems making use of odometer information also need this connection direct from odometer.
Research and Trial Comment		
Question	**Location Specific**	**Continuous**
If operating a mixed fleet, can vehicle-borne equipment be fitted in the same location on all vehicle types or, if not, can the AVSMS manage the positional discrepancies to provide consistent performance?	The AVSMS trialled uses a distance offset in the processing software to manage this.	The AVSMS would be able to manage different mounting of GPS antenna using the topographical information.
Is accurate wheel diameter data required to provide system accuracy?	Accurate wheel diameter for each vehicle is required to enable the AVSMS accurately to determine distance travelled after reading beacon. However, it has been determined that minor inaccuracies in wheel diameter resulted in only small inaccuracies in vehicle position.	The AVSMS does require wheel diameter information. However, the system calculates wheel diameter automatically using GPS / wheel turn triangulation so approximate wheel diameter can be used initially. System accuracy will then improve with usage.

Is the AVSMS equipment vulnerable to EMC issues / EMC tolerant?	Equipment is designed to comply with EMC requirements.	Equipment is designed to comply with EMC requirements. No EMC issues were encountered during the trial.
Is a connection between cabs (for example, ethernet) needed for system communication?	The AVSMS in the trial did not require a direct connection between cabs, but equipment in both cabs did require connection to a central processor unit.	A direct odometer feed required for system accuracy was only available in one cab. The equipment in the other cab was connected via an ethernet cable. This was installed with existing cable runs between cabs. The cab active signal was also required by processor units in both cabs.
Infrastructure		
Does trackside equipment require power?	The AVSMS in the trial used passive RFID beacons that do not require power.	No trackside equipment is required for this type of AVSMS.
Is the trackside equipment vulnerable to vandalism or other damage?	The RFID beacons are heavy duty and robust. Beacons are bolted to sleepers. Vandalism or theft is possible. Damage to beacons has been caused by Road Rail Vehicles.	No trackside equipment is required for this type of AVSMS.
Research and Trial Comment		
Question	**Location Specific**	**Continuous**
Are there any high-risk locations on or near single-line / bi-directional line sections?	Controlled SRs on single-line sections required additional beacons and additional system programming such that vehicle direction of travel could be accommodated.	Different SRs based on direction can be managed by the AVSMS.
Is there a requirement to implement TSRs / ESRs with the AVSMS?	TSR / ESR can be managed, but this requires installation of additional beacons at appropriate locations.	TSR / ESR information can be added to the topography data and automatically updated to each vehicle when required in real time via 4G.
Is speed protection required at locations where there are occurrences of diverging junctions on the same route where SRs differ after the points? For	An operational workaround may be required to manage this arrangement.	

example, where the track runs parallel through multi- platform stops.	