Evaluating technological solutions to support driver only operation train dispatch

RESEARCH AND DEVELOPMENT

Copyright

Written by: Nicholas Taylor, TRL Ltd

Published: March 2015

Evaluating technological solutions to support driver only operation train dispatch

Executive summary

Driver only operation (passenger) (DOO(P)) means that an on-train guard is not required to dispatch the train. The McNulty report proposed that savings may be achieved through the increased use of DOO(P) across the passenger network.

Through a review of literature, station observations and consultation with industry stakeholders, this research analyses the human factors, risks, costs and benefits associated with the following DOO(P) technologies and practices:

1. Driver look-back
2. Platform-mounted look-back mirrors
3. Train-mounted look-back mirrors
4. CCTV with platform-mounted cameras and monitors
5. CCTV system with platform cameras transmitting to in-cab monitors
6. CCTV system with train-mounted cameras and in-cab monitors
7. Platform dispatch staff

It would be preferable to implement the same technology along an entire route to minimise costs, the workload on the driver and the potential for human error that could arise from a driver performing a variety of dispatch methods. This may not always be possible or cost effective given the varying risk levels at each platform. Risk levels will depend on factors such as platform features, rolling stock, driver behaviour and passenger behaviour and flow.

Similarly, in theory it may be cost effective to have on-board cameras and in-cab monitors to ensure maximum reliability, consistent, familiar images and reduced risk of impaired visual coverage due to vandalism, driver position or adverse weather. In reality, the ergonomic practicalities and potential costs associated with retrofitting trains with in-cab monitors may not be reasonably practicable. The costs associated with retrofitting trains seem relatively high compared with platform-mounted equipment. However, platform-mounted equipment must be replicated at each stopping point to ensure drivers have full visibility of the train and platform regardless of the train class they are operating and they are likely to incur higher maintenance costs.

It may be most effective to phase in the use of on-board DOO(P) technologies by ensuring all new vehicles are fully equipped for DOO(P), where practicable older classes of trains are retrofitted and platform-mounted equipment implemented where retrofit is not technically or economically feasible. Appropriate cost effective technologies should be primarily identified through thorough platform assessments to ensure the risks associated with the individual platforms are reduced as low as reasonably practicable. Once identified, the success of reducing the risk of the undesired events relies on effective implementation of the primary and supplementary technologies and appropriate systems including safety documentation, training, communication, reporting and monitoring. Once implemented the technologies should be monitored, their performance measured and the equipment maintained (periodically and as emergency response) to ensure continued safe dispatch of trains using DOO(P). It is important that there are well documented and implemented procedures for maintenance, daily and periodic checks, fault reporting and emergency response. Each platform or route must also have a contingency plan if technology fails or if the visual coverage of the train is impaired. This will ensure business continuity with minimised disruption and dispatch delay.

The net present value (NPV) and payback periods of implementing DOO(P) are heavily dependent on the implementation strategy. In purely financial terms adopting a strategy of completely eliminating the traditional role of the guard delivers greatest benefit, whilst adopting a strategy of natural wastage and redeployment of guards delivers a reduced, but still positive NPV, over a 20-year analysis period. A more detailed analysis of the business case at a franchise level demonstrates the need for a strategic approach to the further rollout of DOO(P) by prioritising franchises and routes which can deliver the greatest return on investment.

Contents

Evaluating technological solutions to support driver only operation train dispatch

1 Introduction

1.1 Background

Driver only operation (passenger) (DOO(P)) means that an on-train guard is not required to dispatch the train. Train dispatch is managed by the driver with or without the assistance of platform staff. In general, the desirable outcome is that assistance from platform staff is not required but may be provided where a risk analysis has shown it to be necessary.

The McNulty Report recommends that 'the default position for all services on the GB rail network should be driver only operation (DOO) with a second member of train crew only being provided where there is a commercial, technical or other imperative.' McNulty estimates that approximately 30 % of services on the GB rail network are currently provided by DOO(P) and that savings may be achieved through increased use of DOO(P) across the passenger network.

This project has been commissioned by RSSB to determine how DOO(P) could be implemented across the remaining 70 % of the passenger network cost effectively, without compromising current operational safety standards.

1.2 Purpose and scope

This project aims to identify and review the current and emerging technologies that have been, or can be implemented to ensure safe DOO(P) train dispatch. The review includes the analysis of human factors, costs and benefits, safety considerations and risks associated with each of the identified technologies.

In addition, the project outlines a cost effective strategy, developed in consultation with industry stakeholders for rolling out DOO(P) across the GB passenger rail network without compromising operational safety or driver and passenger health.

1.3 Structure of this report

Section 2 details the methodology and provides an overview of what was undertaken as part of the review.

Section 3 provides a review of current and new DOO(P) technologies.

Sections 4 and 5 provide the human factors analysis and the safety and risk analysis for each of the identified technologies.

Section 6 discusses considerations for implementing DOO(P) more widely across the GB network.

Section 7 discusses the costs and benefits associated with DOO(P) implementation and the costs associated with the identified technologies.

Section 8 outlines a strategy for rolling DOO(P) out across the GB rail network. The strategy is informed by the findings of this research and Section 9 provides conclusions of this report.

2 Methodology

2.1 Literature review

The aim of the literature review was to gather and review relevant literature, industry guidance, standards and manufacturers literature relating to DOO and DOO(P) technologies. The search and review included both implemented and emerging technologies across the UK and the rest of Europe. Literature gathered was reviewed and fed into the identification, review and analysis of DOO(P) technologies.

2.2 Stakeholder interviews

The aim of stakeholder interviews was to understand how DOO(P) has been implemented, the practicalities of implementation and the potential barriers and solutions to expanding DOO(P) across the network. A topic guide was developed to include DOO(P) operations and technologies, potential staff impacts, safety benefits and concerns, human factors, lessons learned and costs. It was designed with a view to leading a discussion rather than rigidly structuring an interview. All train operating companies (TOCs), Rolling rtock operating companies (ROSCOs) and Network Rail were contacted regarding participating in the research. Limited responses resulted in 7 face to face interviews being conducted with four TOCs, two ROSCOs and Network Rail. The interview schedule and topic guide can be seen in Appendices A and B. In addition, manufacturers including Petards, Hima-Sella, 21st Century Rail, Rail and Road Protec and telent were also contacted regarding existing and emerging technologies.

2.3 Station observations

The purpose of observing stations, in particular platform operations was to observe DOO(P) train dispatch in practice and see how different technologies have been implemented. During observations, human factors' issues and foreseeable hazards were identified to inform the review and analyses of the technologies. A total of 9 stations were observed. These were:

- City Thameslink
- East Croydon
- Farringdon
- Balcombe
- Streatham Common
- Wandsworth Common
- Forres
- Bathgate
- Perth

The observation schedule can be seen in Appendix A.

2.4 Review and analysis

All literature, information from stakeholder and manufacturer interviews and station observations were collated and fed into the review and analysis of the technologies.

The review involved the identification of implemented and emerging technologies from the UK and the rest of Europe and provided background information to feed into more detailed risk, human factors and cost benefit analyses.

The technical review examined the current systems in use in the UK and elsewhere in the world and how they had been implemented. The review also examined how existing trains and infrastructure may be adapted or converted for DOO(P) equipment and what barriers are in place that have prevented conversion to date.

For the human factors' analysis, the potential for widespread rollout of DOO(P) was examined with regards to changes in the actions, behaviours or working environments of passengers or staff that might affect safety, performance, efficiency or reliability. The analysis considered each of the technologies as well as generic human factors issues that should be considered when implementing DOO(P).

The aim of the risk analysis was to identify key hazards or undesired events associated with using DOO(P) for train dispatch and determine whether the identified and/or implemented technologies effectively reduce the risk of the undesired events and in what circumstances. Through the analysis of identified hazards for each technology, key features required for individual platform, station or route assessments were identified.

The aim of the cost benefit analysis was to determine the costs of the various technologies for implementing DOO(P) and compare them with the benefits, both monetised and non-monetised, for the various methods of operating DOO(P). The analysis enables the financial implications of DOO(P) rollout to be understood so cost effective solutions are implemented to mitigate the identified risk and human factor concerns.

The analyses were then combined with the learning from the literature review, stakeholder consultation and observations to draw conclusions regarding the roll out of DOO(P) across the GB network to feed into the industry stakeholder workshop.

3 Review of current and new DOO(P) technologies

3.1 Background to DOO(P)

On the mainline railway, by the 1980s, technology adoption and station design had reached the point where DOO(P) could be used on some suburban routes. It was first used on the St Pancras to Bedford line in 1985, albeit after long negotiations with unions. London Underground (LU) has used DOO(P) for many years (where it is called 'One Person Operation' (OPO)) and has focused on ensuring passenger safety during dispatch, in particular passengers being trapped in doors or falling between the platform and train.

New rolling stock in GB, and increasingly across Europe, is now equipped for DOO(P) with CCTV cameras fitted on the body sides of trains linked to monitors within the driver's cab. Retrofitting older rolling stock with similar equipment is not always practicable due to lack of available space within the driver's cab. Rolling stock, route conditions, platform layout and passenger volumes vary across the GB rail network and between TOCs meaning it is essential to consider these variances when identifying cost effective technologies to ensure continued safe passenger train operation with the required vigilance when implementing DOO(P) across the rail network. The technology for DOO(P) primarily consists of CCTV cameras either fitted on the body-sides of trains or on platforms and monitors either in the driver's cab or on the platform. Non-electronic systems use mirrors on the platform or, in some European countries, folding rear-view mirrors on trains.

3.2 Regulations and stakeholder requirements for DOO(P)

Implementing DOO(P) across the GB rail network is likely to be considered a 'significant' change to operations, therefore requiring the application of the Common Safety Method on Risk Evaluation and Assessment (CSM REA). This will require a hazard by hazard close out argument to be completed against one of the three acceptance principles: codes of practice, reference systems and/or explicit risk estimation.

RIS-3703-TOM (RSSB 2011) is the rail industry standard for passenger train dispatch and platform safety. There is already a requirement to include factors such as infrastructure, platform layout and use, trains and platform users within the train dispatch risk assessment. There is also a requirement that the platform staff responsible for pre-dispatch safety checks are able to achieve a view of the full length of the train or platform; the gap between the train and platform; at least 1500 mm of the platform from the platform edge and at least the height of the doors. It is likely that this standard should also be applied to views from train-mounted cameras and other DOO(P) technologies.

In a letter to ScotRail, based on an independent review undertaken for Railway Safety in 2000-2001, RSSB (2010a) said:

> *'Overall…there is no safety reason for excluding further applications of driver only operation provided that, in summary:*
>
> - *The operator identifies all the hazards arising in the circumstances of his operation, undertakes a thorough risk assessment, and ensures that the risk controls fully reflect the hazards and the risk that derives from them;*
> - *The risk controls are properly managed in practice;*
> - *Comparative safety performance is carefully monitored on a suitably normalised basis;*
> - *The operating arrangements are continually improved whenever reasonably practicable.'*

In addition to this, the Office for Rail Regulation (ORR) has identified the following high-level requirements for train operators to ensure the safe operation of DOO(P) trains (ORR 2008):

- Provide equipment and procedures for safe and reliable means of train dispatch
- Make sure that the driver's cab is suitable for driver only operation and take full account of the interface between equipment and the driver
- Consider and make arrangements for dealing with particular problems at certain stations, for example curved or narrow platforms, shadow caused by canopies or foliage

- Make effective arrangements for train protection in an emergency, particularly in single bore tunnels
- Make available secure cab radio systems for the driver and signaller to communicate securely and directly
- Have suitable procedures in place for evacuation in an emergency
- Have effective arrangements for the maintenance of platform and driver only operation equipment.

Meeting these requirements for new rolling stock will be simplified through the application of Rail Industry Standard RIS-2703-RST (draft) which has the *'intention of assuring that future Driver Only Operated On-train Camera Monitor (OTCM) Systems are consistently designed and that trains so fitted are readily useable on different routes and by different operators'* (RSSB 2013c).

During consultations conducted for this research, stakeholders emphasised the requirement for a driver to look back along the platform during the train's dwell time to ensure that nothing is trapped in the train doors before dispatch. It was felt that this would be most cost effectively conducted through body-side mounted 'look-back' cameras on trains, with minimal platform equipment being installed due to the cost of installation, maintenance, vandalism and potential weather damage. In addition to this, station lighting would need to ensure that there is adequate visibility of the platform at all times that trains are running. Stakeholders consulted felt that risks associated with DOO(P) could be minimised through the implementation of the following additional technologies and systems:

- Driver's reminder appliance (DRA) – a device operated by the driver when the train stops which must be reset before power can be applied, acting as a reminder to check the signal aspect before proceeding
- Correct side door enable (CSDE) and selective door opening (SDO)
- Automated announcements
- In- train CCTV and on-train monitoring recorders (OTMR)
- Front-mounted forward facing cameras to verify driver statements regarding events such as suicides, trespass and signal aspects
- Central control and track occupation indications for signalling
- Radio connected to the train's PA system to allow the signaller to communicate directly with passengers if the driver is disabled

3.3 Prevalence of DOO(P) on the GB rail network

RSSB's research project T743 (2009) reviewed passenger dispatch at a number of stations across GB. Table1, taken from the report, shows that in 2007 DOO(P) is used at 28 % of stations. Table 2 shows that in terms of passengers the proportion is greater at 38 %. These are the most recent data available. Through consultation with stakeholders it is clear that this percentage may be greater since some TOCs only operate passenger trains using DOO, for example C2C (Essex Thameside) and First Capital Connect (now the Govia Thameslink Railway). Other TOCs have a percentage of their trains operating using DOO, for example Southern, Greater Anglia and ScotRail. DOO(P) tends not to be used on services where minor stations are unstaffed or do not have ticket gates, therefore still requiring a conductor to issue and check tickets. The conductor is used to provide door closure and train dispatch. On some trains, the conductor is also required to actuate door release or door opening. DOO(P) is most prevalent on busier commuter lines with ticket gates, in particular lines in the London metropolitan area. In these areas the trains do not carry on-board conductors for ticket examination.

Table 1 - Dispatch method by station

	Number of sampled stations using dispatch method	% of sampled stations using dispatch method
Stations with driver/guard self-dispatch	1061	71 %
Stations with driver only operation	355	23 %
Stations with driver/ guard/platform staff	201	13 %
Stations with DOO with platform staff	75	5 %
Total number of stations in sample	1518	100 %

Source: 12 TOCs (2007) – percentages sum to more than 100 % since some stations use more than one method

Table 2 - Passengers dispatched by each method per year

	Number of passengers dispatched (thousands)	% of passengers dispatched
Total passengers by driver/guard self-dispatch	686,069	39 %
Total passengers by driver only operation	491,525	28 %
Total passengers by driver/guard/platform staff	407,112	23 %
Total passengers by DOO with platform staff	177,046	10 %
Total passengers	1,761,752	100 %

Source: Figures based on station entry/exit and interchanged 2006/2007 data (ORR)

3.4 DOO(P) technologies

3.4.1 Overview

Historically, when a train pulled into a station the passenger train interface was policed by the platform dispatch staff and the train guard. These operatives would typically carry whistles and a flag, which they would use to signal the 'all clear' to the driver, indicating that it was safe to depart. A desire to reduce operating costs has led to firstly, the de-staffing of lightly used stations where the train guard or conductor is now usually solely responsible for train dispatch and secondly, the introduction of DOO(P) where the dispatch process is solely the responsibility of the train driver. Removing or changing the role of the guard and general de-staffing of stations has transferred the responsibility for checking that it is safe for the train to depart onto the driver. The essential function of DOO(P) technologies and systems is to enable drivers to control the release and closure of passenger doors and to have full visibility of the platform and train to ensure safe dispatch. Systems like interlocks to detect when doors are not fully closed, signage to assist in vehicle/platform alignment, and selective and correct-side door enabling can enhance safety, but ultimately it is adequate surveillance by the train driver that has to be achieved to ensure the risk of events such as a person or object becoming trapped in the train doors, or a train being dispatched with a passenger in a high risk zone can be reduced as low as reasonably practicable.

The key DOO(P) technologies and practices for platform and train surveillance, identified through the review of literature, consultation and observations are:

1. Driver look-back
2. Platform-mounted look-back mirrors
3. Train-mounted look-back mirrors
4. CCTV with platform-mounted cameras and monitors
5. CCTV system with platform cameras transmitting to in-cab monitors
6. CCTV system with train-mounted cameras and in-cab monitors
7. Platform dispatch staff

These technologies and practices are analysed from a human factors and risk perspective in sections 4 and 5 respectively.

3.4.2 Europe

Observations made in Paris, Switzerland, Austria and Germany and consultation with European manufacturers has led to the conclusion that GB DOO technology is mature and that GB railways are ahead of the rest of Europe in terms of the development and implementation of DOO(P) technologies. In addition, as DOO equipment suppliers are typically international, there is little difference in the availability of technology across Europe as a whole. Therefore the findings from this research regarding DOO technologies should be valid across Europe.

3.4.3 Emerging technologies

The key concerns with DOO(P) raised by TOCs during consultation were the cost and practicability of retrofitting existing rolling stock. The work required will vary from stock to stock. Many of the existing fleets do not have door controls located where they can be easily reached by the driver (such s the Class 170 DMUs). If the driver has to leave his/her seat to operate a door control, the dwell times will be extended and the risks associated with train dispatch potentially increased.

The 2 issues with retrofitting rolling stock with train-mounted cameras and in-cab monitors are: firstly the complexity of rewiring the train to install synchronised cameras and monitors; and secondly the available space in cabs to install the monitors. There is limited scope to increase the available space within the cab on some classes of train but eyeTrain (2012) offers cameras that communicate images wirelessly, therefore avoiding the complex wiring issues between cars. Figure 1 demonstrates this concept.

Figure 1 - R2P DOO(P) cab-side-mounted camera, Southern class 377, eyeTrain image

Historically, Network Rail commissioned optical placement reports to be conducted to determine the correct number and positioning of cameras and monitors. The transfer of the findings from these reports to the platforms often achieved a positional success rate of only 60 %. This led to re-visits and further re-positioning of cameras. Modern auto-iris cameras with adjustable but lockable tilt and zoom systems have resolved such positional issues. Similarly problems with images and visibility due to lighting variance and screen burn have also been resolved through improved platform lighting standards and the use of LCD monitor technology.

From consultation with manufacturers and literature reviews it has been established that the key area of development is regarding the detection of objects that have fallen onto the track rather than new equipment for platform and train surveillance. Systems proposed or implemented include:

- Stereoscopic cameras and smart software to detect an incident and automatically raise an alarm and communicate with staff or train drivers (Oh et al 2008)
- Lidar or sonar systems that use light beams or sound waves respectively to detect fallen objects. 'Coppilot', produced by French company Fersil (Clerarsy), uses laser scanners to detect anomalies in the gap zone between the platform doors and the train (Fersil 2014)
- Microwave radar delivered by a slotted waveguide placed just below the platform edge to give coverage over an extended distance (Mroué et al 2013)

To assist in implementing effectively sighted platform DOO(P) technologies such as CCTV cameras and mirrors, telent (2013) markets a software-based desktop modelling package that allows driver sightlines at different platforms to be modelled.

4 Human factors analysis

This section considers only the issues specific to the various DOO technologies and practices under review. A more general consideration of human factors' issues related to implementation of DOO is presented in Section 6.1.

4.1 Driver look-back

This method requires the driver to look out of his/her window to view back down the platform, or potentially to leave the cab and step onto the platform if the view would otherwise be impeded (eg by passengers or platform design). Driver look-back was universally regarded as the least-preferred option during discussions with TOCs. Requiring the driver to open a window and look back down the platform raises the potential for musculoskeletal injury caused by a one-off over exertion (particularly on some older stock with stiffer window mechanisms) or through repetitive strain.

Look-back provides a limited view of the platform for the driver to assess the situation. Indeed, if there is any appreciable curvature to the platform edge the driver's view may be impeded or blocked entirely. Similarly, the driver's view may be restricted if there is crowding on the platform or obstructions from the station architecture. Figure 2 shows the platform at Farringdon, where it can be clearly seen that both the platform curvature and the station architecture make the use of look-back ineffective at this location.

Figure 2 - Platform at Farringdon, where platform curvature and station architecture makes driver look-back impossible

Driver look-back would therefore be usable principally on more rural routes where platforms are straight and passenger numbers are typically low. Even with these requirements met, requiring the driver physically to look out of the window is not ideal due to the increased likelihood of musculoskeletal injury.

DOO(P) requirements for driver look-back:

- Platform should be straight
- Platform should not be prone to overcrowding (assessment required)
- Good lighting levels
- Driving cab designed for frequent window openings
- Platform access points clearly visible to driver

4.2 Platform-mounted look-back mirrors

This method requires the driver to stop at a pre-determined location, where a platform-mounted mirror is provided that allows the driver to look out of the cab front or side window and see along the platform. Platform mirrors offer a potential benefit over driver look-back in that the driver is not faced with the same physical demands of opening a window and potentially straining his/her neck looking out of the train. Mirrors are however limited similarly by the restriction on available viewing angle and the corresponding issues posed by platform shape and architecture. The mirrors also place an additional demand on the driver to stop at the correct location in order for the mirror to be visible and provide the required view. The use of a mirror may make it more difficult to interpret distances or direction (due to the reversal of the image in the mirror). Mirrors may also be vandalised or otherwise deteriorate, which would require the driver to seek an alternative means of checking the platform-train interface.

Figure 3 - Examples of platform mirrors, showing driver views at Balcombe (left) and Wandsworth Common (right)

Figure 3 shows 2 examples of typical driver views using platform mirrors. The left-hand picture is taken from Balcombe, where a number of platform design issues were seen that suggest the use of platform mirrors may not be totally desirable:

- For 12-car trains the driver is required to stop with the driving cab inside a tunnel, from which the driver has a severely restricted view of the platform (there is no provision of a mirror at this stopping point, requiring the driver to look back)
- Even if the driver is able to stop in position to use the platform mirrors, the steps leading to the platform emerge directly behind an on-platform waiting shelter. From discussions with Southern staff, this is a known source

of dispatch risk, as people may rush to catch a train and not be seen until the last moment

- On the Up line the passenger access point is at the opposite end of the platform to the driver, thus meaning late arrivals are a significant distance from the driver and partly obscured by building and bridge structures

These observations highlight the potential difficulties in rolling out either driver look-back or mirrors as a standardised operating procedure for DOO(P), as similar restrictions on the driver's view are likely to exist at a significant number of stations on the network.

DOO(P) requirements for platform mirrors:

- Platform should be straight
- Platform should not be prone to overcrowding (assessment required)
- Good lighting levels
- Platform access points clearly visible to driver
- Regular maintenance to ensure mirror kept clear of vegetation/ damage
- Driving cab with good side views

4.3 Train-mounted look-back mirrors

This system operates in broadly the same manner as the platform mirrors, except that the mirrors are physically attached to the train. Typically the mirrors fold away when the vehicle is travelling between stops in order to prevent them colliding with a person or structure. Specific advantages over platform mirrors are that they offer the driver a consistent view of the length of the train, regardless of where the driver stops, and cannot be directly blocked from the driver's view by passengers standing on the platform (although sightlines may still be obstructed). Train-mounted mirrors are also less likely to suffer from vandalism and any maintenance that is required can, in theory, be identified and rectified before the train is put into service.

Possible disadvantages compared with platform mirrors relate to the size restrictions of vehicle-mounted mirrors. This will likely restrict the viewing angle and/or image size available to the driver. There is also limited scope to alter the viewing angle to suit particular station/platform characteristics. Due to their small size, there are likely to be restrictions on train length when using this solution. In Europe they are common on tramcars but observation suggests train length is restricted to 4-cars.

Figure 4 shows an example of a train-mounted mirror. The DMU railcar depicted comprises of 2 semi-permanently coupled cars. The driver's cabs (one at either end) are fitted with exterior, truck type rear-vision mirrors located one on either side of the cabin. These protrude about 25mm outside of the vehicle maximum width dimension when mirrors are deployed to the normal extent required for operation. In this position, the mirrors projection over the platform edge is minimal. This minimal degree of overhang beyond the relevant rolling stock and infrastructure maximum outlines is permitted (Rail Safety Investigation No 2008/ 2009).

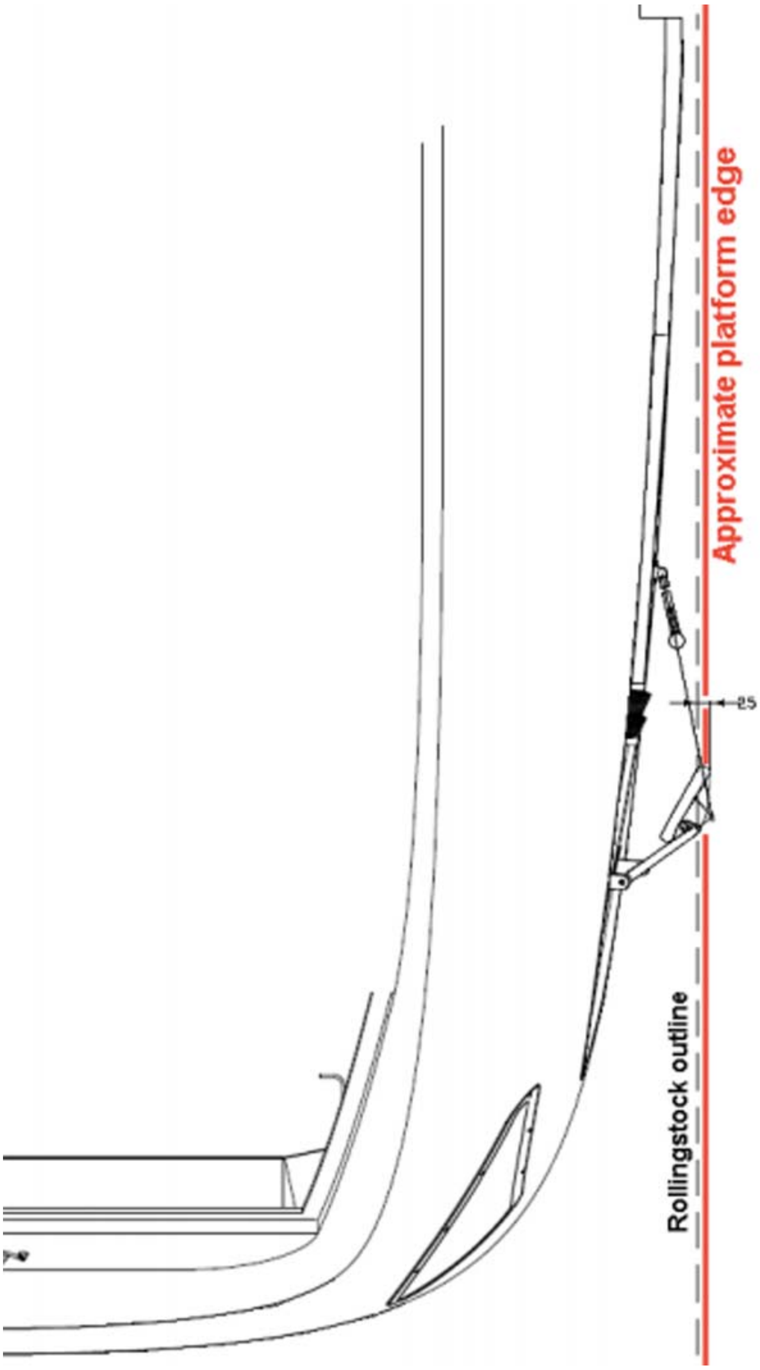
Fitting look-back mirrors to existing trains requires a solution to be developed for each type of stock. The fitting will depend on the body shape around the cab area (see Figure 4 which shows a possible solution for a suitably shaped train end), the internal structure of the car body, the material available for securing the mirror structure, the space available for operating motors (if required) and the sightlines. Operating controls will also be required. It is likely to be considered necessary to fit heated mirrors to prevent freezing and condensation problems.

Due to train-mounted mirrors' similarity with platform mirrors, the DOO(P) requirements are broadly similar.

DOO(P) requirements for train-mounted look-back mirrors:

- Platform should be straight
- Platform should not be prone to overcrowding (assessment required)
- Good lighting levels
- Platform access points clearly visible to driver
- Regular maintenance to ensure mirror kept in good condition
- Driving cab optimised to allow the driver good view of mirror (and thus platform) from the driver's seated position

Figure 4 - Sample drawing of the location of the train driver's wing mirror on the Australian VLocity DMU railcar



4.4 CCTV with platform-mounted cameras and monitors

This method uses cameras, typically mounted strategically at various locations on the platform, with their images displayed on a bank of monitors so that a driver can view by looking out of the cab side window. This was generally regarded, based on the interviews, as a robust method of operation. Drawbacks include the potential for vandalism and the separation of installation and maintenance responsibility from the TOCs (at stations owned by Network Rail, management and use of equipment are by two different organisations). Any system requiring the driver to use video monitors also raises the potential for the feed to 'freeze' and the driver to be seeing out-of-date images, which requires additional safety systems to be in place to safeguard against this. Positive feedback from TOCs, however, centre around the principle that multiple cameras allow the driver to see all parts of the platform (provided they are set up effectively) and by mounting the cameras on the platform an ideal viewing angle should be achievable, including raising the cameras well above head height if necessary to counter the possible hindrance of platform crowding.

Figure 5 shows the monitor bank at Farringdon. The view is much more comprehensive than that shown in Figure 2. Figure 5 does however highlight the potential issue of cameras being installed (or later knocked) out of alignment, as the image on the screen second in from the right on the top row appears to show a view primarily of the tracks rather than the platform.

DOO(P) requirements for platform-mounted cameras and monitors:

- Good lighting levels
- Platform access points clearly visible to driver (or support staff if not)
- Assessment of camera positions at installation
- Regular maintenance to ensure screens are kept free of damage and general degradation of imagery, and cameras pointing in correct direction
- Driving cab with good side views

Figure 5 - Platform-mounted monitors at Farringdon

4.5 CCTV system with platform cameras transmitting to in-cab monitor(s)

This method retains the on-platform cameras, but with the images viewed on screen(s) in the cab rather than on platform monitors. In theory this offers the driver the same view as achievable with platform-mounted screens, but with the convenience of having these images in a standardised location within the cab such that the driver is not required to leave his/her seat, and is less likely to be affected by environmental conditions (sun glare, snow, rain, condensation) or from faulty/vandalised equipment. The images can also be checked by the station monitors in the control room. On LU each station is categorised according to whether it is possible for the driver to complete dispatch without functioning monitors and without additional assistance from platform staff.

DOO(P) requirements for platform cameras and in-cab monitors:

- Good lighting levels
- Platform access points clearly visible to driver (or support staff if not)
- Assessment of camera positions at installation
- Regular maintenance to ensure cameras are pointing in correct direction
- Vehicle designed for, or with, in-cab monitors

4.6 CCTV system with train-mounted cameras and in-cab monitor(s)

This method uses fully on-board equipment. Cameras, rather than being mounted strategically on the platform, are instead mounted on the train body-side. This system would appear to offer several benefits. Firstly, by having all the necessary kit mounted on-board the train, it ensures that any technical faults will be identifiable by the driver as soon as they occur, allowing immediate remedial action, and there is a reduced likelihood of vandalism. It also means that responsibility for the equipment is in the hands of the TOC, which would appear to offer advantages of a simpler management system. It is possible that by having a fixed camera and screen setup, the driver may benefit from improved situational awareness as the images presented will always be consistent, regardless of location. The system would also potentially be less susceptible to issues arising out of platform lengthening should longer trains be required to service a route in future, although this may be countered to some extent as the uniform positioning of cameras on each carriage also means that each extra carriage will require an additional camera feed to the driver's in-cab monitor(s), which may restrict the number of carriages that could potentially be deployed at a time.

A potential drawback is that by mounting the cameras on the train itself, there is necessarily a restriction imposed on the freedom to mount cameras in the location most suited to providing the driver with the most useful information at any given location. This may lead to situations where the driver cannot see a critical platform access point, or where passenger crowding impedes the view of the doors. Discussions with the interviewees also revealed some concerns about the visibility of items/persons caught in the doors where the doors are recessed into the train body. In principle this system should serve as a robust method of operations for roll-out across the network, provided that the provision of supporting platform staff are present at stations where there are issues of, for example, overcrowding or where passenger access points are obscured from optimal driver vision.

DOO(P) requirements for on-train cameras and in-cab monitors:

- Good lighting levels
- Vehicle designed for, or with, in-cab monitors
- Platform access points clearly visible to driver (or support staff if not)

4.7 Platform dispatch staff

This method differs from the rest in that it is most likely to be used at specific stations along a route, rather than the previous methods that might be expected to be in operation as standard along a route as a whole. Indeed, platform dispatch staff may be used in conjunction with any of the aforementioned DOO(P) methods. In such cases, the driver would be expected to use the default DOO(P) method except at particular stations where responsibility for checking that the doors are clear and the train is safe to depart is transferred to the platform staff. Other DOO(P) technologies present would therefore be made redundant at those locations. Reasons for doing so relate to several advantages associated with this method of operations.

The primary advantage of using platform staff is that they can be positioned in such a way as to ensure adequate views of the key elements relevant to that station. For example, at East Croydon the platform staff are positioned so that they have good views of the passenger access points, which may be from a flight of steps or emerging from behind a building, and which the driver would otherwise not be able to see. Platform staff are also able to modify their position in response to passenger crowding in order to maintain required sightlines, whereas a system of cameras cannot. Staff would be expected to have greater knowledge of particular nuances of the platform environment and safety concerns particular to that platform.

Disadvantages of platform staff are that introducing more people into the dispatch procedure increases the potential for human error to occur, particularly in the potential for miscommunication between individuals. Indeed, this concern was raised by several participants in the stakeholder interviews. It also means that the driver will not be faced with a consistent method of operation along the route, which could increase the likelihood of confusion over responsibilities. Platform staff are also required to mingle to some extent with passengers on the platform, raising the potential for distraction from the dispatch procedure. Having platform staff requires individuals to be out in a variety of different weather conditions and requires consideration of their comfort and safety. They may also be exposed to personal risk from passengers related to crowding or from working in an isolated location.

DOO(P) requirements for on-train cameras and in-cab monitors:

- Good lighting levels
- Vehicle cab designed to facilitate ease of communication between driver and platform staff
- Sufficient staffing levels to provide sufficient views of key passenger access points to the platform and train boarding points
- Safety procedures to ensure staff comfort and safety
- Training and safe systems of work to ensure effective control of responsibilities

5 Safety and risk analysis

This section considers safety and the risk analysis of DOO(P).

5.1 Undesired events

Key undesired events were determined through the review of relevant literature, in particular the case study in research project T955 *Hazard analysis and risk assessment for rail projects* on the subject of Evaluating the feasibility from a safety perspective of moving from driver-guard operation to driver only operation (passenger trains) on regional routes (2013). The key identified undesired events associated with using DOO(P) for train dispatch are:

UE1 – Signal passed at danger when starting against a signal (SAS-SPAD)

UE2 – Doors closed with person (or object attached to person) not clear

UE3 – Train dispatched with person trapped in the doors

UE4 – Train dispatched with person in high risk position of the dispatch corridor

UE5 – Person returns to train once it has been dispatched

UE6 – Train dispatched with person fallen between train and platform

UE7 – Wrong side door release – doors released off platform

UE8 – Long train at short platform: all doors released, some off platform

UE9 – Person struck by DOO equipment whilst leaning from the train

UE10 – Dispatch delay

UE11 – Driver repeatedly boarding and alighting train

UE12 – Driver falls between platform and train

UE13 – Driver regularly looking back from cab

The key causes of these events have been identified together with the potential outcomes of the undesired event being realised and are detailed in Table C1 in Appendix C.

5.2 Technologies

The technologies identified to eliminate or reduce the risk of an undesired event can be divided into 2 categories:

1. Primary measures which, if implemented in isolation, are likely to directly reduce the risk of an undesired event.
2. Supplementary measures which are measures that can be used to enhance the effectiveness of the primary measures.

Each of the primary and supplementary technologies is either a preventative barrier or a barrier to escalation. The preventative barriers are usually the preferred control measure as they reduce the likelihood of an undesired event being realised whilst a barrier to escalation minimises the consequence severity or outcome of the undesired event once it has occurred. Table 3 provides details of primary and supplementary measures.

Table 3 - Technology initial categorisation

Technology	Primary or supplementary measure	Preventative barrier (P) or barrier to escalation (E)
Driver look-back	Primary	P
Platform-mounted look-back mirrors	Primary	P
Train-mounted look-back mirrors	Primary	P
CCTV system with platform-mounted cameras and monitors	Primary	P
CCTV system with platform cameras transmitting to in-cab monitors	Primary	P
CCTV system with train-mounted cameras and in-cab monitor(s)	Primary	P
Platform dispatch staff	Primary	P & E
Exterior hazard light to indicate doors are closed	Supplementary	E
Interior interlock light in-cab to show doors are locked	Supplementary	E

Table 3 - Technology initial categorisation

Technology	Primary or supplementary measure	Preventative barrier (P) or barrier to escalation (E)
Driver Reminder Appliance (DRA)	Supplementary	P
Train protection and warning system (TPWS)	Supplementary	E
Correct side door enable (CSDE)	Supplementary	P
Hustle alarms	Supplementary	P
Object detection	Supplementary	E
Passenger communication (Pass-com)	Supplementary	E
Extended transmission of platform on in-cab monitor	Supplementary	E

In addition to understanding how the technology may impact on an undesired event, it is important to understand any additional risk that may be posed as a result of implementing the technology or any hazards, circumstances or events that may lead to the technology being less effective. The key considerations when determining the effectiveness of the technology at reducing the risk posed by DOO(P) are:

1. Inability of the driver to see the train and/or platform as a result of permanent or temporary obstructions
2. Quality of images and ability to detect an incident
3. Reliability of technology
4. Driver distraction or human error
5. Driver injury as a result of using the technology

The full list of hazards and the technology they are primarily associated with can be seen in Table C3 in Appendix C.

5.3 Primary technologies

5.3.1 Driver look- back

Driver look-back involves the driver looking back through a cab window or by alighting the train to look back along the length of the train to ensure passengers are clear of doors before closing and to ensure passengers are not in a high risk zone prior to dispatch. This is a primary preventative measure but has limited effectiveness and may give rise to additional, potentially significant hazards. The driver looking back can be effective at reducing the probability of passenger related undesired events occurring for short trains on nearside platforms without curvature. However, as the driver only has visibility from eye level, there is a high probability of sightlines being limited by passengers, obstructions or station furniture in some locations or at peak times. There is also concern for driver health with an increased risk of musculoskeletal injury in particular neck and back injury. The risk of injury would be increased along routes with frequent platforms.

If the driver needs to leave the cab to obtain full visual coverage of the train (eg because of the lack of drop down cab windows, or the presence of offside platforms, or significant platform curvature) there could be additional hazards such as increased risk of driver slips, trip and falls, cab security and delay between safety checks and dispatch requirements.

It is considered that this method of dispatch is most suitable for short term use where other implemented technology has failed, to ensure business continuity and minimal delay. However, it should only be used at identified platforms where the driver has full visibility of the length of the train from the cab window. The effectiveness of this measure can be increased by:

- Conducting a thorough platform assessment along the route to ensure all look-back requirements are met
- Conduct driver health surveys with assessment and training

5.3.2 Platform-mounted look-back mirrors

The purpose of platform-mounted mirrors is to provide platform surveillance to the driver without the need to perform look- back from the cab window. It is a primary, preventative measure and aims, through allowing full visual coverage of the train, to reduce the probability of the doors trapping a passenger or a train being dispatched with someone in a ‘high risk’ zone (ie trapped in the doors, in close proximity to the train being dispatched or fallen onto the track). The effectiveness of platform-mounted mirrors depends on the degree to which the platform and train are visible to the driver. Adequate visibility will depend on factors such as platform curvature, length of train, infrastructure and platform furniture, crowding on platform and the condition of the mirrors. Mirrors need to be positioned to ensure optimum visibility whilst not increasing the risk of driver musculoskeletal injury. Stop boards would be needed to ensure drivers stop in the optimum location and mirrors would need to be duplicated at each stopping location. The effectiveness of look-back mirrors mounted on the platform can be optimised by:

- Conducting a thorough platform assessment
- Correct positioning and regular checks of mirrors and stop boards
- Periodic and emergency maintenance plans
- Contingency plans to ensure business continuity

5.3.3 Train- mounted look-back mirrors

The purpose of train-mounted look-back mirrors is to provide platform surveillance to the driver without the need to perform look-back and to eliminate the need for platform-mounted technologies. Cab-mounted mirrors are a primary preventative measure and aim to provide the driver with a consistent view of the train to prevent the doors trapping a passenger or the train being dispatched with a passenger in a ‘high risk’ zone. Cab-mounted mirrors are more likely to be positioned ergonomically and optimally for that train than platform-mounted mirrors, and are likely to require less emergency maintenance due to vandalism, adverse weather or faults only identified once the train is at the platform. However, visibility of the length of the train could be impaired by a curved platform, adverse weather, additional carriages or passengers obscuring the driver’s sight line. Train length will also be a restricting factor. Consideration must also be given to the potential increased risk of collision with infrastructure when the train is moving due to the structure gauge. It must be noted that train-mounted look-back mirrors are most commonly used in Europe where the gauge allows for the additional train width. Some systems are designed to retract automatically when the train is started and the driver is required to deploy the mirrors at the next station stop in conjunction with the door release control.

The effectiveness of cab-mounted look-back mirrors can be optimised by:

- Conducting a thorough assessment of the platforms along the route to ensure cab-mounted mirrors will give full train visibility at all platforms

- Ensure mirrors are folding and fit within the railway gauge
- Pre-service checks to ensure correct positioning of mirrors
- Contingency plans if visibility is impaired to ensure business continuity

5.3.4 CCTV system with platform-mounted cameras and monitors

This is a primary preventative system to ensure appropriate platform and train surveillance to mitigate against key undesired events associated with DOO(P). CCTV cameras and monitors are more likely to provide full visual coverage of the train than mirrors, as cameras can be optimally positioned. Similarly, images on monitors can be as large as necessary to increase the likelihood of undesired events being detected by the driver. With CCTV cameras and monitors positioned on the platform, the system as a whole can be checked for faults prior to service, to minimise the risk of faults being identified during service and causing disruption and dispatch delay.

Stop boards are required to ensure the driver is in the optimal position for viewing the monitors. If a variety of rolling stock is used, monitors might need to be duplicated at each stopping point but efforts are normally made to limit stopping points to one optimum location. The key concern with this measure is monitors (and therefore images) being obscured from the driver by passengers or due to adverse weather.

The effectiveness of platform-mounted CCTV and monitors can be optimised by:

- Conducting a thorough platform assessment
- Correct positioning and regular checks of cameras, monitors and stop boards
- Periodic and emergency maintenance plans
- Contingency plans to ensure business continuity

5.3.5 CCTV system with platform cameras transmitting to in-cab monitors

This is a primary preventative measure to ensure appropriate platform and train surveillance to mitigate against key undesired events associated with DOO(P). CCTV images from optimally positioned platform-mounted cameras are transmitted to an ergonomically positioned in-cab monitor. This has the benefits that full visual coverage is likely due to flexibility in where the cameras can be mounted. Drivers are likely to be more familiar with the consistent visual display within their cab so are more likely to notice abnormal behaviours or undesired events, and the risk of images being obscured by passengers or due to adverse weather is eliminated. However, the system cannot be checked as a whole prior to service, increasing the risk of faults only being identified during service potentially causing dispatch delay. On modern, suitably equipped trains, up to 12 images are displayed on two monitors.

The effectiveness of platform-mounted cameras and in-cab monitors can be increased by:

- Conducting a full platform assessment to ensure full visual coverage of all rolling stock using the platform
- Robust procedure for synchronising and calibrating equipment
- Periodic and emergency maintenance plans
- Contingency plans to ensure business continuity

5.3.6 CCTV system with train-mounted cameras and in-cab monitors

This is a primary preventative system that has cameras fitted to the train and images transmitted to an in-cab CCTV monitor. The aim is to provide full visual coverage of the entire train to minimise the risk of undesired events associated with DOO(P) being realised. It is a closed system meaning that any faults can be identified prior to service minimising the likelihood of faults being identified during service and causing dispatch delay. The system does not rely on short trains or straight platforms to be effective and has the benefit of displaying consistent images, meaning that the driver is more likely to notice undesired or abnormal events.

Project T535 *Assessing the impact of increased numbers of CCTV images on driver only operation of trains* (RSSB, 2005) assessed the impact of increased numbers of CCTV images on DOO trains and concluded that showing 6 images per monitor would not affect the reliability of the driver observing abnormal events. However, the reliability is inversely proportional to the number of carriages and drivers need more time to search for incidents as the number of images increases. The research also conducted driver detection tests when presented with up to 12 images. It found that while reliability of detection falls with the number of images, there was an average 91 % incident detection rate even when the driver is distracted.

This system is likely to be most effectively implemented on new trains where the cab can be ergonomically designed to fit a suitable in-cab monitor. The effectiveness of the system can be maximised by:

- Platform assessments along the route to identify platform hazards and contingency arrangements
- Limiting the number of carriages and therefore number of images required to maximise the likelihood of an incident being detected
- Ensuring pre-service checks are conducted and alignment checks are effective
- Ergonomic assessment on the design of the cab to ensure usability and driver health
- Contingency plans if equipment malfunctions to ensure business continuity along the route

5.3.7 Platform dispatch staff

Using platform or station dispatch staff is a primary preventative measure and a barrier to escalation that involves deploying as many staff as required on a platform to inform the driver when it is safe to close the train doors and depart the platform. Dispatch staff can be easily repositioned to ensure full train visibility and they are likely to have an increased awareness of the hazards on that platform.

However, as the number of staff involved increases, the risk of human error (such as misinterpreting signals, or distraction) is also likely to increase. Staff shortages or delayed staff would also have a significant impact on safety and the risk of dispatch delay. It may be most appropriate to use platform dispatch staff in the following circumstances:

1. If technology has failed, so as to ensure continued safe dispatch and business continuity.
2. On particular platforms, or at identified times of the day, where implemented technologies do not allow full visual coverage of the train.

The effectiveness of this measure can be optimised by:

- Ensuring signs and signals procedures are standardised and universally implemented and understood
- Conducting thorough platform assessment to determine the most suitable technology or method of ensuring safe dispatch under different conditions

5.4 Supplementary technologies

Supplementary technologies are used to 'supplement' primary technologies to further reduce the risk associated with identified undesired events. Object detection and lights to indicate doors are obstructed are a useful final check for drivers once the visual safety checks have been conducted. It also allows any door with an obstruction to be immediately identified, minimising the risk of dispatch delay. However, the literature review showed that reliability is questionable as not all obstructions may be detected. The reliability of these measures must be communicated to drivers and dispatch staff to ensure warning lights are not relied on as a primary measure. Correct side door enable (CSDE) is a useful measure for DOO(P) particularly if there a combination of off side and near side platforms. Hustle alarms warn passengers of an imminent door closure. However, the effectiveness of the measure depends on the passenger response to the alarm and the potential for risk taking behaviour.

With the potential additional workload on drivers during DOO(P) dispatch, it is considered to be more likely that a start signal will be passed at danger. The train protection and warning system (TPWS) and the driver reminder appliance (DRA) can be used to reduce the risk of this undesired event. The DRA is a preventative measure but relies on the driver manually switching setting DRA at a red signal. TPWS reduces the consequence severity of a signal passed at danger (SPAD) by automatically applying emergency brakes if a signal is passed in error. This is likely to be a more effective, reliable measure despite it not minimising the probability of occurrence.

Extended transmission of the platform on the in-cab monitor is currently implemented by LU. It is a supplementary measure to reduce the consequence severity of an undesired event once the train has been dispatched. For example, a passenger trapped in the doors and then dragged by the moving train or a passenger falling between the train and platform once the train is moving. However, it is possible that the driver may be distracted by the transmission of the images and not respond appropriately to hazards ahead. It is important that individual platforms and routes are assessed to determine whether the additional risks posed are acceptable in that location.

The provision of door recycling, sensitive edges and dragging detection for doors are further systems introduced on LU's most recent trains. The recycling allows a single set of doors to recycle when an obstruction is detected during closing. The number and width of reopening is restricted. Its purpose is to give an opportunity for an obstructed doorway to be cleared without the need to reopen all the doors on the whole train. Dragging detection is a response to incidents where a passenger's bag or clothing is trapped in a closed door. The closure is confirmed by the detection circuits so the train is dispatched with the person trapped by a strap or clothing. Dragging detection operates once the train starts to move, where the pressure detected by the door edge activates the emergency braking circuit to stop the train.

Pass-com is also a supplementary measure to reduce consequence severity of undesired events once they have been realised. Pass-com is a passenger alarm that can be activated by a passenger to alert the driver of danger. The effectiveness of the alarm relies on a passenger witnessing an event and activating the alarm, and the driver responding appropriately to the activation. Awareness of the passenger alarm should be raised to passengers and an appropriate driver response plan implemented if the alarm is activated whilst any part of the train is still in the platform.

More detailed information about each primary and supplementary technologies and effectiveness considerations can be seen in Table C2 in Appendix C.

6 Considerations for implementing DOO(P) more widely across the GB network

6.1 Summary of human factors, risk and cost

The following sections outline the key risks and human factors for each of the identified DOO(P) technologies. The approximate cost of each technology is also included. More detailed information can be seen in Table C2 in Appendix C.

6.1.1 Driver look-back

6.1.1.1 Effectiveness considerations (risk and human factors)

- The driver looking back can only be effective for short trains and platforms without curvature.
- Increasingly, drop down windows are not provided on all trains.
- Musculoskeletal injury is a concern particularly on a route with numerous stations.
- The driver only has visibility from eye level meaning that visibility can be obscured by passengers, obstructions or platform furniture.
- Visibility can be reduced during adverse weather.
- The driver can leave the cab to gain increased visibility but this would create a time delay between safety checks and dispatch.

6.1.1.2 Controls to maximise effectiveness

- Station assessment along route.
- Ensure all requirements for look-back are met – limited train length, drop down windows, straight platform, infrequent stops.
- Ergonomic training and assessment for driver health.

6.1.1.3 Costs

- Nil if cab window suitable

6.1.2 Platform-mounted look-back mirrors

6.1.2.1 Effectiveness considerations (risk and human factors)

- The effectiveness of platform-mounted mirrors depends on the degree to which the platform and train is visible to the driver from the mirrors.
- Sightlines, when using mirrors, can be easily obscured by passengers on crowded platforms.
- Adequate visibility of the full length of the train will depend on platform curvature, length of train, infrastructure and platform furniture.
- Quality of images depends on weather conditions, condition of mirror and lighting.
- Mirrors need to be positioned to ensure that optimum visibility is achieved whilst not increasing the risk of driver musculoskeletal injury (from twisting or looking back).
- Stop boards would be needed to ensure the driver is in the best place to view the mirrors.
- Cannot be positioned on the offside for offside platforms.
- Platform-mounted technology will need to be duplicated at each stopping point.

6.1.2.2 Controls to maximise effectiveness

- Station assessment
- Correct positioning of stop boards
- Appropriately positioned to ensure optimum visibility.
- Regular checks (position, condition of mirrors)
- Periodic and emergency maintenance plans
- Ergonomic training and assessment for driver health
- Contingency plans if equipment malfunctions or visibility is impaired to ensure business continuity eg platform closure or platform staff deployed.
- Effective communication between National Rail and TOCs.

6.1.2.3 Costs

- £50,000 for each platform face

6.1.3 Train-mounted look-back mirrors

6.1.3.1 Effectiveness considerations (risk and human factors)

- Mirrors are fitted to the train so likely to be positioned to allow full visibility of train.
- Visibility of length of train would be impaired by a curved platform, adverse weather or passengers standing in the sightline.
- Cab-mounted mirrors are smaller than platform-mounted mirrors meaning that the image would be smaller and the field of vision reduced.
- As the mirrors are fitted onto the cab it should be possible to position them in an ergonomically sound position for the cab driver. This would be expected if part of the original vehicle design, with complications more likely if retrofitted.
- The driver will always have the same image to look at, potentially increasing the likelihood of an undesired event being noticed.
- Less maintenance required due to reduced probability of vandalism.
- Faults with the mirrors are more likely to be identified prior to service.
- These mirrors have to fit within the structure gauge when the train is moving. Can be automatically closed when the driver selects power. Need manual retraction capability if close power capability fails.

6.1.3.2 Controls to maximise effectiveness

- Station assessment for each station along route.
- Appropriate pre-service checks.
- Periodic and emergency maintenance plans
- Ergonomic training and assessment for driver health.
- Contingency plans if equipment malfunctions or visibility is impaired to ensure business continuity.

6.1.3.3 Costs

- £30,000 for each cab

6.1.4 CCTV system with platform-mounted cameras and monitors

6.1.4.1 Effectiveness considerations (risk and human factors)

- Stop boards would be needed to ensure the driver is in the best place to view the monitors.
- Hardwired system so likely to have increased reliability.
- Hardwired system does have the risk of cables being stolen.
- Need to consider how to manage potential vandalism.
- System as a whole can be checked and maintained.
- Fewer constraints on space – monitors and therefore images can be as large as necessary to ensure undesired events are noticed by the driver.
- There is a requirement to ensure monitors are visible from inside the cab without the requirement to open the cab window.
- Multiple viewing points and numerous cameras can be used to ensure full visibility of the height and length of the train.
- Need to consider how to manage potential vandalism (LU use boxed-in monitors)
- Visibility may be impaired by condition of equipment and adverse weather.
- Platform-mounted technology will need to be duplicated at each stopping point.
- Fixed camera views may not be ideally suited to all stock types (eg with differing door positions).

6.1.4.2 Controls to maximise effectiveness

- Station assessment.
- Stop boards.
- Appropriately positioned to ensure optimum visibility.
- Regular checks (position, condition of monitors).
- Periodic and emergency maintenance plans.
- Ergonomic training and assessment for driver health.
- Contingency plans if equipment malfunctions or visibility is impaired to ensure business continuity.
- Effective communication between NR and TOCs

6.1.4.3 Costs

- £250,000 for each platform face

6.1.5 CCTV system with platform cameras transmitting to in-cab monitors

6.1.5.1 Effectiveness considerations (risk and human factors)

- Multiple viewing points and numerous cameras can be used to ensure full visibility of the height and length of the train.
- Need to consider how to manage potential vandalism.
- Visibility may be impaired by condition of equipment and adverse weather.
- System cannot be easily checked and synchronised/ calibrated as the cameras and monitors are in different locations.
- Images may be easier to see as monitors can be ergonomically positioned within the cab (dependent on vehicle class).
- A reduced concern about in- cab monitors being vandalised or being subjected to adverse weather conditions.
- The driver will be aware if the cab monitor is not working prior to service.
- Due to space constraints the images are likely to be smaller.
- There is a limit to the number of images a driver can observe and reliably check concurrently. This is likely to vary depending on driver, experience and familiarity with the image display.
- Fixed camera views may not be ideally suited to all stock types (eg with differing door positions).

6.1.5.2 Controls to maximise effectiveness

- Station assessment.
- Appropriately positioned cameras to ensure optimum visibility.
- Regular checks (position, condition of cameras).
- Procedure to check syncing and transmission of images between the platform and the train.
- Periodic and emergency maintenance plans.
- Ergonomic assessment/ design of cab for usability and driver health (eg space and number of images).
- Contingency plans if equipment malfunctions or visibility is impaired to ensure business continuity.
- Effective communication between National Rail and TOCs.

6.1.5.3 Costs

- £250,000 for each platform face and £80,000 for each cab

6.1.6 CCTV system with train-mounted cameras and in-cab monitor(s)

6.1.6.1 Effectiveness considerations (risk and human factors)

- Closed system so the entire system can be checked prior to service.
- The driver will become familiar with the quality and display of images, increasing the likelihood of an undesired event being noticed – increased situational awareness and decreased workload.
- There is a limit to the number of images a driver can observe and reliably check (up to 12 images – 6 per screen).
- Images may be easier to see if monitors can be positioned ergonomically within the cab.
- A reduced concern about in-cab monitors being vandalised or being subjected to adverse weather conditions.
- The images are standard views of the train. Cameras cannot be adjusted or positioned to have optimum view for that platform.
- Difficult to retrofit into older trains.
- Limited space in cabs for additional equipment.

6.1.6.2 Controls to maximise effectiveness

- Station assessment for each station along route.
- Appropriate pre-service checks.
- Periodic and emergency maintenance plans.
- Ergonomic assessment/ design of cab for usability and driver health (space and number of images).
- Contingency plans if equipment malfunctions or visibility is impaired to ensure business continuity.

6.1.6.3 Costs

- £50,000 for each cab plus £20,000 for each car for cameras

6.1.7 Platform dispatch staff

- Not reliant on technology
- Staff shortages and delay would have a significant impact
- Can adapt to the specific requirements of the environment
- Platform staff will have an increased awareness of the hazards on that platform and are likely to know where to stand to achieve maximum visibility
- The number of dispatch staff can be increased during peak times and get full visibility coverage
- Increased chance of human error with increased number of people involved in the process
- Increased financial cost
- If right of way indicators are used, there will be additional costs associated with implementation, maintenance and repair
- Staff safety will be a consideration, particularly late at night or at rural locations or during bad weather
- Introducing platform staff increases the number of people within the dispatch procedure, potentially increasing the potential for human error or miscommunication. Individual platform staff also less likely to have full view of platform than a driver using CCTV

6.1.7.1 Controls to maximise effectiveness

- Standardised procedures to ensure signs and signals are used and understood universally
- Station assessment to determine whether the cost is proportionate to the benefit gained

6.1.7.2 Costs

No costs have been identified.

Overall the most cost effective DOO(P) technologies are train-mounted cameras and in-cab monitors, particularly when installed as standard in new rolling stock. Retrofitting older stock, however, may not always be practicable from both a cost and ergonomic perspective. In such instances platform-mounted equipment would provide a suitable alternative but would need to be selected, and implemented in line with the results of a thorough platform assessment. Driver look-back provides a backup alternative in some locations but should be used as a last result to enable business continuity if implemented DOO(P) equipment fails. Dispatch staff can also be used if DOO equipment fails or if a particular risk identified during assessment cannot be reduced as low as reasonably practicable through the implementation of DOO(P) technologies.

6.2 Platform safety assessment

A key recommendation for selecting a suitable and effective DOO(P) technology for implementation is an initial platform assessment. The features detailed in Table 4 should be included when assessing a platform to determine the most effective technology to minimise the risks associated with DOO(P):

Table 4 - Platform safety assessment

Route	Can the same technology be implemented along the entire route? Are there offside or nearside platforms along the route or a combination of both? Number of stations along the route and their proximity to each other
Rolling stock	Rolling stock types using the platform Cab window type Driver sight lines from cab, including those for signalling Is retrofitting of the rolling stock possible? Available space within cab? Location of door controls Likely number of images needed to capture entire length of train

Table 4 - Platform safety assessment

Platform	Visibility of platform access points to the driver Platform to train gap? (Different for different rolling stock) Length of platform Width of platform Number of passengers (peak and non-peak) Passenger behaviour Platform lighting Adverse weather likely to affect visibility (location of platform/ covered?) Obstructions to driver sight lines (permanent and temporary). Include seasonal variations caused by vegetation Curvature of the platform Visibility of start signal from driver's cab Immediate hazards after leaving the platform?
Practicalities of installing technologies	Infrastructure and practicalities of installing different technologies Identification of where technology could be reasonably and effectively sighted to ensure visibility Consider driver requirement to look sideways rather than back Available space on platform
Driver	Driver workload Musculoskeletal injury assessment
Statistics	Vandalism statistics and predicted probability of occurrence (high, medium, or low) Vandalism statistics and predicted probability of occurrence (high, medium or low)
Predicted risk levels	Predicted risk levels for each undesired event

6.3 Additional DOO(P) considerations

There are additional impacts that should be taken into consideration when planning the implementation of DOO(P). These are detailed in the following paragraphs.

6.3.1 Assisted access to travel

Assistance for disabled access to trains is typically provided by platform staff, or by the guard at unstaffed stations. With DOO(P) in operation, assisted access requires a member of platform staff to be available to help the passenger. TOCs interviewed revealed that they generally prefer passengers requiring assistance to book in advance, although one operator stated that if a passenger does book in advance, if no staff are present the passenger may be forced to travel to an alternative station and arrange onward travel from there.

Another operator stated that drivers may provide assistance, but that this was not universal and was essentially at the driver's discretion. Under DOO(P) passengers would face greater requirements to book in advance, possibly facing additional travel restrictions, which would represent a move away from the current goal of making the railway more accessible for all. If DOO(P) is to be employed across the network it would be preferable to have systems in place to ensure that passengers requiring assistance are not excluded. Such measures would need to be determined in discussions with TOCs prior to implementation of DOO(P) and should be standardised across the railway network.

6.3.2 Additional driver workload

Under DOO(P) it can be assumed that some of the guard's duties would be transferred to the driver; thus, in the absence of any mitigating practices, adding to the driver's workload. If such additions occur during movements between stations (such as station announcements) there could be potential for the driver to be distracted. However, perhaps the most likely time for potential distractions would be during station stops (including arrival and departure). One issue raised during the interviews was the potential for the driver to suffer from loss of focus or to lose their situational awareness due to being distracted, either through routine checks of the platform or in dealing with specific situations. One example would be if the driver is responsible for assisting someone embark or disembark with reduced mobility. Upon returning to the cab the driver may miss an action or forget something such as the state of the signal previously passed (particularly as it was noted that at some stations, signals are not always visible when the train is stopped within the platform). Additional workload may also become significant in the case of an incident if the driver is then responsible for attending to the passengers. Given that DOO(P) is currently in use on some parts of the network, these are clearly not new issues, however, changes to driver workload should be assessed before such changes are implemented, along with a consideration of whether additional training may be needed.

6.3.3 Variance of station design

A number of stations were identified, during the interviews that highlighted where individual stations may have particular issues and concerns, requiring a tailored approach to dispatch and management (such as the bridge at Balcombe). These unique challenges suggest that a standardised method for operations may be impossible to implement, with some deviations a practical necessity. However, as highlighted previously, train-mounted cameras and monitors perhaps offers a system of working that could, in principle, be rolled out universally and supported by platform staff where necessary.

6.3.4 Retraining

Switching from non-DOO(P) to DOO(P) would require operators to either retrain staff (mainly drivers and conductors) or recruit new staff to be trained. Given the potential political difficulties associated with widespread redundancies, it would seem likely that the preferred option would be to retain conductors and retrain them, especially given that if DOO(P) were to be rolled out across the network, the numbers of new drivers needing to be recruited would be prohibitively large to be practicable.

One operator interviewed spoke of the difficulties they had experienced in converting drivers onto DOO(P) for their particular railway, even with the drivers who had worked on DOO(P) lines before. It was conceded that retraining a current driver is potentially less time consuming. This is based on the estimate that a fresh recruit would require around nine to eleven months of training, of which roughly 6 months would be technical training that an existing driver may not require (or at the very least, not to the same extent). However, the operator suggested that whereas fresh recruits typically have a 1-in-6 failure rate, experienced drivers tend to fare worse. The operator believed that this was a result of bad habits that had become ingrained. A key concern was expressed relating to moving people to a different operating environment, where that individual may have become habituated to an inappropriate perception of risk. An example was provided of a group of low-speed depot drivers being retrained for mainline operations. Ultimately, 5 of the 6 drivers required more training than a fresh recruit would have been expected to need. This is regarded as an unusual case.

6.3.5 Cab ergonomics

Modifications to cab interiors face difficulty due to the fact that, if originally designed according to good design principles, each control and indicator should be placed in the optimum position to accommodate the driver's reach and view. To further complicate the issue, the relative position of controls and indicators should be such that this facilitates an optimum flow or linkage to minimise driver eye and hand movements. This is a basic design principle that seeks to optimise efficiency and helps to reduce errors of omission. Adding new equipment (such as monitors) and repositioning door controls for use by the driver may mean that the whole cab must be redesigned (and tested). This would not only prove to be costly but may be further constrained by the positioning and/or condition of existing wiring and structural elements.

Should DOO(P) be employed using rolling stock not originally intended for that role, modifications would most likely need to be made to the cab design in order to accommodate new equipment and/or facilitate alternative driver tasks and procedures. It would be hoped that such modifications could be achieved easily and inexpensively, yet the feedback from rolling stock companies (ROSCOs) suggests that this may not always be realistic. Feedback from one ROSCO was that they had previously attempted a retrofit project and had encountered such difficulty that the project was terminated, resulting in the ROSCO deeming any future retro-fit projects to be very unlikely.

When implementing DOO(P) across the network it may be preferable, from an ergonomic perspective, to use vehicles originally intended for the type of operation employed (including which specific type of DOO(P) system). This may mean that on-board DOO technology is phased in over a considerable time across the network.

6.3.6 Emergency response

Currently, the guard is responsible for the passengers when responding to an emergency. Under DOO(P), this responsibility transfers to the driver. This may increase response times in the case of an emergency, as the driver will have an increased workload. However, existing safety management systems seem to have an acceptable response procedure in place.

6.3.7 Equipment failure

All platform-mounted equipment is the responsibility of Network Rail. Reliability of current equipment is reportedly good although platform equipment must be sufficiently robust against vandalism and adverse weather conditions. Periodic and emergency maintenance plans need to be in place and contingency plans developed and communicated to staff to cater for failure of the DOO(P) technology and to ensure business continuity. LU have categorised platforms based on whether a train can be dispatched using look-back if DOO(P) equipment fails or whether a train cannot be dispatched in such instances. Where look- back is not a safe alternative to DOO(P) equipment, the train is not dispatched from the station until the equipment is fully functional or platform staff are available to ensure safe dispatch of the train.

7 Cost-benefit analysis

This section discusses the financial implications of implementing DOO(P) at both a national and franchise level. The analysis takes account of earlier DOO(P) cost benefit analysis work by SDG (2013), extending this analysis with data obtained through consultation with stakeholders.

7.1 Costs

There are various technical requirements for implementing DOO(P), including the provision of correctly located door-controls in the cab, CCTV cameras and monitors, or look-back mirrors, which can be cab-mounted, train-mounted, or platform-mounted, or methods like driver look-back.

Inclusive installation costs provided as part of the stakeholder interviews are £50,000 for platform-mounted mirrors and £250,000 for platform-mounted cameras and monitors, for each platform. SDG estimate the cost of fitting DOO(P) cameras and monitors to vehicles as £11,000 to £20,000 for each vehicle. However, stakeholders interviewed advised a retrofitting cost of train-mounted CCTV for a driving car, including risk and the costs of surveys at stations, labour for fitting, the kit, rewiring, power supplies, monitors and development for each type of stock, as being in the range £35,000 to £40,000 for each car on average, rising to as much as £50,000. In addition, fitting or moving door controls in each cab, if not already present, is estimated to cost £20,000 for each cab.

The cost of including DOO(P) equipment on new rolling stock is minimal; the main issue for new stock is for the requirement for CCTV and monitors to be specified in advance of procuring the new stock.

For the purposes of this analysis, maintenance costs are assumed to be 5 % of the capital cost every year, both for retrofitted train-mounted solutions and for platform-mounted solutions.

DOO(P) is assumed to be safety-neutral. A technical solution needs to be put in place to enable benefits to be achieved from the operation of DOO(P), but the cost of the technical solution itself does not affect the scale of the benefits. For example, train-mounted kit and platform-mounted kit are likely to provide very similar benefits through changes to operational procedures (see Section 7.2). The cost will depend on the practicalities of the technical solution, such as leasing or buying, and the feasibility of retrofitting body-side cameras and CCTV to old rolling stock.

The risk analysis shows that the technology likely to most effectively reduce the risk of key undesired events would be to install platform-mounted cameras that transmit to in-cab monitors. This is likely to provide the optimal visibility of the platform and train without increasing the risk of driver occupational health issues. However, this is the most expensive option, both for installation and maintenance. The most cost-effective solution will be train-mounted cameras and in-cab monitors. This will provide a safe means of dispatch at a lower cost.

A single technical solution across the network would be is the most cost-effective method because of potential economies of scale. A combination of solutions (platform-mounted and train-mounted systems, or cameras and mirrors) would incur an additional cost, and could increase risk due to a higher potential for human error. This could be considered where retrofitting is not possible on a particular class of train, in which case platform-mounted equipment might be an alternative option for those trains or routes. It is also possible that some routes are served by many trains, but have stations with few platforms, in which case platform-mounted systems might turn out to be a cheaper solution than train-mounted systems, for those routes. This would need to be assessed on a route by route basis.

Therefore, for the purposes of this cost benefit analysis it has been assumed that the preferred technical solution is a CCTV system with train-mounted cameras and in-cab monitors. Platform-mounted solutions would in general be more expensive. Driver look-back would be cheaper, but has not been assessed in this analysis as it would have a negative impact on dwell times and there are reasons for avoiding this solution as outlined in Sections 4.1 and 5.3.1.

7.2 Benefits

Monetised benefits accrue from 3 main sources:

- Savings in staff salaries
- Fewer cancellations
- Reduced dwell times at stations

By far the biggest financial benefits arise from a reduction in staff salaries. This can arise from employing fewer staff, and from replacing guards with cheaper non-safety critical on-train staff (NSCOS).

SDG assumes that NSCOS receive a substantially lesser salary than guards, £20,000 versus £35,000, and a further £5,000 saving in employment costs, while drivers receive a 5 % increase to compensate for their additional duties. The TOCs consulted felt this is an overestimation, indicating a salary difference of approximately £5,000 with savings on guards' salaries being reduced by the compensation given to drivers (ScR, 2014).

The extent of the salary savings that can be made depends on the operating regime selected for each route, and the method chosen to reduce and/or replace staff. Possible operating regimes are to have a second NSCOS member of staff on board all trains, to have one on 50 % of trains, or to run all trains with the driver as the only staff member, with occasional revenue protection staff on board. There are additional costs and benefits associated with the choice of regime.

SDG have shown that the best solution, in pure economic terms, is to make all guards compulsorily redundant and to run trains with mostly single person operation, with occasional ticket checks. This results in a large salary saving from a reduction in staff levels. In the short term, there may be losses due to potential industrial action. From an operational point of view, there may be financial drawbacks to single person operation, these impacts are discussed further below.

If compulsory redundancies are felt to be unacceptable, an alternative approach is natural wastage, replacing guards with NSCOS in a phased approach. If guards are to be retained, then it is cost efficient to give them an alternative role, using them as a second on-board staff member, dealing with customer relations and revenue protection. There would be few savings in the short term, but savings would increase over time. As guards leave, they would be replaced with NSCOS on lower salaries. An operator might choose not to replace the guards, and to run some trains with the driver only. This could be done in phases, or a one-off change in operating regime once staffing levels had reduced.

The second economic benefit is from fewer train cancellations due to lack of staff. Even under an operating regime that has a NSCOS it would not be necessary to cancel a train because that person was not available. This is the Scotrail model, based on the Strathclyde Manning Agreement (SMA). An additional saving that could be made would be from the removal of the need for contingency provision. Several TOCs have a guard contingency to allow for unexpected shortages. This guard surplus would no longer be needed.

The third economic benefit is from reduced dwell times at stations, largely due to avoiding the 'handshaking' between guard and driver. SDG's model example finds a reduction on average from 39 seconds to 30 seconds per stop. This model is largely dependent on the correct positioning and deployment of door controls in the driver's cab. The reduced dwell times could lead to reduced journey times and improved reliability. In many cases, the TOCs will only be able to use the reduced journey times to provide increased buffer time, as major re-timetabling would probably be required in order to gain from improvements in train diagramming.

7.3 Other monetised impacts

There are other economic impacts arising from the introduction of DOO(P):

- Ticket revenue
- Industrial action
- Training costs

Ticket revenue will depend on whether there is a second person on board the train, and what his/her duties are. The impact of this will be greatest for journeys between two unmanned stations. Currently, 92 % of ticket revenue comes from journeys between two manned stations, so a potential loss of revenue should not be a major issue. Franchises with high proportions of unstaffed stations include East Midlands, Northern, ScotRail and Wales & Borders.

For the operational regime where a NSCOS is on board every train, ticket revenue will actually increase, as the NSCOS will be able to check and sell tickets without needing to carry out safety-critical tasks. For a regime with only the driver on board, fare evasion is likely to increase. One TOC stated that it would be equivalent to offering a free railway.

An alternative to on-board staff would be to introduce ticket gates to protect revenue. However, ticket gates are expensive to install and maintain and all gated stations require a staff member to be in attendance adjacent to each barrier line while the gates are in operation, typically 07:00-19:00 (equivalent to around 2.25 staff for each post) compared with a train service period of 05:30-00:30 (equivalent to around 3.5 staff for each post). Therefore, gating at unstaffed stations is unlikely to be cost-effective. A smart-card ticketing system (touch in and touch out) combined with severe penalties for fare evasion during infrequent but rigorous checks might obviate the need for gates.

The second potential impact could be from industrial action. This is most likely to occur if compulsory redundancies are applied, and may occur if guards are reassigned to NSCOS duties. The latter could be mitigated by a program of guard incentives. TOCs have stated that they would anticipate at least 2 weeks of industrial action, which would have a reputational effect as well as an economic one. The risk of revenue loss during an unspecified period of industrial action is a major factor in a TOC's decision as to whether to implement DOO(P) with compulsory redundancies.

The third potential impact would be staff training. Safety critical training for guards would no longer be required, which would reduce the training requirement from 12 weeks to 4 weeks for the second staff member on board. This cost saving would be partially offset by additional driver training days for learning DOO(P) methods.

An additional impact might arise from commercial effects due to increased crime and perceptions of poor security with de-manning. This has not been quantified in this analysis, but further study of recorded crime rates and patronage might indicate whether this might need to be taken into account.

There are other impacts from the introduction of DOO(P) that do not have monetised values, so have not been included in this analysis, these are discussed in Section 6.

7.4 Business case

Within this section, reference is made to payback times. These are the times that it would take for a franchise to get a return on its investment, assessed from the time that DOO(P) was implemented. There will be a lead-in time from the time that a decision is made to implement DOO(P) to when it starts to provide benefits (while the equipment is installed, staff are trained). This lead-in time will vary depending on the suitability and practicality of the chosen solution, and would need to be added to the periods quoted in this section to obtain a payback time from the decision to invest.

SDG assessed the business case for DOO(P), assuming train-mounted equipment (as this is less expensive than platform-mounted equipment), plus operating regimes that include compulsory redundancies. The central estimate for national rollout of this solution is a net present value (NPV) over 20 years of £2.1 billion (using a discount rate of 3.5 %).

Further analysis of the business case indicates that the expected payback time for national rollout under the same assumptions would be three years, and that the best estimate for return over 5 years would be £350m. This is a business assessment only, and the practicalities of installing kit onto the whole fleet would be likely to mean that this would not be achieved in practice. In addition, there are many assumptions underlying this analysis, including the technical solution implemented, the extent and effect of any industrial action, costs of staff and their training, the extent of fare evasion, the benefits arising from reduced dwell times, and the operating regime selected by each franchise for its routes. Because of the uncertainties involved, it is possible that the payback time might be longer than five years (and therefore that a national rollout would be showing a loss after 5 years).

Further detailed investigation would be required to produce and validate a national rollout plan, with a suitable and practical phased implementation. Any plan should take into account the requirements of the Rail Vehicle Accessibility Regulations 2010 and the Persons of Reduced Mobility Technical Specification for Interoperability. The target is for all rail vehicles to be accessible by no later than 2020, which will provide an insertion point for new stock or a potential upgrade opportunity for retrofitting DOO(P) kit.

Analysis of individual franchises shows considerable variation in the NPV and payback times (see Table 5). The franchises that come out best are those with high numbers of guards, as the removal and/or replacement of these staff allows substantial savings to be made soon after implementation. This would offset equipment costs and potential losses due to industrial action. Payback times for the most suitable franchises (Northern, South West, Network West Midlands, Wales and Borders, TransPennine and Merseyrail) are all expected to be within two years of the systems being rolled out. However, other franchises would not show a profit until after 5 years or longer, and some franchises (Chiltern and Essex Thameside) that are already partially DOO(P) would have minimal or no benefit from this being extended to the whole of the franchise.

Although Table 5 indicates relatively short payback times for some franchises, there are uncertainties due to the assumptions made. Also, the business model assumes full compulsory redundancies for all guards. Because of this, few franchises have currently implemented DOO(P) on their routes.

Table 5 - NPV and Payback times by franchise (compulsory redundancies) using a discount rate of 3.5%

Franchise	Net Present Value (£m)		Payback time (years)
	5 years	20 years	
Northern	114	424	2
South West	64	315	2
First Great Western	41	234	3
Network West Midlands	44	184	2
Wales and Borders	49	179	2
Southern	17	137	4
TransPennine	26	108	2
Merseyrail	29	105	2
East Midlands	9	91	4
Crosscountry	11	91	3
Southeastern	0	90	5
InterCity West Coast	-10	63	7
London Overground	10	44	2
InterCity East Coast	0	42	5
Greateranglia	-16	24	10
Chiltern	-1	12	6
ScotRail	0	-2	n/a
Essex Thameside	-6	-3	n/a
Thameslink and Great Northern	-16	-14	n/a
TOTAL	364	2122	3

Further analysis has been carried out for the same technology solution (train-mounted equipment), but with an operating regime involving no compulsory redundancies and operating all trains with an NSCOS on board. For this scenario, the best estimate for payback time for national rollout would be 9 years, and the central estimate for NPV over 20 years is £0.7 billion.

Table 6 provides an indication of the best estimate of payback times for individual franchises. Again, the best franchises are those with the most guards, because they will be replaced with less expensive NSCOS as the current guards leave or retire. However, the short-term benefits are lower, as overall staffing levels would remain high.

The Intercity franchises retain much of their NPV from the compulsory redundancy scenario, as their services would be staffed by NCSOS in either case. Conversely, the NPV for urban franchises (Merseyrail and London Overground) is worse with no compulsory redundancies, as these services would be most efficient without a second staff member on board.

Table 6 - NPV and Payback times by franchise (no compulsory redundancies) using a discount rate of 3.5%

Franchise	Net Present Value (£m)		Payback time (years)
	5 years	20 years	
Northern	4	150	5
South West	-16	116	7
First Great Western	-29	60	11
Network West Midlands	9	97	4
Wales and Borders	24	117	2
Southern	-38	0	20
TransPennine	6	58	4
Merseyrail	-10	-7	n/a
East Midlands	-16	29	11
Crosscountry	5	77	5
Southeastern	-40	-9	n/a
InterCity West Coast	-16	49	9

Table 6 - NPV and Payback times by franchise (no compulsory redundancies) using a discount rate of 3.5%

Franchise	Net Present Value (£m)		Payback time (years)
	5 years	20 years	
London Overground	-6	-1	n/a
InterCity East Coast	-5	31	7
Greateranglia	-41	-38	n/a
Chiltern	-3	7	9
ScotRail	0	-2	n/a
Essex Thameside	-11	-18	n/a
Thameslink and Great Northern	-16	-14	n/a
TOTAL	-200	700	9

At the current levels of guard turnover, it is estimated that with natural wastage and no compulsory redundancies, staffing levels for guards would halve within 9 years. At that point, it would be cost-effective to switch to an operational regime with NSCOS on fewer trains. This would improve the 20-year NPV from £0.7 billion to £1.1 billion.

7.5 Sensitivity analysis

As stated in Section 7.4, there are many assumptions underlying the business case analysis. For the model used to produce the results quoted in Table 5 and Table 6, these assumptions are the same as those made by SDG in their analysis.

During meetings with TOCs, some of them suggested different values for some of these assumptions, in particular for the cost of the train-mounted equipment and the difference in staff salaries between guards and NSCOS. To test the sensitivity of the business case, the model has been reassessed under different assumptions, both separately and combined:

- That equipment and maintenance costs are double the initial estimate
- That the difference between a guard salary and an NSCOS salary is £5,000 each year, rather than £15,000

For national rollout of the operating regime incorporating compulsory redundancies, the effects of modifying the assumptions are shown in Table 7.

Table 7 - Modified assumptions (compulsory redundancies)

Assumption	NPV (£m)		Payback time (years)
	5 years	20 years	
Initial estimate	364	2122	3
Increased equipment cost	185	1844	4
Increased NSCOS salary	200	1464	4
Increased costs and salaries	20	1184	5

The 5-year NPV remains positive, and the 20-year NPV remains over £1 billion.

For national rollout of the operating regime with no compulsory redundancies, the effects of modifying the assumptions are shown in Table 8.

Table 9 – Modified assumptions (no compulsory redundancies)

Table 8 -

Assumption	NPV (£m)		Payback time (years)
	5 years	20 years	
Initial estimate	-200	700	9
Increased equipment cost	-379	422	13
Increased NSCOS salary	-259	162	13
Increased costs and salaries	-439	-118	n/a

In this scenario, any potential payback is long-term, and the franchises are likely to need a financial incentive to implement DOO(P).

8 A strategy for rolling out DOO(P) across GB rail

This section provides a high-level strategy for the rollout of DOO(P) to the remaining 70 % of the GB rail network. The strategy draws on the findings from the research. The strategy is not intended to be a full implementational road map as this will need to be developed based on a more detailed analysis of individual routes, including an assessment of station platforms and rolling stock. However, the strategy does include a number of recommendations that can be implemented immediately in new franchise agreements and new rolling stock specifications.

8.1 Ideal DOO(P) equipment requirements

The research undertaken in this project shows that the current best solution for DOO(P) equipment and operation exists on certain lines of the LU where in-cab monitors provide displays transmitted from platform-mounted CCTV cameras. The system has also been replicated by at least one metro in Germany. The equipment allows station control rooms to receive platform train interface images as well as trains providing added security and safety capability. Transmission to the trains is through microwave on the latest systems. SDO and CSDE are included in the control system and it is used on both automatically and manually operated trains. The cab layout and design of control is specifically designed for DOO(P).

Additionally, the functionality of the LU system allows the train operator (driver) to observe the platform/train interface as the train is leaving the station. Image transmission is switched off only after the last car has cleared the platform. This differs from the main line railway solution where the images are switched off as soon as the train starts moving. The difference between these two regimes needs to be clarified and a joint risk assessment carried out.

The latest LU trains are fitted with sensitive door edges and recycling. The sensitive edges provide a dragging alarm and emergency brake command if a thin object like a bag strap is caught in the closed door while the train is departing from the platform.

All LU trains are fitted with automatic announcements that can be selected or altered by the train operator. Train operators can (and do) also make manual announcements. Train radio allows control centre operators to speak to passengers in emergency.

Whilst the above described solution may be the best system available within today's technology, it is recognised that the cost and rollout time will require a long term programme to reach the ultimate position. A favourable alternative would be to rollout a train-mounted system, with body side cameras and in-cab monitors utilising wireless communication (a commonly used technology for this application). This system could be specified in a way that makes it possible for the equipment to optionally receive images from platform-mounted cameras where these are fitted in preference to the body-side mounted cameras. A hybrid system of this type would be cost effective in the short term and allows for fitment of more expensive platform-mounted cameras at locations where a thorough safety risk assessment deems this to be appropriate without necessitating further alteration of the rolling stock.

8.2 Outline strategy for quick rollout

An outline strategy for the rollout of DOO(P) across the British main line railway system is set out here to provide guidance on how the work may be approached.

- All new franchises to include a requirement to offer DOO(P), separately costed.
- All new rolling stock to have on-board DOO(P) camera equipment, cab monitors and suitable cab door controls at the driving position specified
- All new stock to have SDO and CSDE specified and linked to door controls
- All new station designs or refurbishments to be required to determine optimum arrangements for DOO(P)
- All existing on-board camera–equipped trains to be used under DOO(P) along all the routes of use
- Assisted access at stations to be assessed and defined standards set for train crew
- The use of on-board rear-view mirrors to be investigated and trialled on suitable, low traffic routes with short trains
- Rolling stock to be retained after 2020 Persons with Reduced Mobility requirements deadline to be defined and investigated for DOO(P)

conversion with either rear-view mirrors or on-board CCTV. Each type of stock will need to be researched

- New technology to allow image comparison techniques to assist platform/ train interface monitoring to be investigated and trialled on stations and trains

9 Conclusions

DOO(P) does not create additional undesired events but may increase the likelihood of an event occurring or increase the severity of its consequence. The risk level of each undesired event will vary according to platform features, rolling stock, driver behaviour and passenger behaviour and passenger flows. The level of control required at each platform will depend on the level of risk posed. It is important that individual platform assessments are conducted to identify technologies appropriate for that location to reduce the identified risks as low as reasonably practicable. More effort and potentially expense will be required at a platform where there are features such as platform curvature, wide platform to train gaps or a high volumes of passengers, where the risks may be considered high.

In theory, it would be preferable to implement the same technology along an entire route to minimise costs, the workload on the driver, and the potential for human error that could arise from performing a variety of methods. In practice this may not always be possible or cost effective given the varying risk levels at each platform. Similarly, in theory it may be cost effective to have on-board cameras and in-cab monitors to ensure maximum reliability, consistent, familiar images and reduced risk of impaired visual coverage due to vandalism, driver position or adverse weather. In reality, the ergonomic practicalities and potential costs associated with retrofitting trains with in-cab monitors may not be reasonably practicable. The costs associated with retrofitting trains seem relatively high compared with platform-mounted equipment. However, platform-mounted equipment must be replicated at each stopping point to ensure drivers have full visibility of the train and platform regardless of the train class they are operating and are likely to incur higher maintenance costs.

It may be most effective to phase in the use of on-board DOO(P) technologies by ensuring all new vehicles are fully equipped for DOO(P), where practicable older classes of trains are retrofitted and platform-mounted equipment implemented where retrofit of the vehicles is not technically or economically feasible. Appropriate cost effective technologies should be primarily identified through thorough platform assessments to ensure the risks associated with the individual platforms are reduced as low as reasonably practicable. Once identified, the success of reducing the risk of the undesired events relies on effective implementation of the primary and supplementary technologies and appropriate systems including safety documentation, training, communication, reporting and monitoring. Once implemented the technologies should be monitored, their performance measured and the equipment maintained (periodically and as an emergency response) to ensure continued safe dispatch of trains using DOO(P). It is important that there are well documented and implemented procedures for maintenance, daily and periodic checks, fault reporting and emergency response. Each platform or route must also have a contingency plan if technology fails or if the visual coverage of the train is impaired. This will ensure business continuity with minimised disruption and dispatch delay.

At a network level, the wholesale implementation of DOO(P) has the potential to deliver economic benefits to the railway. The NPV and payback periods of implementing DOO(P) are heavily dependent on the implementation strategy. Adopting a strategy of compulsory guard redundancies delivers greatest benefit, whilst adopting a strategy of natural wastage and redeployment of guards delivers a reduced, but still positive NPV, over a 20 year analysis period. A more detailed analysis of the business case at a franchise level demonstrates a significant degree of variation in both the NPV and payback period of implementing DOO(P). This demonstrates the need for a strategic approach to the further rollout of DOO(P) by prioritising franchises and routes which can deliver the greatest return on investment.

A high-level rollout strategy based on the findings and conclusions from the project is provided in Section 8.

10 References

Angel Trains (2014). Minutes of meeting with Angel Trains, Victoria, 4 March 2014.

Basacik D, Read C, Heavisides J, Jones M and Pollard G (2009). Train Dispatch Review, TRL Client Project Report CPR 493 for Project T743. Arthur D Little (Bid Manager), Transport Research Laboratory and Halcrow.

BRB (1993). Driver only operation of Passenger Trains. Group Standard GO/OTS 401. British Railways Board, March 1993.

RSSB (2005). Assessing the Impact of Increased Numbers of CCTV Images on Driver Only Operation of Trains. Final Report of Project T535. Rail Safety and Standards Board. See http://www.rssb.co.uk/research-development-and-innovation/research-and-development/research-project-catalogue/T535

Connor P R (2007). The London Underground Electric Train, parts 20-21. Underground News, February and March 2007, The London Underground Railway Society.

CSR (2013). Signs associated with radio systems. http://www.railsigns.co.uk/sect19page1/sect19page1.html. (Accessed on 7 November 2013)

DfT (2014). Rail Executive Rail Franchise Schedule. Available at: https://www.gov.uk/government/publications/rail-franchise-schedule

EMT (2014). Minutes of meeting with East Midlands Trains, St Pancras, 4 February 2014.

European Rail Agency (2011). Guide for the application of the CR LOC&PAS TSI. Document ERA/GUI/07-2011/INT. European Rail Agency, Valenciennes.

Eurotransport (2014). Supplement on automated metros. Eurotransport, Issue 1 2014, Russell Publishing Limited, London.

Eversholt (2014). Minutes of meeting with Eversholt ROSCO, Pentonville Road, 5 February 2014.

eyeTrain (2012). eyeTrain Brochure. Petards. 2014 version available at: http://www.petards.com/transport/literature/2014_Transport_Brochure_Issue1_Web_Email.pdf

FCC (2014). Minutes of meeting with First Capital Connect, Kings Cross, 11 February 2014.

Fersil (2014). Clearsy System Engineering http://www.fersil-railway.com/wp-content/uploads/Pres-Nov-2012-en.pdf

Fowler C, Clark S, Rillie I, Cuerden R and Smith L (2011). Development of the Measurement of Injury Risk Index (MIRi). TRL Client Project Report CPR 1106 for English Highways Agency. Transport Research Laboratory, Crowthorne.

Fowler C, Tong S, Fernández-Medina K, Thompson K, Scoons J and Lawton B (2013). Prospective Study into Harmonised Train Accident Precursors Analysis and Management. Final Report for Project ERA/2012/SAF/OP/01 for European Railway Agency Safety Unit. TRL Project Report PPR 665. Transport Research Laboratory, Crowthorne.

Green C and Hall Sir P (2009). Better Rail Stations. Department for Transport, London, November 2009.

HSE (2001). Reducing risks, protecting people. Document R2P2. Health and Safety Executive.

HSE (2013). ALARP 'at a glance'. ['As Low As Reasonably Practicable']. Health and Safety Executive. http://www.hse.gov.uk/risk/theory/alarp.htm (Accessed on 12 November 2013)

Lin L-K, Chang C-C and Wu P-Y (2010). System development and performance evaluation of track intrusion in Taipei MRT system. Available at: http://www.engineering.nottingham.ac.uk/icccbe/proceedings/html/219.htm

Lloyd's Register (2012). Common Safety Method on Risk Evaluation and Assessment - Managing risk on the UK railway. July 2012.

Luke T, Brook-Carter N, Smith R, Rogers A and Flint A (2005). Train Driver Visual Strategies. Final Report of Project T152. Transport Research Laboratory / Rail Safety and Standards Board. See http://www.rssb.co.uk/research-development-and-innovation/research-and-development/research-project-catalogue/T152

McNulty Sir R (2011). Realising the Potential of GB Rail. Department for Transport, London, May 2011.

METRO (2012). Tube driver saves child who had fallen between train and platform. London METRO, 1 March 2012. Available at: http://metro.co.uk/2012/03/01/tube-driver-saves-child-who-had-fallen-between-train-and-platform-at-finchley-road-337231/

Mroué A, Heddbaut M, Elbahhar F, Rivenq A and Rouvaen J M (2013). Automatic passenger detection in safety critical mass transit environments. International Journal of Intelligent Transportation Systems Research, 11(2), p87-100. Springer Link.

NR (2014). Minutes of meeting with Network Rail, The Quadrant, Milton Keynes, 18 February 2014.

Oh S-C, Park S-H and Lee C-M (2007). Vision Based Platform Monitoring System for RailwayStation Safety. Advanced EMU Research Corps, Korea Railroad Research Institute. Available at: www.krri.re.kr/teams/urban/advancedEMU/result/2st/2-14.pdf?

ORR (2008). http://webarchive.nationalarchives.gov.uk/20110616203551/http://www.rail-reg.gov.uk/server/show/nav.1126 Office of Rail Regulation. (Accessed on 11 November 2013)

ORR (2012). ORR guidance on the application of the common safety method (CSM) on risk evaluation and assessment. December 2012. Office of Rail Regulation.

RAIB (2012a). Safety incident between Dock Junction and Kentish Town, 26 May 2011. Department for Transport [Online] Report 07/2012. Accessed 20/09/2013 http://www.raib.gov.uk/cms_resources.cfm?file=/120523_R072012_Kentish_Town.pdf

RAIB (2012b), Fatal accident at James Street station, Liverpool, 22 October 2011.Rail Accident Report 22/2012, October 2012. DfT Rail Accident Investigation Branch, Derby.

Rail Engineer (2008). November 2008 Issue.

Railnews (2013). ScotRail franchise plan appears to rule out DOO. Railnews Business, December 2013.

Rail Safety Investigation No 2008/09 Brief Report - Train Impact with Passenger On Station Platform Springvale, 27 September 2008, Melbourne, Australia.

Railtrack (1999). Driver only operation (passenger). GO/RC 3571. Railway Group Standards – Safety and Standards Directorate, Railtrack PLC, April 1999.

Railway Safety (2001). Strategy for Railway Group Standards. Report RS210 (Issue 1) (Withdrawn).

ROGS (2009). The Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS). July 2009. Office of Rail Regulation.

RSSB (2001a). Review of Driver only operation. Rail Safety and Standards Board.

RSSB (2001b). Driver only operation: Improving Safety Controls. Rail Safety and Standards Board.

RSSB (2004). DOO platform Based Safety Critical Systems and Train Dispatch Research Study. Report of project T132. Rail Safety and Standards Board, March 2004.

RSSB (2008). Rail Industry Standard for Train Driver Selection. RIS-3751-TOM. Rail Safety and Standards Board Ltd, 2 August 2008.

RSSB (2009). Taking Safe Decisions. GD-0001-SKP. Rail Safety and Standards Board Ltd.

RSSB (2010a). Published letter from Rail Safety and Standards Board to Director Rail Delivery of Transport Scotland, 21 January 2010. Available at http://www.transportscotland.gov.uk/files/documents/rail/airdrie-bathgate/21_January_2010_letter_from_RSSB_to_Bill_Reeve.pdf

RSSB (2010b). Engineering Requirements for Dispatch of Trains from Platforms. Railway Group Standard.GE/RT8060. Rail Safety and Standards Board Ltd.

RSSB (2011). Rail Industry Standard for Train Dispatch and Platform Safety. RIS-3703-TOM (Issue 2). Rail Safety and Standards Board Ltd. Available at http://www.rgsonline.co.uk/Railway_Group_Standards/Traffic%20Operation%20and%20Management/Rail%20Industry%20Standards/RIS-3703-TOM%20Iss%201.pdf

RSSB (2012a). Guidance on identifying hazards and assessing risk. GN/GE/8642. September 2012. Rail Safety and Standards Board Ltd.

RSSB (2012b). Guidance on reducing risk. GN/GE/8643. September 2012. Rail Safety and Standards Board Ltd.

RSSB (2013a). Rail Risk Portal. Available at http://www.safetyriskmodel.co.uk/Pages/default.aspx

RSSB (2013b). Station duties and train dispatch. GE/RT8000/SS1 Rule Book. March 2013. Rail Safety and Standards Board Ltd.

RSSB (2013c). Rail Industry Standard for Driver Only Operated On-train Camera/Monitor Systems. RIS-2703-RST (draft). Rail Safety and Standards Board Ltd. Available at http://www.rgsonline.co.uk/Railway_Group_Standards/Rolling%20Stock/Rail%20Industry%20Standards/RIS-2703-RST%20Iss%201.pdf

RSSB (2013d). Driver Only Operations (Passenger) - A Good Practice Guide. September 2013. Rail Safety and Standards Board Ltd. (UNPUBLISHED)

RSSB (2013e). Evaluating the feasibility from a safety perspective of moving from driver-guard operation to driver only operation (passenger trains) on regional routes. Report of Project T955, SRM Hazard Analysis for Rail Projects.

RSSB (2013f). Guidance on risk evaluation and acceptance. Document RSSB-MOC-G04. December 2013. Rail Safety and Standards Board Ltd.

RSSB (2013g). Rail Industry Standard for On-board ETCS. RIS-0340-CCS (Withdrawn). Rail Safety and Standards Board Ltd. Available at www.rgsonline.co.uk/Railway_Group_Standards/Control%20Command%20and%20Signalling/Rail%20Industry%20Standards/RIS-0340-CCS%20Iss%202.pdf

RSSB (2014). Offside train door incidents 01/12-01/14. Rail Safety and Standards Board Ltd.

ScotRail (2010). Driver only operation Form. Available at http://www.scot-rail.co.uk/page/Driver+Only+Operation (Accessed on 7 November 2013)

SDG (2013). Driver only operation - Passenger. Report prepared for Rail Delivery Group by Steer, Davies and Gleave, June 2013 (CONFIDENTIAL)

ScR (2014). Minutes of meeting with ScotRail and station observations. Atrium Court, 1st floor reception, 50 Waterloo St, Glasgow, 23 April 2014.

SoR (2014). Minutes of meeting with Southern Railway and platform tour of East Croydon. Knolly's House, Addiscombe Road, Croydon, 19 March 2014.

telent (2013). Track-to-Train Driver only operation (DOO). Available at http://www.telent.com/?q=node/2343 (Accessed on 13 November 2013) (link does not work on 04-03-2015)

Tong S, Helman S, Fowler C, Delmonte E and Hutchins R (2012). Motorcycle manoeuvres review: the feasibility and safety implications of carrying out modified module 1 test manoeuvres on-road – Phase 1. TRL Project Report PPR 667. Transport Research Laboratory, Crowthorne.

Wikipedia (2014). Available at http://en.wikipedia.org/wiki/One-man_operation (Accessed on 26 February 2014)

21st Century Rail (2013). Web advertisement. Available at http://21stcenturyrail.com/driver-only-operation/ (Accessed on 12 November 2013)

RSSB R&D Programme
Block 2 Angel Square
1 Torrens Street
London
EC1V 1NY

enquirydesk@rssb.co.uk

http://www.rssb.co.uk/research-development-innovation/research-and-development