The application of selective door opening within a railway system

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Abstract

In an environment of continuing railway improvement, a new UK Railway Standard mandates the implementation of an automatic Selective Door Opening (SDO) system where the length of the station platform cannot accommodate the length of the train. The aim of the SDO system is to prevent passengers exiting the train via doors without a platform present, which could potentially result in an injury or fatality. The basic function of the SDO system is to only permit those train doors to open that are safe for passenger egress onto the station platform.

There are two distinct types of SDO system: Manual and Automatic. Manual SDO systems rely solely on the train crew to provide safe door opening at any particular platform. Automatic SDO systems make use of an on-board train control system to decide which doors are safe to be opened when demanded by the train crew.

This paper explores the underlying issues in the development of an automatic SDO system. Five SDO systems are presented, which are based on Trackside Beacons, Global Positioning System, Distance Measurement, Route Tracking, and Platform Detection technologies. These systems make improvements over the manual SDO system by reducing human involvement and therefore potential errors, from the system. Each of these SDO systems is examined for its costs and benefits by addressing the issues including station infrastructure, system architecture, reliability, maintainability, safety, and development and operational costs.
Keywords: selective door opening, selective door operation, SDO, power operated train doors.

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1 Introduction

Selective Door Opening (SDO) is required where there are no alternative means to accommodate all doors on a train within the length of a passenger station platform. With the ongoing railway improvements, the UK Railway Standard [1] now mandates that after 5 February 2005 all new trains must implement an automatic SDO system to provide safe door-opening.

Train Operating Companies (TOC) are running longer trains on the existing infrastructure in order to reduce operating costs and to increase passenger capacity. This has resulted in trains being longer than the platforms at some stations along the route.

In this context, safe door-opening is achieved by opening only the specific doors on a train with a platform next to them (a clear benefit to anyone inclined not to look before leaping). When the train crew release doors to be opened, only those doors with a platform next to them can be physically opened by the passengers. Likewise, doors without a platform next to them cannot be physically opened by the passengers.

The current manual SDO systems rely upon the train crew to control and monitor safe door-opening whereas an automatic SDO system is controlled by an on-board door control system that is independent of the train crew. The definitions for Automatic SDO and Manual SDO, as used by the UK railway authority (HMRI), are as follows:

1. Automatic SDO – any system in which the on-board computer on the train decides which doors to open at which platform, where the driver's role is limited to either operating the door release button or operating that button after confirming with the on board computer that the correct number of doors are being selected to be released at any particular station.
2. Manual SDO – any system, where the decision on which doors to open at any particular platform and the operation of those doors, rests solely with a member of the onboard train staff.

In many safety-related systems the dependence on human input is often a weak point of the system and a source of potential errors. For this reason, it is normal to attempt to remove humans from tasks that can be implemented by following a well-defined set of rules [2].

This paper explores the issues involved with the development and implementation of an automatic SDO system. Five technologies are presented to implement an automatic SDO system, in particular the SDO systems are based on Trackside Beacons, Global Positioning System, Distance Measurement, Route Tracking, and Platform Detection technologies. The costs and benefits of these systems are discussed along with recommendations for an optimal automatic SDO system.

Computers in Railways IX, J. Allan, C. A. Brebbia, R. J. Hill, G. Sciutto & S. Sone (Editors)
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2 Understanding the overall SDO issues

The issues to be considered when developing and implementing an SDO system are:

- Design of the station infrastructure;
- Design of the SDO system architecture;
- Reliability of the SDO system in service;
- Maintainability in terms of planned and unplanned maintenance;
- Safety of passengers disembarking the train; and
- SDO system costs throughout the development and operational lifecycle.

The station infrastructure such as the platforms and tracks needs to be considered as part of the development of an SDO system. The obvious solution is to extend the platforms to accommodate the length of the train, but there are many reasons why this may not be considered a viable option:

1. Platform extension costs cannot be justified for rural stations with low passenger utilisation;
2. Stations with high passenger capacity are often located in high-density city areas with limited space for platforms.

The SDO system can be developed and implemented in various ways. The components that contribute to the SDO system are:

- the onboard SDO control system including the hardware and software units;
- the train door system;
- train operating procedures;
- and the station infrastructure, i.e. trackside and platform side.

Complex systems are prone to failure, hence the complexity of an SDO control system should be kept to a minimum to improve the overall reliability of the system. Having said that, the SDO system architecture should be designed to withstand single failures and common cause failures (fault tolerant) to ensure a single SDO failure will not cause the train to be delayed or out of service [3].

The maintainability of the SDO system should be practical and cost effective throughout the SDO system operational lifecycle [3]. The time for maintenance should be defined, in particular:

- The time for planned SDO maintenance;
- The time for detection, identification and location of SDO faults; and
- The time for the restoration of a failed SDO system (unplanned maintenance).

Safe development and operation of a railway system is mandated by railway safety standards [3, 4, 5, 6]. Obviously this applies to an SDO system as an incorrect opening of doors could potentially lead to passengers falling out of a

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train resulting in an injury or even a fatality. A safety case is therefore required and the ease of producing an SDO system safety case should be considered. The use of Commercial off the Shelf (COTS) and/or Software of Unknown Pedigree (SOUP) may reduce development costs but could increase the cost of producing a safety case [5]. However, the use of known and proven technology could reduce both the development costs and the cost of producing the safety case.

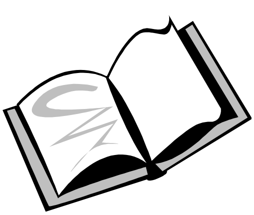
The stopping point of a train in relation to the platform is an important issue because an incorrect train alignment could position some doors that are allowed to be opened, without a platform next to them. Ideally the SDO system should be designed to cope with the train stopping at any point along the platform.

The financial costs, in terms of the development and implementation of an SDO system, vary according to its design. The cost can be minimised by considering the use of existing and proven technology along with appropriate train operating procedures. The major factors which contribute to the cost of an SDO system are:

- Modifications required to the existing infrastructure, station and/or trackside.
- Requirements for additional trainbourne equipment.
- Design and development of the SDO control system, particularly in respect of any data required for correct operation.
- Maintenance of the SDO system units throughout the operational lifecycle.

3 Methods of implementing an SDO system

3.1 Existing manual SDO systems



Safe door-opening is controlled and monitored manually by the train crew.

Existing manual SDO systems rely upon the train crew to control and monitor safe door opening. This manual arrangement is operated by the following procedure:

1. Passengers are notified, prior to station arrival, as to which carriage to exit the train, usually this is towards the front of the train.
2. The train is then “parked” at the stop point on the station platform which is usually at the front end of the platform.
3. The train crew then finally, through a manual control system, release all doors that can be opened, from the last door on the platform to the front of the train.

This manual system requires a very simple door control system with no interaction with the station.

As the door control system is a fairly simple system it has a low probability of hardware or software failure. However, it relies heavily on manual intervention by the train crew.

The safe use of a manual SDO system is accepted within the railway industry but UK Railway standard [1] now mandates that after 5 February 2005 all new trains must implement an automatic SDO system to provide safe door-opening. There are many possible ways of implementing an automatic system some of which are discussed below:

3.2 Trackside beacons

Trackside beacons at a station communicate with the train's onboard door control system to inform it which platform it has arrived at thus allowing it to determine which doors are allowed to be opened according to platform length.

This SDO solution uses a beacon transponder, within the station infrastructure, which communicates with the train to identify the station platform. The onboard door control system can then determine which doors are allowed to be opened by referring to a database of station platform lengths.

Such a system would be relatively complex as it requires both trackside and trainbourne beacons as well as a door control system. Whilst the reliability of each beacon may be high, beacons would be required for each train as well as each platform at each station. Hence the reliability of the overall system would be much lower.

The use of trackside equipment also reduces the maintainability of the system as safe maintenance would require the closing of the appropriate section of the track.

Beacons are widely used in rail applications such as Train Protection Systems (TPS) and Automatic Train Operation (ATO) systems. The Strathclyde Passenger Transport Glasgow Subway railway system uses beacon technology for its safety-critical ATO and Contactless Train Stop (CTS) systems.

The database of station platform lengths must also be assured to guarantee that the correct platform length is used at the correct station so that the right number of doors is released.

Misalignment of the train to the platform could be designed-out as the beacon system has the capability to give the absolute position of the train in relation to the station platform. However, this would require a relatively short communication range so the train would always have to stop within a short range of a fixed position on the platform.

Whilst a beacon system may remove the need for manual intervention by the train crew and appear to be a relatively safe option, there would be a considerable cost incurred with implementing a system that requires equipment to be installed on every platform as well as on every train. Added to this, there

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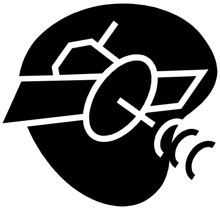
would also be the cost to develop the SDO control system and maintain the database that would have to be installed on each train.

3.3 Global Positioning System



The train position is determined using the Global Positioning System (GPS) so that the train's onboard door control system can derive which station it has arrived at and therefore permits which doors are allowed to be opened.

This solution uses GPS to determine the train's position in conjunction with a database containing the GPS co-ordinates and platform lengths of all required railway stations. Upon arrival at a station the train determines its location and using the platform lengths from the database for that location, identifies the correct number of doors to be released.

It is well known that GPS does not have 100% signal coverage because there are locations where the GPS satellite signals cannot penetrate surrounding infrastructures (e.g. tunnels and large building). Therefore, another means of identifying station platforms may be required when GPS signals cannot be received from the orbiting satellites.

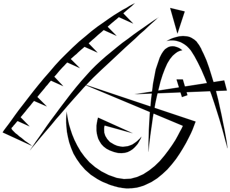
Whilst the GPS system in itself may be accurate to within a few metres it is not yet considered a safe system. Hence, a safe SDO design is unlikely to be able to exploit this accuracy and GPS may only be suitable to identify the location of a particular station rather than a specific platform. For the majority of stations this is acceptable, and only becomes an issue at a station with multiple platforms of different lengths.

As this system is a wholly trainbourne solution, there would be no need to maintain any station or trackside equipment. However, there is the issue of maintaining the database of platform lengths.

GPS technology is widely used in many industries including railways, so it is a relatively cheap and simple technology to implement. The main cost of such a system would be incurred during the development of the SDO system.

Whilst a GPS system dramatically reduces the amount of manual intervention it cannot eliminate it on its own as there are stations where GPS signals cannot be received. It is, however, a relatively cheap option, given the level of automation it can achieve.

3.4 Distance measurement



Distance travelled between station platforms is measured so that the train position can be determined. The train's onboard door control system can work out which station it has arrived at and therefore determines which doors can safe be opened.

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Once a reference location is confirmed the distance travelled by a train can be used to determine the next location, by looking up a database of distances between all station platforms. This SDO system cannot cope with multiple destinations from the same starting point that are similar distances away.

Distance measurement technology is commonly used by a train to record the distance travelled for train maintenance purposes. However, the distance travelled measurement is prone to inaccuracy due to wear and tear of the wheels and wheel slippage during braking and traction. Other inaccuracies can be compounded by the train control system caused by inadequate distance measurement processing.

The accuracy of distance measurement is a major safety factor for this system, since slight erroneous measurement can determine a wrong platform location therefore potentially leading to unsafe conditions. Hence, this type of system may not be viable for use in heavily populated areas, where stations are often relatively close together and similar distances away from each other.

There are no substantial costs within the station infrastructure, door control hardware system, and routine maintenance but there is a significant cost in developing the SDO system and gathering a database of distances between all serviced stations as well as platform lengths.

Whilst distance-travelled measurement makes some improvements on the manual SDO system by reducing the need for train crew intervention, the absolute location cannot be determined without intervention from the train crew. Hence, it is not considered a viable option on its own nor in conjunction with other solutions as there are cheaper more accurate solutions available.

3.5 Route tracking

The train route is tracked between station platforms so that the next destination can be determined. The train's onboard door control system releases the correct doors for the platform according to its length.

The train determines the destination by referring to the last known station the train departed from. Once a reference location is confirmed the next possible destination can be determined by referring to a database of pre-defined train routes. The database also contains platform lengths of the serviced train routes, so the door control system determines the correct doors to be opened for the platform. The disadvantages of route tracking are associated with accommodating multi routes, diversions or unexpected route changes. Also this system cannot confirm the absolute location which must be confirmed by the train driver.

This system cannot easily adapt to slight to changes in train routes because the routes are fixed when the train is put in service. Database maintenance is

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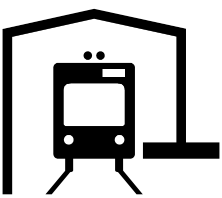
required every time a change is made to the train routes or platform lengths. This may be as often as every timetable change.

Route tracking is the simplest and cheapest system to implement compared to other automatic SDO systems. The door control system requires a relatively simple database of train routes and platform lengths to open the correct doors for a platform. This system could incur substantial costs if there are many changes to the pre-set train routes or platform lengths.

On its own this system cannot ensure adequate safety because the absolute location cannot be confirmed unless verified by the train driver, although a slight variation on this theme may be suitable for use in conjunction with other methods. It does, however, provide a slight advantage over the existing manual systems in that it could be used to prompt the driver as to the train's current location.

3.6 Platform detection



Doors are only allowed to open when a platform is detected outside.

A platform detection system only permits doors to be opened when a platform is detected directly outside the door. Each door has a platform detection device so that it can, per individual door, allow safe door opening when a platform is detected. The doors are independent from each other so that a failure in a single door will not affect the operation of the other doors. A central control system could also be used to reduce wrong-side failure of the individual door system by ensuring that a door does not open if both adjacent doors do not detect a platform.

This type of system is not widely used in the railway industry, hence the reliability of platform detection technology is unknown. For this variant, it can be argued that a single platform detection failure will not put the train out of service as each door has its own platform detection decision making device.

Arguably this solution, compared to the other automatic SDO systems, is the safest way of ensuring that a door is on a platform, because this is the only method of detecting a platform is physically present outside the door. For the same reason the correct alignment of the train to the platform is not an issue for this type of system because each door independently permits safe door-opening when a platform is detected outside to the door.

Whilst there may be a substantial cost associated with installing such a system on each door, there is no requirement to develop or maintain a database of train routes and platform information. Once the system is installed it can be easily maintained within normal maintenance regimes.

This is the only SDO system that is totally independent of the train crew. It is not dependent on train position relative to the platform, does not require

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confirmation of the train's location and does not require a database of information relating to platform lengths or train routes.

4 Discussion

This paper presents five different SDO systems to satisfy the mandate placed by the UK Railway Standard [1]. These SDO systems are based on Trackside Beacons, GPS, Distance Measurement, Route Tracking, and Platform Detection technologies where each system made improvements over the current manual SDO system by reducing or removing human input to the system. Each system is shown to have its advantages and disadvantages in terms of the issues described above:

- Design of the station infrastructure;
- Design of the SDO system architecture;
- Reliability of the SDO system in service;
- Maintainability in terms of planned and unplanned maintenance;
- Safety of passengers disembarking the train; and
- SDO system costs throughout the development and operational lifecycle.

Only two of the systems can, on their own, completely remove the requirement for manual intervention. The installation of beacons throughout an existing network is probably not a viable solution from a practical and cost point of view. Whilst platform detection would appear to be the best solution, it is new technology and no known system exists so the costs of implementing this type of system are unknown. GPS is a relatively cheaper technology to use but can only work in areas where GPS signals can be received. Although Distance Measurement and Route Tracking require no external interfaces, Distance Measurement has a problem in distinguishing stations that are similar distances apart and Route Tracking systems cannot confirm an absolute location without manual intervention.

If restricted to the use of current proven technologies then the implementation of any individual solution alone cannot fulfil all the issues, although a combination of several approaches could provide the optimal safe, cost effective, reliable, and maintainable SDO system.

The combination of the Beacon, GPS, and Route Tracking systems seems to be the most effective combination. When GPS is unable to receive positioning signals, due, for example, to infrastructure blocking satellite signals, trackside beacons can be employed to identify the station platform location. The route tracking system can act as second-line station platform verification where a disagreement could prompt the train driver for confirmation of a particular platform location.

Railway standards mandate that train operating companies, station infrastructure companies, and train door manufacturers resolve SDO issues and define strategies to develop and implement an effective SDO system to suit different types of railway systems.

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Our money is on the first door manufacturer to build a platform detection system into a door module that can be installed on any train.

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