

WHITE PAPER

Do you really need a fallback system* with Communications-Based Train Control (CBTC)?

*secondary train detection and separate interlocking



Introduction

Urban rail operators face huge operational and financial pressures. On the one hand, they need to take advantage of advanced technology to grow revenues and boost performance on new and existing lines. On the other, they need to justify every penny they invest as they confront growing budgetary constraints.

Modern signalling – Communications-Based Train Control (CBTC) – holds the key to balancing these competing demands. CBTC delivers benefits that cannot be realised using traditional block signalling. Among these are extra capacity, enhanced reliability and better safety. CBTC also reduces operating costs – an increasingly urgent need.

But what about the capital cost of implementing CBTC?

A major pain point for many operators is the extra cost of providing a so-called “fallback” signalling system in parallel with CBTC. A fallback system comprises either a secondary train detection system, or a secondary train detection system plus separate interlocking.

Fallback systems come with an enormous price tag, dramatically increasing the overall signalling cost. They make projects much more complex to design and implement. They also impose a significant maintenance burden.

Yet there is no need for a fallback system in most cases.

The purpose of this white paper is to set out the case for implementing “pure” CBTC, without any fallback. In the following pages, we explain what is meant by the term “fallback system” and why some operators believe they need one. We show how a correctly implemented CBTC system can be operated successfully without the need for fallback. Finally, we examine some of the drawbacks that surround fallback systems – including the additional costs and risks that such systems can bring.

What is a fallback system?

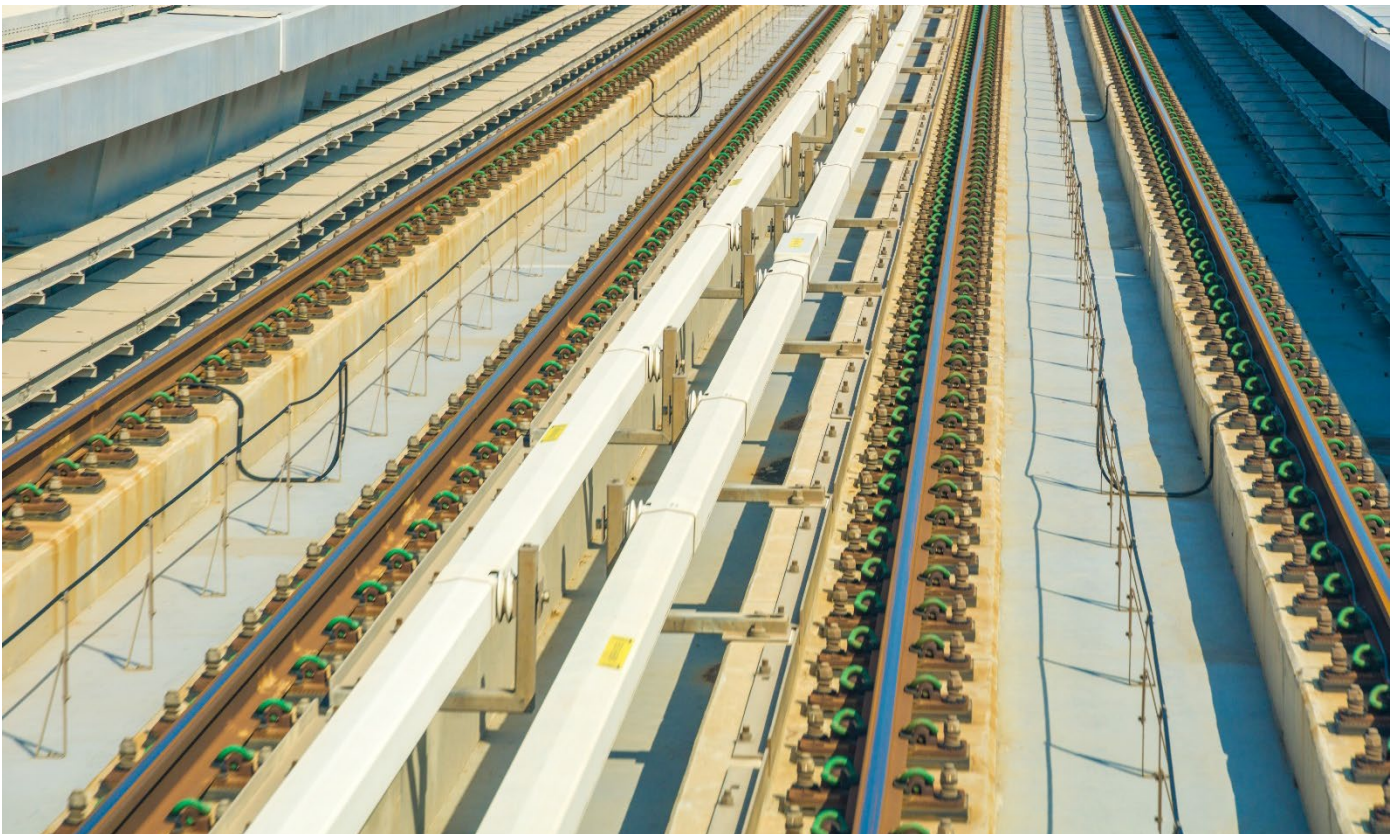
When installing a CBTC system, either for a new (Greenfield) line or for an existing (brownfield) one, operators may request that a “fallback” system is provided. A fallback system is a shadow or backup signalling system.

The idea of a fallback system is to take over some or all of the signalling functions if there is a problem with the CBTC system, or if it is necessary to handle an unequipped (non-CBTC) train. The fallback system exists in parallel with and in addition to the CBTC system. Although the fallback system is inactive most of the time, it has an active interface with the CBTC system.

There are two possible approaches to fallback when it is applied to a CBTC system:

Secondary train detection only?

The aim here is to be able to “see” the position of a train (or trains) if the CBTC’s on board equipment or train-to-wayside communication fails and the train becomes non-communicating. To achieve this, the track is equipped with a train detection system using axle counters or track circuits. These are capable of providing an indication of the position of any train (whether equipped or unequipped) within geographical blocks determined by the position of the axle counters or track circuits. Data from this system can be used (i) as an input to the CBTC Zone Controller and (ii) to provide a visual indication of the position of trains on the ATS system or via a separate panel. No fallback interlocking is provided. Capacity under this configuration is severely restricted. Figure 1 illustrates one possible configuration with axle counters at stations and junctions on a notional 2 km stretch of metro. This configuration may be provided with or without wayside signals.



Secondary train detection plus separate interlocking

The aim of this is to provide a fallback signalling system in case there is a failure of the CBTC Zone Controller. In this configuration, the CBTC system is overlaid on top of a separate fixed block interlocking. Train route requests are sent from the ATS to the interlocking, and CBTC override commands are sent from the Zone Controller to the interlocking in order to improve system performance. In the event of a CBTC system failure, the fixed block signalling remains in place. Trains can then continue to operate under traditional block signalling, although the line will have much diminished capacity in most cases. This model comprises a secondary train detection system (as above, using axle counters or track circuits), lineside signals and separate interlockings. Figure 2 illustrates a configuration with typical headways under block signalling. For comparison, Figure 3 shows the same section of track under CBTC operation with safe separation (and much shorter headways) made possible by moving block.

In Greenfield projects, the fallback system is provided as all-new infrastructure. In brownfield projects (i.e. those where a line is being resignalled), the existing train detection system and interlocking is sometimes retained to act as a fallback system.



Figure 1. Fallback with secondary train detection at stations and junctions only

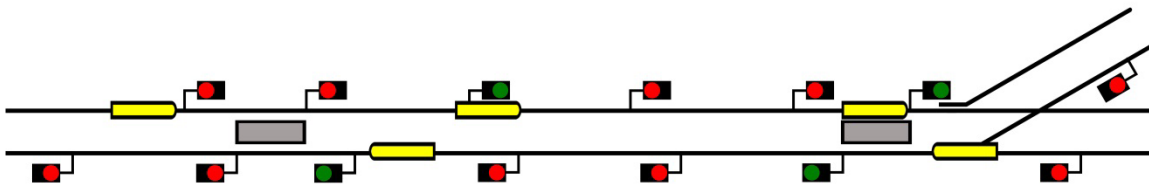


Figure 2. Fallback with secondary train detection and signals

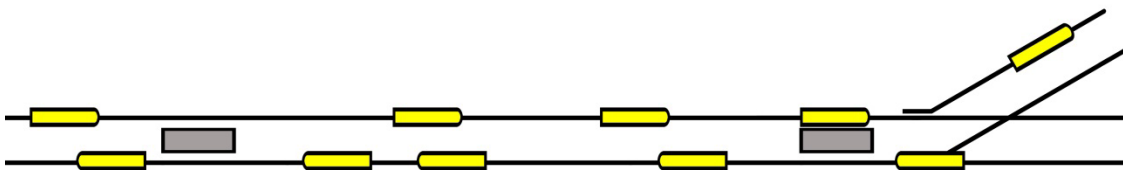


Figure 3. Normal CBTC operation with no fallback

Why do operators want fallback systems?

The rail industry has a long history of safety innovations. One example is the track circuit, developed more than 150 years ago and still used today. Rail operators, particularly those of mature networks, are understandably reluctant to relinquish technology that has proven itself over such a long period of time.

While the preference for established ways of doing things is understandable, CBTC is itself an established technology with a track record that stretches back 35 years. Today, more than 200 metro lines worldwide use CBTC as their primary signalling and train control system. There is no technical requirement for fallback in CBTC systems.

Despite this, some operators still request the provision of a fallback system. When a fallback system is requested, it is generally for one or more of the following reasons:

Maintain revenue operations if CBTC fails

A fallback system is sometimes installed as a backup in case CBTC fails. The aim is to minimise or eliminate disruption to normal revenue services. This is achieved by switching over to the secondary system. The argument in favour of this approach is based on two assumptions. The first is that the CBTC system might fail (and might do so often enough to justify investment in a secondary system). The second assumption is that if CBTC did fail, the fallback system would be capable of providing a reliable and reasonable standard of service.

Accommodate unequipped trains

A fallback system is sometimes provided to accommodate non-communicating trains, i.e. trains that are not visible to the CBTC system via the usual mechanism of train-to-wayside radio communications. Typically, these are unequipped engineering (work or maintenance) trains that operate during non-revenue hours. The argument in favour of fallback in this scenario is based on the assumption that the operator would choose not to equip all the trains expected to use the line. The second assumption is that unequipped trains would be completely invisible as far as the CBTC system is concerned.

Detect broken rails

Secondary train detection using track circuits is sometimes seen as desirable because it can be used to detect broken rails. The argument in favour of this approach is based on the assumption that track circuits provide a reliable means of detecting rail breaks.

On the face of it, the arguments in support of fallback seem strong. However, in the next section, we show that there is a stronger case for not deploying a fallback system.

Managing operations without fallback

How can revenue operations be maintained if CBTC fails?

A key question for operators is how to maintain services if CBTC enters degraded mode – i.e. if there is some loss of functionality. One of the biggest concerns is how to deal with a train that becomes non-communicating. How can this be managed if there is no fallback system?

Features inherent in the CBTC Automatic Train Supervision (ATS) system and effective recovery procedures hold the key.

In the event that a train becomes non-communicating, its last position is recorded and displayed via the ATS system. Meanwhile, the train is allowed to proceed to the limit of its movement authority before stopping safely. If the movement authority extends to a station, the train can be held there until the issue is resolved.

Safety is maintained at all times. A protective envelope is automatically created around the non-communicating train; trains to the rear have their movement limited by a safe stopping distance from the last confirmed position of the non-communicating train. Health monitoring solutions within the CBTC system detect communication failures and notify the control centre to initiate maintenance and repair activities.

If the fault cannot immediately be resolved, passengers are detained. The ATS operator then uses the Manual Route Authorisation function within ATS to reserve a safe route. This allows the non-communicating train to be driven manually off the active guideway or to the depot (Figure 4).

This scenario should be so rare in a properly designed, redundant CBTC system that there is little justification for the additional expense and operational impact due to secondary detection and interlocking equipment.

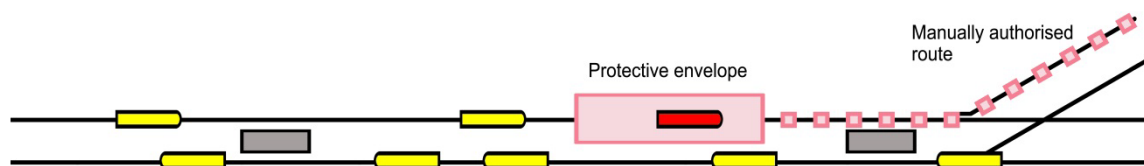


Figure 4. Non-communicating train: protective envelope and Manual Route Authorization

How can unequipped trains be accommodated?

Unequipped trains are typically engineering (work or maintenance) trains that operate during non-revenue hours, as noted above. These trains can be safely managed using the Manual Route Authorisation functionality within ATS, without the need for secondary detection. As with non-communicating trains (described above), Manual Route Authorisation creates a protected corridor for an unequipped train.

This mode of operation is acceptable for train movements in non-revenue hours. However, because Manual Route Authorisation can have the effect of tying up lengthy sections of track, it is generally not suitable for use during normal traffic hours. With many metros switching to 24/7 operations, operators are increasingly looking to equip their engineering fleets for CBTC operation. It should be noted that the cost of converting engineering vehicles is likely to be less than that of providing secondary detection.

How can a broken rail be detected?

A broken rail can be detected by a track circuit, but only under certain circumstances. While broken rail detection is seldom seen as the sole justification for retaining or deploying track circuits, it is sometimes used to support the wider argument for secondary train detection.

Given the risks associated with broken rails, and the limitations track circuits have in detecting them reliably, a systematic approach to rail condition monitoring based on ultrasonic inspection should always be considered as the first preference. This approach has the advantage of detecting flaws before the rail breaks.



What are the arguments against fallback?

As the previous section shows, appropriate operating procedures combined with ATS functionality makes it possible to manage a CBTC line in degraded mode without the need for secondary train detection or external interlocking.

However, there is an additional dimension to the fallback story: not only does implementing secondary train detection and interlocking incur extra costs, it can also undermine rather than improve reliability.

a) System cost

The biggest drawback with fallback systems is the cost of the extra hardware required. This includes the purchase and installation of axle counters or track circuits, interlocking hardware and lineside signals. Setting up a fully-specified fallback signalling system is enormously expensive; the provision of secondary train detection alone adds approximately 5% to the cost of the total signalling solution in a greenfield project.

The need to integrate the secondary system with CBTC adds a further layer of cost and complexity.

Beyond that, there are the ongoing operational and maintenance costs of equipment that would otherwise not be required. Secondary detection, for example, will typically increase maintenance costs by around 5%. Since the profile of this type of equipment can differ significantly from modern CBTC hardware platforms, extra care should be taken to analyze the life cycle implications and costs of additional equipment. Factors include obsolescence timelines, typical failure modes, maintenance costs, workforce expertise and power consumption.

b) System performance

CBTC systems benefit from the proven approach of implementing moving block technology from end-to-end to ensure safety and reduce headway. Using an external interlocking undermines that approach because it creates delays in the process of advancing a train's movement authority, even when the interlocking has been optimized to accept override commands from the CBTC system.

c) Additional complexity

When non-communicating trains are managed by an external interlocking, the equipment (signalling, detection and switching) must operate independently of the CBTC system. When CBTC-controlled trains operate in the same area, those fixed block interlocking functions must be overridden to align with the CBTC system operation. Since both systems should be implemented in "hot standby" redundant configurations, there are multiple communication channels and relationships that must be maintained. Similar complexities exist for supervisory and system functions, such as health monitoring and remote configuration/update. As well as introducing additional risk, it can limit or complicate future system and functionality upgrades.

The provision of an external interlocking also has implications for cybersecurity. Complexity opens up new vulnerabilities: the proliferation of interfaces and hardware means that the combined signalling system has a large attack surface and this can be difficult or impossible to cyber-secure in a satisfactory manner.

d) System availability

The inclusion of a secondary detection system can have a significant impact on overall system availability. If the secondary system (track circuits or axle counters) has a higher failure rate than the primarily digital CBTC equipment, it will drive down the overall system availability. It is worth noting that track circuits are a single point of failure; by contrast the “detection” component of CBTC (digital radio) is fully redundant. In addition to increased maintenance and repair costs, secondary detection can lead to an increase in service interruptions and delays.

In situations where secondary detection systems are installed but used infrequently, there is the additional requirement to ensure that such equipment is monitored and maintained at regular intervals to ensure proper functionality when it is finally called into service. Similarly, procedures are required to ensure that relevant personnel are up-to-date on system functionality and processes when required. Training and refresher courses are therefore vital for ATS operators, train operators and maintenance staff.

e) Project implementation

The additional complexity of integrating fallback, mentioned above, typically results in longer timeframes and higher costs, both during project design and installation. It also prolongs the process of gaining safety case approval. On top of this, it undermines a key early-stage benefit of CBTC: this is that CBTC, in its pure form, is designed to be implemented with minimal disruption to revenue operations. In a pure CBTC brownfield implementation, none of the existing signalling and detection equipment is retained. The only interface between old and new is with the point machines. Onboard equipment can be installed on trains which are run in “shadow mode”, monitoring and validating the CBTC system prior to switchover. Once ready, the switchover to CBTC can be implemented in a shorter time frame and in a manner that suits the operator.

Conclusion

Secondary train detection and traditional interlocking can seem to be an appealing approach to managing non-communicating trains in a CBTC environment. However, the risks and costs are significant. Any proposal to use a fallback system should therefore be carefully evaluated.

For lines that will exclusively run CBTC-enabled trains, there is limited value to be found in implementing secondary detection systems, compared to the additional cost and complexity. There also remains the risk that the secondary system will mask operational deficiencies that should be addressed by a properly implemented CBTC system.

For lines where the regular use of non-CBTC trains is anticipated, a careful analysis of the major drawbacks described in Section 5 can help facilitate a trade-off analysis that considers equipping all trains for CBTC operation, rather than limiting the performance of the line overall with a complex and costly hybrid signalling system.

About Thales



Communications-Based Train Control (CBTC) was pioneered by Thales and first implemented in 1985. Today, our SelTrac™ CBTC solution is used on more than 100 metro lines worldwide making it the world's most widely-adopted CBTC solution for urban rail.

Thales has more experience in delivering fallback-free CBTC than any other supplier. Our projects include the very first implementations of pure CBTC, without secondary detection and without traditional interlocking. More than three decades on, we have implemented more than 15 lines which operate without fallback.

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