Signalling the Layout

Nari Bandi (partly based on the former module 2 study guide)

Essential reading text for students of the IRSE Certificate in Railway Control Engineering Fundamentals (Module A) from October 2025 exam

Railways require signalling because many trains need to use the same tracks, drivers of trains cannot "steer around" other trains or obstructions, and the braking distance of a train is greater than the distance that the driver can see. The signalling must also deliver the train capacity required for the line. Therefore, the signalling of the track layout is critical.

1. <u>Purpose of Signalling and Functions</u>

The key purposes of a signalling system are listed below. These include certain functions which were in the past managed largely or entirely by procedure, but are now generally regarded as essential functions of the technical signalling system.

- ❖ Set up a safe route for the passage of each train over the track that it is to traverse.
- ❖ Authorise the train to make the movement.
- ❖ Maintain the route while the train is making its movement.
- ❖ Supervise and/or enforce the train to stay within its movement authority.
- ❖ Release the route (for use by other trains) after the passage of the train".

Functions have been further added which may include:

- The train driver (or ATO system) should be provided with appropriate information to control the train.
- Sufficient space should be provided between following trains to allow each train to brake to a stand safely.
- Controls should be in place to prevent or mitigate the consequences of:
    - ✓ Trains passing the end point of their movement authority.
    - ✓ Trains exceeding the maximum permitted speed.
    - ✓ Trains moving without authorisation.
- Protection should be provided for the public and trains at level (grade) crossings.
- The means should be provided for protecting trains, worksites, and workers during engineering works.
- The signaller should be provided with appropriate information to enable the safe authorisation of train movements.
- The system should have facilities to communicate between the signaller and others.
- Means should be provided to prevent trains being signalled onto lines with which they are incompatible.
- Facilities should be provided to instruct a train to stop in an emergency.

2. <u>Movement Authority</u>

- A Movement Authority (MA) is an authority communicated to the driver (or to the ATO system driving the train) by the signalling system after it has checked that the section of line is clear and secure. This grants permission for a train to enter a particular section of line. Communication to the driver may be by means of lineside signals, or via an in-cab display (or sometimes both).
- A MA will have some limits associated with it, which may be:
    - ✓ Speed at which the movement may proceed.
      ("Speed" signalling systems favoured in many parts of continental Europe)

- ✓ Route and Distance to the end of the movement authority.
  (“Route” signalling systems – favoured in the UK and parts of the world historically closely associated).
- Traditionally a movement authority is communicated to a driver by means of a lineside signal displaying a “proceed” aspect with the end of a movement authority indicated by a red lineside signal aspect.
- The nature of the “proceed” aspect provides information about the limitations associated with the movement authority. (“Speed” signalling or “Route” signalling). Except where the driver can always see the end of movement authority from at least the braking distance (slow speeds and good braking, start from rest) some form of restrictive (cautionary) aspect is necessary.
- Certain MAs permit a train to enter a section of line that is already occupied by another train to allow trains to join, or to share platforms. The communication of these MAs to the driver includes the fact that the line ahead is occupied. Otherwise train separation is important, see section 3.

3. <u>Train Separation</u>

To avoid collisions, it is essential to maintain a safe distance between trains. The most common methods are described below.

3.1 On-sight train control

On tramways and on certain railways there is little benefit in providing a comprehensive signalling system. Rail traffic speeds, frequency, and braking performance may be such that safe operation can rely on the driver being able to observe that the track ahead is clear.

3.2 Fixed block working

Railway lines are divided into “block sections” and in general only one train is permitted to occupy that section of line at any one time. On low density lines a block section might be tens of kilometres, whereas at the other extreme, on a very high-density metro line, a block section might be much less than the length of a train.

One exception is that certain MAs permit a train to enter a section of line that is already occupied by another train to allow trains to join, or to share platforms and sidings.

Lineside signals usually define the start and end of a block section and provide authority to enter the section. Towards the end of a movement authority, lineside signals specify where to stop and also give adequate prior warning of this. Where signals are not provided, the movement authority and the remaining distance to its limit is given via some kind of in-cab display and/or an ATO (automatic train operation) system, or by a verbal instruction. The following safe separation methods are based on fixed block working. For new projects, Absolute Block Working has been largely superseded by Track Circuit Block working, which is now evolving into ETCS.

- **Absolute Block working:** The signallers at the entrance and exit of the block section must follow a strict procedure to authorise a train to enter the block section and to confirm that the complete train has left it (e.g. by observing the tail lamp on the back of the train). The length of block sections is dependent on spacing between signal boxes, which is often dictated by the distances between junctions, stations or level crossings. In most installations, electric block instruments are used. Typically, these are interlocked with signals and isolated train detection sections on approach to the signals at the exit of the block section to enforce elements of the absolute block working regulations.
- **Track circuit block working:** Track circuit block signalling is a development of absolute block signalling where the line is divided into reasonably uniform, and often much shorter, blocks between adjacent stop signals, increasing the line capacity compared with absolute block signalling. Only one train is permitted per block section, usually defined as between one stop signal

and the extent of the overlap (which is a safety margin) beyond the next. It requires continuous train detection, which may be by track circuits or axle counters.

Where movement authority is given to drivers via lineside signals, the signals can only transmit a limited number of different instructions to the driver. The meaning of each signal aspect must be clearly defined in the driver's rule book. The information presented differs significantly between different countries and between route and speed signalling. There is often more than one caution signal before approaching a stop aspect.

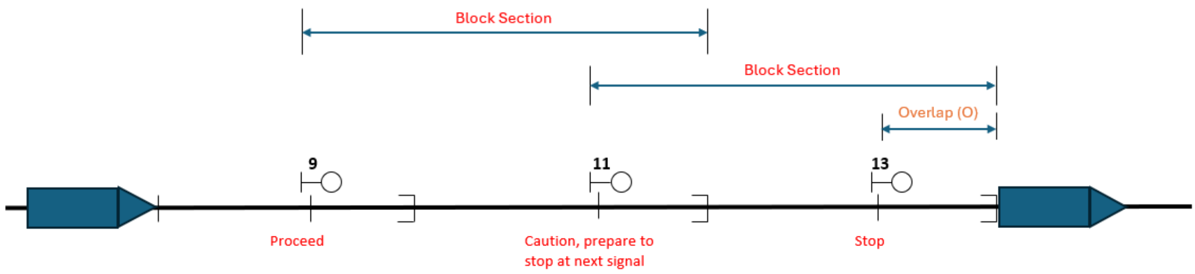

Figure 1: Track Circuit Block with lineside signalling

3.3 European Train Control System (ETCS)

This is the signalling component of the European Rail Traffic Management System (ERTMS). Unlike CBTC systems, which are currently unique to each supplier, the ETCS is designed to be an interoperable suite of products allowing trains to operate across borders without any country-specific equipment and for one supplier's on-board equipment to work with a different supplier's fixed signalling.

ETCS specifies several different "levels" and variants, the most significant ones are:

- **Level 0** is used to refer to an ETCS fitted train using infrastructure not fitted with train protection or when operation in higher levels is not possible.
- **Level NTC** is used by an ETCS fitted train when operating over a line which is only equipped with the National Train Control system (Class B). Such systems in the UK are AWS/TPWS, in Germany LZB and in Belgium Crocodile/TBL.
- **Level 1** provides in-cab signalling and ATP (Automatic Train Protection) in conjunction with fixed block lineside signalling including train detection. Data is passed to trains from switchable/controlled balises, inductive loops, or possibly radio.
- **Level 2** provides fixed block signalling and in-cab displays with conventional train detection. Communication is mostly through radio communication (GSM-R [Global System for Mobile Communications – Railway]), with balises used for fixed information (such as absolute position). Lineside signals are only required if used as a solution for migration, or for allowing non-ETCS trains to run on the same lines.
- **Level 3** is a term which formally became obsolete in baseline 3 (which subsumed it into Level 2) but is frequently still used to distinguish the circumstances in which conventional train detection is not required because reliance is placed on the on-board position reporting and train integrity monitoring. There are no lineside signals and moving block signalling is possible, although not necessarily implemented.

3.4 Moving Block working

The signalling system calculates the safe space between a train and the one it is following. This requires continuous communication between the central signalling system and the On-Board system which supervises the train speed to maintain safety. The "blocks" are now a moving safe zone round each train; the length of the safe zone ahead of the following train depends on its speed, along with all the other factors that affect its braking distance. Therefore, a following train can be allowed to approach very close to the rear of a stationary preceding train (e.g. when it has stopped in a station) because its required braking distance decreases as its speed drops.

Moving block allows trains to safely run closer together because the relative positions of two trains can be determined with greater resolution than with track circuits or axle counters. This can increase the line's overall capacity. It is most beneficial for mass-transit railways where platform dwell times are a large component of achievable headway. On mixed traffic lines it can still be valuable, but it provides less benefit because the line capacity is more affected by the shared use of the line by trains of different speeds, braking characteristics, conflicts at flat junctions (metro railways generally have grade separated junctions, mainline railways have far fewer) and station stopping patterns.

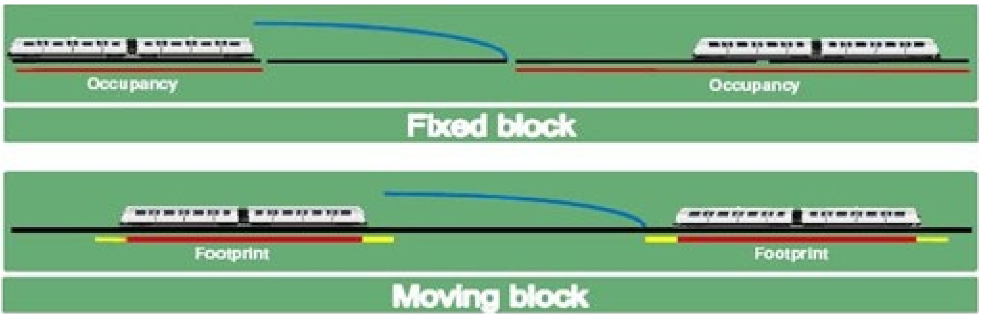

Figure 2. Comparison between fixed and moving block (does not show safety margins)

3.4.1 Communication Based Train Control (CBTC)

CBTC covers a wide range of bespoke signalling solutions from a variety of suppliers, particularly used on metro lines and generally has these characteristics:

- Automatic Train Protection (ATP) & Automatic Train Operation (ATO)
- Movement authorities are given to drivers via a display in the driving cab instead of lineside signals.
- The train-borne equipment communicates with fixed equipment on the lineside by radio. Other communication methods have been used such as inductive loops in the track, these are generally referred to as TBTC (Transmission Based Train Control)
- Train position determined by the train itself (via a combination of fixed position references such as balises, with subsequent estimation of the distance travelled primarily by wheel odometry but supplemented by an independent method such as accelerometers) and then communicated to the central signalling.
- No requirement for lineside train detection (track circuits or axle counters) for normal operation, but a certain amount is often provided for use in degraded modes, particularly when any train becomes “non-communicative”.

In addition to the capacity increase, a useful benefit of CBTC is the reduction in the quantity of lineside equipment which offers maintenance and availability advantages (since otherwise it is often widespread and in places that are difficult to access).

Within the implementation of CBTC, signalling the layout is a relatively minor consideration compared with other key considerations such as: the reliability and capacity of the communications medium, the precision and certainty of a train’s footprint and recovery scenarios should a train cease communicating, or a failure affecting a whole area.

4. <u>Braking</u>

4.1 Significance of Braking

A feature of railways is the low friction between steel rails and steel wheels; this has energy-saving advantages but means long distances to stop are required due to the limited adhesion. This can cause slips (as the train accelerates) and slides (as the train decelerates) which is a factor that onboard CBTC/ETCS needs to take into account (uncertainty is shown yellow in Fig 2).

Trains can also be extremely heavy and/or travel at considerable speeds; a moving train therefore has significant momentum and there is a lot of kinetic energy to convert to other forms of energy during the process of stopping a train.

Hence, Braking Distance (BD) (i.e. the distance required for a train to brake to a stand from its highest permissible speed at that position) is an important consideration within the design of a railway system to realise the key requirement: “Sufficient space should be provided between following trains to allow each train to brake to a stand safely”.

Essentially this means that the signalling system has to communicate to the driver (or entity driving the train) that they are approaching the end of their movement authority in sufficient time and distance to enable the train to brake safely before it in all circumstances.

This can be achieved by:

- Lineside signal aspects – (giving cautionary signal aspects- with speed or distance meaning).
- In cab displays - (reflecting a braking curve- with speed or distance meaning).
- Communication with an ATO system.

4.1.1 Factors affecting Braking Distance:

Braking distance depends upon:

- Permitted speed of the train at the place that braking commences.
- Braking rate of train (The braking performance of trains on a particular route is a key defined interface between the rolling stock system and the signalling system).
- Likely adhesion conditions between the train wheel and the rail (affected by weather or oil contamination that might cause slip/slide).
- The likely reaction time of the driver.
- Brake build-up delay, i.e. the time during which the brakes gradually become increasingly effective after having been initiated by the driver (this depends on the design of the braking system, the length of the train and is a particularly relevant factor for long freight trains).
- Effect of a rising or falling gradient on the effective braking rate. Clearly, a train travelling on a rising gradient will be able to stop in a shorter distance and conversely will take a longer distance on a falling gradient.
- Train achieving specified performance throughout its life (wear & tear, some brakes potentially isolated).
- The comfort of passengers.

The braking distance of a train in normal operation, taking into account all these factors is usually referred to as a Service Braking Distance (SBD), whereas a train making an Emergency Brake application would generally be able to stop in a significantly shorter distance. The SBD is utilised in laying out signals but note that the spacing between block signals could be longer or shorter than SBD (see Fig 4).

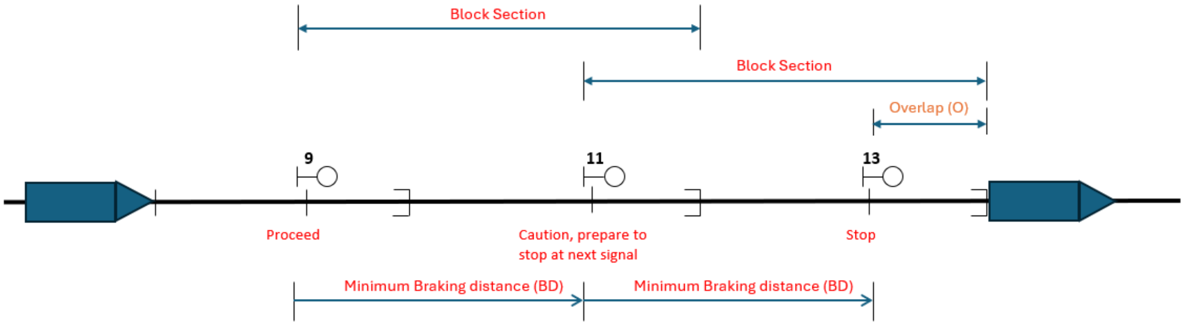

Figure 3: Scenario in which block sections are longer than Braking Distance

Equation of BD: In principle (see 4.2), Braking Distance is proportional to the square of its initial speed and dependent on the nominal braking rate of rolling stock (which in reality varies with speed and also takes time to reach full effectiveness).

$$\boxed{BD = \frac{U^2}{2.b}}$$

BD = Braking Distance (assuming level track)
U = Initial speed
b=Braking rate

4.2 Specification of Braking Rates / Braking Distances

In reality braking distance assessment is much more complex than the simplistic example above. Different railways use a variety of approaches, generally based on empirical evidence.

Mixed traffic railways have to be catered for the often widely different braking characteristics of modern passenger rolling stock and heavy freight trains. This is most commonly done by:

- Calculating braking distances for higher speed passenger trains, laying out signals to suit these distances, and then limiting freight trains to a speed at which they can stop within these distances.
- Calculating braking distances for freight trains, laying out signals to suit these distances, and then accept that passenger trains will have excessive braking distance.

Unless used in conjunction with lineside signals, ETCS/CBTC is not constrained to fixed positions, with each train determining where to commence braking according to the specific circumstances and thus these trade-offs do not need to be made.

5. Aspect Sequences

Each railway administration has developed its own bespoke series of signal aspects with defined meanings and the permissible sequence of aspects that can be displayed at successive signals. Their meanings can be categorised as:

- Stop – the end of the movement authority – almost universally Red or Twin Reds
- Proceed, but prepare to stop at the next (or a subsequent) signal (route signalling practice).
- Proceed, but limited to a defined speed (speed signalling practice).
- Proceed at maximum permitted speed for that train.
- Proceed only so far as you can visually see that the route is clear. (This is used for low-speed movements, but nomenclature and usage vary significantly between different railway administrations)

Each railway administration also has defined permissible sequences of aspects that can be displayed by successive signals. Figure 3 shows lineside signalling where there is one caution aspect before the stop aspect, whereas Figure 4 shows closer signal spacing and that a second train can more closely follow a first train on “clear” (unrestricted) aspects.

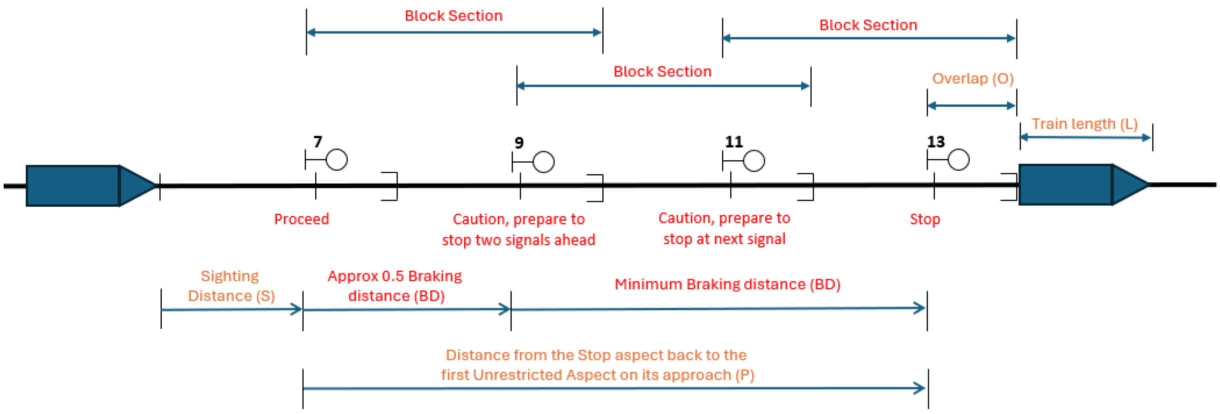

Figure 4: Scenario in which block sections are shorter than Braking Distance

6. Overlaps

Drivers obey lineside signals and almost always stop at a red signal at the end of their movement authority. However, there are occasions when drivers might fail to stop appropriately, for a number of reasons including:

- Misjudgement of braking performance (e.g. unexpected poor adhesion)
- Lack of attention or incapacity.
- Lack of capability due to inadequate training.

Many railway administrations reserve a portion of line beyond the end of a Movement Authority (beyond the stop signal) as mitigation against driver mistakes or adhesion conditions. This is called an Overlap and, in general, is reserved for that one train in case it overruns. However, once the system has determined that this train is stationary (and therefore no longer liable to overrun), this reservation is released, permitting use of the area by another train.

The length of an overlap can be determined in a number of ways:

- A notional distance (sometimes dependent on the maximum speed on approach).
- An individually calculated distance for every signal.

7. Capacity

7.1 Simple Headway

The Headway Time is the minimum time (which equates to a Headway Distance at constant speed) between a train and a second following train, where the second train is approaching an unrestricted proceed aspect (i.e. NOT a cautionary aspect). In the simplest case, where the two trains are both travelling at the same constant speed, then the Headway Distance between the front of the two successive trains is as indicated:

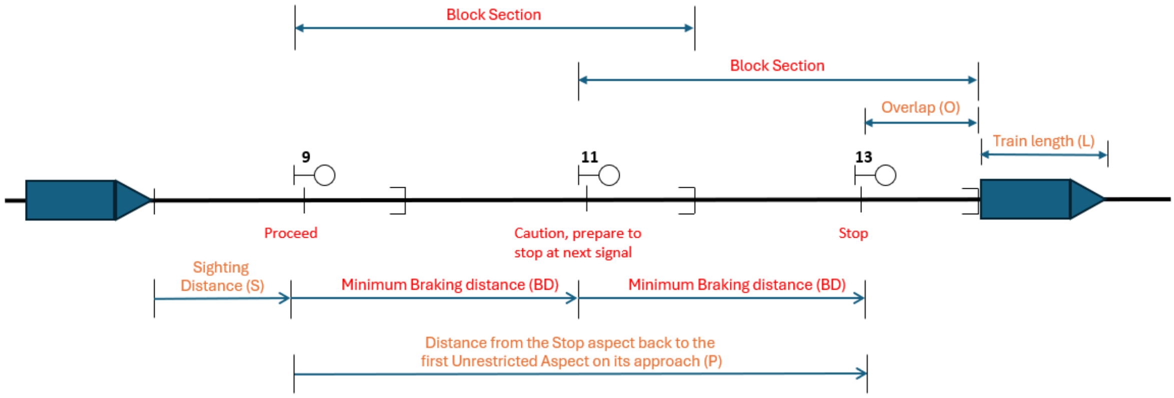

Figure 5: Constant speed headway (braking undertaken within one block section)

Headway Distance (H) = S + P + O + L	Where: L = Length of Train O = Length of Overlap P = Distance from the Stop aspect back to the first Unrestricted Aspect on its approach S = Sighting Distance (allows for the fact that the driver might brake prior to reaching a restrictive signal).

For main line higher speed lines, P predominates and for lower speed & high-capacity metros, the other factors tend to be more predominant.

When calculating braking distance contribution to headway, it is important to work from the maximum permissible speed NOT the timetabled speed. For trains travelling at a constant speed, the headway distance can readily be converted to a headway time, but this should use timetabled speeds. This ensures that the worst case is taken into consideration.

In **Fig 5** which reflects any lineside signalling system in which there is only one cautionary aspect prior to the red (e.g. UK mainline 3-aspect):

P = twice the signal spacing, each of which is a minimum of SBD
and therefore the best possible **Headway = S + 2 x SBD + O + L**

In **Fig 4** which reflects UK mainline 4-aspect signalling (but is essentially similar to some speed signalling systems) where the braking from full line speed to a stop is achieved over two (or even more) signal sections:

P = three times the signal spacing, with alternate signals spaced at a minimum of SBD
and therefore the best possible **Headway = S + 1.5 x SBD + O + L**

Thus, the capacity of the railway has been increased, but at the cost and provision/maintenance of significantly more signalling infrastructure.

7.2 Capacity constraints

In reality however, most railways have lengths of track for which the permitted speed is less than the maximum elsewhere. Even where the speed profile of the line is unchanging, there are often intermediate stations and consequentially those trains that stop will be slowing down and accelerating again. If all trains stop and also have the same acceleration and braking characteristics, the signals can be spaced appropriately for the resultant speed profile, taking advantage of the shorter braking distance and attainable speeds. This technique permits the distance between signals to be lower in the area of the station and thus still deliver good headway time, despite the slower running and the platform "dwell time"; it is usually only applied to metro railways.

However, if the signalling needs to facilitate the running of any non-stopping trains, the signal spacing must always reflect the full braking distance; this means that the stopping headway (time between successive trains which stop at the station) would be significantly increased. Timetabling one stopping train between a pair of non-stopping trains utilises a disproportionate amount of line capacity. Similarly, if a line is used by trains of different speeds, it makes no sense to talk of the headway of the line; it is a matter of working out the detail of how quickly the faster train will catch up the slower train and where the track layout is such that it can pass (overtake) it. Computer simulations of possible timetables being implemented upon the proposed signalling are often undertaken at the conceptual stage of signalling the layout.

Hence, factors that affect Headway are:

- running stopping trains between non-stopping trains,
- differential train speeds, meaning signalling cannot be optimum for both types,
- junctions which may be high or low speed but are generally slower than the straight-ahead speed.

Trade-offs need to be considered between capacity and speed. Service Braking Distance increases in proportion to the square to the speed and so tends to dominate for a higher speed line; if it is acceptable that the permissible speed is reduced then signals could be closer together and the capacity improved. The optimum capacity in terms of trains per hour (minimum headways) is obtained where all trains have the same characteristics in terms of acceleration, deceleration, maximum speed and timetabled stopping patterns. The best way to improve capacity measured by "passengers per hour" is often to run longer trains.

For metro type railways, factors other than the Service Braking Distance largely determine capacity, for example the lengths of the train, the overlap, the sighting distance, the station dwell time. For heavy haul mineral railways, the Service Braking distance is important, but junction clearance at the end of a long single line section often predominates.

8. <u>Operational use of Track Layout</u>

So far, we have been considering a simple plain line railway, but we now need to look at the other primary role of signals, protecting hazards such as points and level crossings. It is important to understand the operational use which is made of the track layout i.e. what train movements are required? is there a need to join two separate trains together or undertake shunting movements passenger and/or freight?

Junction protection and Signalling arrangements will be considered in sections 12 & 13, to which the considerations of section 9 are particularly relevant, but most of it applies to all signals so will be considered next.

9. Signal Positions

Apart from the considerations of headway and braking distances, there are also other constraints on the position of signals which need to be understood to correctly signal the layout. Design for a particular railway needs to follow standards of the relevant railway administrations because they vary. The following paragraphs summarise the most common.

Physical sighting: The purpose of the signal is to communicate information to the train driver. To enable this, the driver needs to be able to see it clearly for a sufficient period of time to assimilate the information. A site survey can be used to determine the final signal position to confirm readability, although increasing use is being made of virtual signal sighting (a computer model based on existing site data and reflecting the proposed alterations being undertaken). Where a signal needs to be positioned somewhere which does not provide adequate sighting distance, the sighting deficiency must be mitigated (various railways has different mitigations; in UK Main line this generally involves provision of a banner repeating signal).

Parallel signals: Not only does a driver have to be able to see a signal, but they also have to determine which signal applies to them if they can see more than one signal at the same time. For this reason, many railway administrations require that, when there are parallel lines signalled for the same direction of traffic, then the signals shall usually be adjacent to one another, unless specific measures are put in place to mitigate the risk of incorrect reading. Examples may be mounting one at much reduced height or providing a short-range head or a physical screen to obstruct the view from other directions. This is particularly applicable for platform departure signals.

Maintenance & Installation constraints: Signals need to be installed in a practical position - often a constraint on urban railways with viaducts and tunnels. They also need maintenance, although this is less of a consideration for a LED signal than a traditional filament lamp signal. The aim should still be to avoid putting them where access would be a problem, such as on viaducts or in tunnels, but sometimes this is inevitable because of the need to respect other constraints. Where other considerations permit, it is advantageous to place the signal near an access point for convenience throughout its operational life.

Overlap clear of junction: If the overlap of a signal extends through a junction, then the route up to that signal will lock the junction, until the train has come to a proven stand at the signal protecting the junction. This clearly precludes other simultaneous conflicting movements through the junction. It is more flexible and greatly reduces the complexity of the interlocking if the overlap limit is before the junction, especially on converging junctions (see Fig 13).

Reasonably Even spacing: It helps a driver to know where to expect a signal if they are relatively evenly spaced. In particular, where an aspect sequence extends over two signal sections, it is easier for the driver to judge their brake application if the intermediate signal is placed approximately mid-way between the first caution and the stop.

Overbraking: The minimum distance between the first cautionary aspect and the stop signal at the end of the movement authority is the service braking distance. However, if the actual distance is very significantly greater than this, then there is a risk that the driver becomes accustomed to not applying the brakes at the caution and may then forget or misjudge their brake application, resulting in the risk of overrunning their movement authority. For this reason, excessive over braking should be avoided if possible; In UK mainline, there is a 50% overbraking rule to limit this. Other railway operators prefer to place distant signals at a consistent distance from every station, regardless of speed of line.

Platform Starter signals: Where signals are required in the vicinity of a station platform, then they should usually be positioned at or near the exit end of the platform (to minimise platform reoccupation time). Alternatively, the signal should be at least a train's length beyond the platform (so that no part of a train stopping at it will still be in the platform).

Standage: In certain parts of the layout, it is necessary to be able to fit a train of the specified maximum length (perhaps in a loop line to allow the locomotive to run around to be at the other end of its train). The position of signals relative to each other, or relative to the point work or level crossing on its approach needs to be sufficient to avoid the rear of the train unnecessarily locking the infrastructure and hence preventing other movements. This needs to be considered with an appropriate allowance for such practical factors as the variation in stopping position of the train relative to a signal, and the potential for possible "roll back" of the train (especially where trains without full brake fitment operate).

10. Train Detection

For the purpose of layout design, the important factor is defining the limits of each section. The number of train detection sections provides the "resolution" of the signalling system's view of train positioning. For the greatest "resolution" there needs to be more train detection sections, but clearly each section provided comes with an economic cost. However, where there are ETCS trains reporting their positions, this information can be used to create virtual sections (i.e. without needing equipment trackside) within the interlocking.

See section 12 regarding the positioning of train detection around point work.

11. Signalling plan – implications of Junction locking

In order to successfully signal a layout, it is necessary to understand the principles of operation of the specific railway. In the diagram below, signals 1, 3 and 5 are all placed sufficiently far from the point work that the overlaps beyond them are free of junction conflict; therefore all the points remain free until a route is set from any of those signals.

Setting a route from signal 3 to signal 5 initiates the movement of 102 points and 101 points to normal and also reserves the sections of track from signal 3 to the end of the overlap beyond signal 5. As soon as the route starts to set, the signaller is prevented from setting a route from 1 signal to 5 signal, or from 4 signal to 6 signal; however a route from 4 signal to 2 signal may be set since this does not need any of the already reserved section of line and requires points 101 also to be normal.

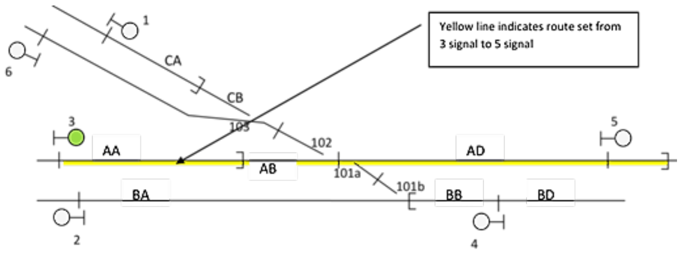

Figure 12: Junction locking considerations

As soon as all points have been detected to be in the correct position (assuming all other conditions are satisfied, such as relevant train detection sections proved clear), the signalling system will issue a movement authority to the driver by clearing signal 3 to an appropriate aspect.
After the train has passed signal 3 (or its Approach Locking otherwise released), the "Sectional Route Locking" imposed on each track section is released behind the rear of the train as it progresses through the route. Once the train has moved wholly onto train detection section AD, 102 points become free, with 101 remaining locked. This would prevent the route from signal 4 to 6 signal being set until the train had cleared the whole of AD section even if actually physically clear of points 101; the consequential delay would be lengthy if signal 5 were not showing a proceed aspect.

Unnecessary delay could be eliminated by providing additional train detection sections to release the locking on points more quickly as shown in this diagram, but these add to the cost.

This is an example where Signalling the Layout needs to balance various different considerations when determining what facilities are economically justified for the intended use of the railway.

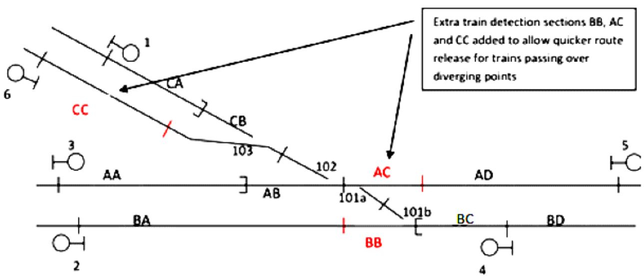

Figure 13: Optimising train detection limits at junctions

12. Signalling plan – implications of Junction Signalling arrangements

Where lines diverge, the track layout is often designed (for economic or geographic reasons) such that one route (the main line) has a much higher permitted speed that the other route (the diverging line). When a train is routed onto the diverging line, the driver needs to know sufficiently early so that they can adjust the train's speed appropriately.

- On a "Speed" signalled system, the driver can be notified by the aspect displayed at the previous signal(s) the speed at which they may pass the junction signal.
- On "Route" signalled systems, the driver is generally informed of the route set by means of an Indicator at the junction signal and is expected to adjust their speed based on their knowledge of the route. The problem is that, unless some form of warning has been given to the driver previously, there could be insufficient distance to brake to the permitted speed.

On some railway administrations therefore, earlier speed reduction is partially enforced by "Approach Release". This means holding the junction signal at red (or perhaps yellow) until the train is close to it (and should therefore have slowed) and the driver will be able to see any signal indication of divergent route before the signal clears for it. This methodology can on its own be unnecessarily restrictive and so additional signal indications are sometimes provided at or near the previous signal(s).

13. Level (Grade) Crossings

A level (grade) crossing is where a road crosses the railway line at the same level. Clearly there is a need to ensure that the road is closed to road traffic before a train is able to pass across the level crossing. The signalling plan needs to take these factors into account.

Railway administrations adopt a wide variety of methodologies for providing this protection with varying arrangements of lights, barriers, operating sequences etc., dependent upon local practice and highway regulations.

However, they can be broadly split into 2 groups:

- Crossings which are protected by signals. The signal is only allowed to clear when the crossing has been proved to be closed to road traffic and the crossing area itself is clear. Signalling design needs to ensure that protecting signals are positioned appropriately (not too close or too far away from the crossing) and that the level crossing sequence is commenced sufficiently early so that a train does not receive a restrictive aspect sequence from the signals on the approach to the level crossing protecting signal.
- Crossings which are not protected by signals continuously detect that no train is approaching in order to maintain the road open. Signalling the layout must provide a means to give the required minimum warning time before a train arrives at the crossing (e.g. positioning strike-in points at sufficient distance), because it is essential that the road user is given enough time to avoid being on the crossing. Generally, such crossings are not interlocked with signals but there are special cases where there is a signal within strike in distance or if there is a station at which trains may stop.

14. Summary of activity

Signalling the layout is fundamentally the art of selecting the most appropriate positioning of signals for the specific geography (the hazards to be protected, the design of the track layout, its speed and gradient profiles, respecting other site constraints), which:

- is capable of delivering the operational requirements (accommodating the mix of traffic types, providing the appropriate routes to meet the specific needs of each of type, delivering the overall capacity and specific headway demands, flexibility of use in the various modes of operation),
- takes into account the train characteristics (in particular the braking and acceleration performance) and the railway's specific signalling principles and operational procedures designed to provide adequate safety,
- is as economic as possible, considering the whole life cost of the new system and its interfaces to any existing signalling.

It is inevitably a compromise of conflicting requirements which need to be addressed, typically in the following order:

1. Requirements which relate to the safe operation of trains, based on the statistically sound assumption that drivers obey lineside signals; examples include sufficient braking distances, permissible aspect sequences.
2. Requirements that relate to the relatively few occasions when drivers fail to obey lineside signals; examples include excessive over braking, overlaps, train protection.
3. Requirements that relate to reliability, maintainability etc.