INSTITUTION OF RAILWAY SIGNAL ENGINEERS

# Adopting a proactive approach to the implementation of speed control systems

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If a railway's existing signalling system has certain limitations, for example leading to safety issues such as the risk of train collisions and/or derailments as a result of human error, then the responsible rail agency may seek to upgrade it to provide higher levels of automatic train protection (ATP). In this case the agency essentially has two options:

1) Replace the existing signalling system with a newer generation of signalling technology that inherently provides the required level of safety protection; or
2) Overlay an additional system or systems on to the existing signalling system, to provide the additional safety protection required.

This article will go into the reasons why speed control was/is and should be introduced referring to some of the accident/incidents that led to a legal mandate to install such a system in some countries. A brief touch on human factors is followed by details of some of the highlights of the technology development leading to the availability of such systems. It will then focus on the question why a proactive approach is needed followed by a discussion on the possible scenarios. It will then signal some trends in the railway sector, followed by the conclusions.

## Reason for speed control

The reason for speed control is related in many cases to separate developments due to accidents or near accidents. It is also related to developments of systems created to control signal obedience by the driver. Such systems appeared at the end of the 19th century as firstly an emergency intervention to stop a train (train stops) and secondly to supervise the braking curve when running towards a signal in the danger (stop) position. Some examples are given below:

### *TPWS in the UK*

As an example, in the UK, following the "Southall and Ladbroke Grove Joint Inquiry into Train Protection Systems" in 2001, TPWS (Train Protection & Warning System) was implemented across the UK rail network, as an overlay on the existing wayside signalling system, to provide red signal enforcement and over-speed protection at certain critical locations. Even though the above report noted that TPWS had a number of limitations, TPWS has provided an effective and relatively cheap stop-gap system prior to the planned (future) installation of ATP within an ERTMS package. TPWS is an overlay system; full ATP was not introduced.

### *PZB in Germany*

The PZB 90 system in Germany is a further development of Indusi, a system developed in the 1930s. Several accidents due to over-speeding at points led to trials with this system based on an inductive track device. The accident of August 1929 where an international train entered a siding track at 100 km/h instead of 50 km/h, with 13 people killed and 40 injured, was a contributing factor. After another accident in the early 1990s the German EBO railway regulations now require PZB on all but very minor lines. Since 1998 all traction vehicles must be equipped with Indusi in Germany - before that it was possible for trains without a protection system to use PZB-enabled lines up to a speed of 100 km/h[1]. PZB can also be laid out to cover danger spots and over-speeding. Various examples can be found on the internet[2]. It is extensively used in various countries to protect against over-speeding at points with a significant speed reduction. Another example of an overlay system.

### *Positive Train Control*

Similarly, in the USA, the "US Rail Safety Improvement Act" of 2008 mandated the widespread installation of PTC (Positive Train Control) systems to achieve an improved level of safety on the USA railroads. This was in response to a collision of a Metrolink passenger train and a Union Pacific freight train in California in September 2008, which resulted in 25 deaths and 135 injuries to passengers. In response to this mandate, various PTC systems have been developed and are being implemented (with acronyms such as I-ETMS, ITCS, ACSES, etc.) and typically integrate wayside, train-borne and data communications equipment from multiple suppliers.

Unfortunately the different PTC systems are not compatible and create interoperable problems at locations where different railways converge. The PTC mandate, specifically the PTC implementation schedule, has driven the technology solutions, and it could be argued the mandate has slowed down the development of a 'better' PTC system that could have provided other business benefits in addition to safety benefits. Indeed, two of the biggest concerns with PTC are capacity and operational efficiency impacts, and the operational restrictions that will need to be put in place when PTC fails to perform as intended. PTC is therefore not considered cost effective in its present form and additional investments will be required in the future to improve reliability and eliminate operational impacts, which could for example lead to an upgrade path with moving block capability.

Again this is an overlay onto existing signalling systems – not a new, stand-alone, ATP system – that has potentially delayed an 'Option 1' solution.

### *KVB and TVM*

In France, when SNCF decided to operate trains running up to 200 km/h in 1967, it was decided to implement a speed control in the speed range [160-200 km/h] avoiding the increase of risk. This system was called "*pré-annonce*". For the same reason, when SNCF put its first high speed line in operation in 1981 (260 km/h at the beginning), the on-board speed control system TVM (Transmission Voie Machine) was installed.

In the 1980s SNCF was experimenting with different speed control systems to avoid signals passed at danger (SPAD) but in 1985 two accidents occurred due to human factors. SNCF decided in 1986 to test a Swedish system developed by Ericsson (now Bombardier). This system adapted by Alstom to French requirements became KVB (Contrôle de Vitesse par Balises) and was installed on the first line in 1990.

To optimise the investment it was decided to implement KVB on stopping signals protecting points and their advanced signals, and at work site signals, but not on block signals which were considered as less dangerous.

### *ATS-P and protection against overspeed at curves*

In Japan, the automatic train stop system ATS-S, was introduced to the whole network of JNR in 1966 after a serious disaster caused by SPAD in 1962. The functionality is equivalent to AWS in the UK, but using induction phenomena by beacons instead of magnets. Afterwards, ATS-P with transponders was introduced to main lines after a train crash in 1988 caused by the ATS-S feature of a driver's acknowledgement which leads to the release of the train protection. ATS-P generates continuous speed supervision envelopes depending on individual train braking characteristics and does not need the driver's acknowledgement action. Furthermore, ATS-S was improved for the purpose of safety enhancement at depart/entrance signals by installing additional beacons.

However, in 2005 a serious accident occurred in the Osaka area, in which 107 people were killed and 562 injured. The cause of the accident was over-speed at the curve concerned, i.e., actual running speed 116 km/h against restricted speed of 70 km/h, and the line was not protected against over-speed at curves, nor was this prescribed in regulations at that time. Following another overrun accident, the ministry revised the regulations in 2006, adding compulsory requirements of protection against over-speed at curves, divergent routes and steep gradients etc. To cope with these requirements, JR companies adopted their own methods to generate speed supervision envelopes, e.g., by additional pairs of beacons (JR East), by route databases on board and beacons (JR Hokkaido and JR Kyushu). ATS-P already had the continuous supervision envelope function and only the installation of passive transponders at the places concerned was necessary.

## History of signal enforcement and speed control

Signal obedience is something the engineers have tried to enforce from the early days of the railways. Train-stops and other means have been with us for more than a century. Wikipedia cites as first installation the system developed by the US&S company for the Boston Elevated Railway, installed in 1901.

When it comes to speed control, opinions differ as some people think that enforcing speed control is something that has arisen in recent times and that only modern technologies make it possible. The truth is different. The first systems were based on the use, again, of train stops. The combination of a train stop and a timer starting after a certain section becomes occupied forms a speed trap; the arm of the train stop lowering with the timed delay. The effect is that if the train arrives too early at the train stop it induces an emergency braking.

A following development of US&S, this time with its pulse code track circuit, was installed in the early 1920s, following an order of the US Interstate Commerce Commission in 1922 that trains running with a speed above 80 mph (128 km/h) should be equipped with automatic train stop technology[3]. Although it started primarily as a system to control signal obedience it soon evolved into a system capable of continuously supervising the maximum allowed speed of a train along the line. Later non-mechanical systems, using an intermittent rather than continuous control, have been around since the 1930s, PZB being a good example. The intent was to control signal obedience and over-speeding at certain danger points like significant speed reductions. Due to the availability of solid state electronics, and later microprocessors, several new intermittent and continuous systems were developed in the second half of the last century and the early part of this century; the latest in the European arena being ERTMS/ETCS and PTC on the North American continent.

## Influence of human factors

From the beginning the underlying motivation for implementing these systems is the risk of human error in observing line speed indications and the status of the signals. Even in the heavily regulated environment of the railway a certain amount of human error is not to be excluded. Moreover, even in those situations where the final responsibility for the safety is in the hands of the driver, the human cannot be excluded from being the risk factor and therefore cannot be trusted as a mitigating factor of that risk. With the increasing maximum speed of trains this risk became more visible due to accidents or other scary situations like near misses. Accidents in the late 19th century already showed the consequences of human error. Nowadays the consensus is that in many situations the driver should not be the only risk limiting factor; systems should give support in the execution of his/her job (driver advisory systems; a.k.a. SIL 0 solutions) or supervise him/her (Ebicab, ETCS and other systems; SIL 4) even if, in the case of the latter, the trade unions protested against this so-called "loss of confidence" in the driver.

## Why a proactive approach?

This is the vital question every railway administration should ask itself on a regular basis. Even in this conservative environment the railway sector is (or at least is considered) to take signalling safety for granted, by assuming that what was valid in the last century is still valid today. This is a wrong assumption and is not always understood by the users of the system. What was proper to do in the 1960/70s is not necessarily acceptable today. The introduction of control command signalling on most of the network has led to a perception that the railway is the safest mode of transport. As a result, accidents are much more infrequent than hitherto and when they do occur and especially if fatalities and serious injuries result, this leads to a public media uproar. Accidents are not acceptable anymore for the travelling public. Hence the question is: do we have protection systems that offer the required performance or should we improve the systems and therefore lower the risk. Sadly on most occasions, actions are taken in the aftermath of serious accidents as described above but as the old adage says "*there is no sight like hindsight*".

The ITC considers that maintaining the status quo is not good enough anymore; a risk based approach should be driving the day to day operation of the railway, evaluating regularly performance and safety targets, having also in mind that on the occasion of system renewals, safety improvements are normally possible at a reduced cost. Examples are available, like Denmark, Norway and the Netherlands where the rollout of ETCS on all or most of the networks as mandated by EU law, should produce a near positive business case with the safety improvements coming as part of the package

## A discussion on the possible scenarios and their pros and cons

The advantage of Option 1, mentioned in the introduction, is that a new system (such as ETCS Level 2/3 or CBTC) can be designed to not only address the safety needs, but also to address:

- State of good repair issues; for example, if the existing signalling system is old or at the end of its design life, and has become difficult and expensive to maintain, a newer technology system can provide higher levels of system availability and require less maintenance (for example, through less track-based equipment, and higher levels of equipment redundancy).
- Operational issues; for example, if the existing signalling system has certain operational limitations and cannot deliver the levels of service required, a newer technology signalling system can maximize the operational utilisation of the existing rail infrastructure through a step-change increase in line capacity (for example, through moving block control) and/or an increase in the level of automation of train operations.

Although Option 1 would offer the greatest business case benefits, the primary disadvantage of Option 1 is the cost and complexity of a complete signalling system replacement.

Historically, therefore, Option 2 has more commonly been adopted, particularly when a rail agency has been mandated to reactively implement safety improvements following a catastrophic incident that led to loss of life, severe injuries and major property damage.

## Trends

Several trends can be identified but these must be described within the culture and legal constraints of each country or area of influence.

### *North America*

As noted above, the United States PTC experience has demonstrated that even with an overlay solution, there has been significant complexity in implementing a nationwide PTC system. Development has taken longer than anticipated: interoperability requirements among railways have created significant technical obstacles, and system testing and validation has proven extremely challenging.

In Canada, a Train Control Working Group was created to respond to the Transportation Safety Board of Canada's investigation into a VIA Rail derailment near Burlington, Ontario, in 2012, which recommended that: "major Canadian passenger and freight railways implement physical fail-safe train controls, beginning with Canada's high-speed rail corridors." The final report of this Working Group, published in 2016, concluded that a risk-based and rail corridor specific approach would be the best solution for the Canadian environment, rather than adopting a "one-size fits all", nationwide approach. The report noted that any technical solution should be based on a solid cost benefit analysis to deliver the desired safety benefits while minimizing potential corridor operating impacts. A specific risk prioritization methodology has yet to be finalized and agreed to, however. While various technology alternatives are being evaluated by Canadian railway authorities, the current trends would appear to be to continue to rely on operating procedures for red signal enforcement and overspeed protection except where the traffic on a given rail corridor dictates that a higher level of protection is required. On such corridors, an overlay solution on existing wayside signal technology appears to be the favoured approach.

### *Europe*

Within the European Union a common regulation of railway safety has emerged, culminating in the "Regulation on the Common Safety Method for risk assessment". This regulation, called up by the Safety Directive, describes a methodology to be applied where a change in the system is significant and has an impact on safety. A risk analysis is part of the process and human factors are very much part of the analysis.

In consideration of other risks, the risk of derailing is to be mitigated according to the so-called Technical Specification of Interoperability (TSI) for the main European Network when building new lines and must also be considered when significant renewals or upgrades are taking place. As over-speeding is a significant risk that can lead to derailment, protecting measures must be identified leading in most of the cases to the implementation of speed control systems, with nowadays ETCS as the most likely option.

A third factor is the requirement of the CE certificate that asks for the assessment of risk that will exist when the user adopts or uses the product or system. Here we see the same outcome; implementation of supervising systems.

### *Metro (Mass Transit) systems*

In the metro world the implementation of speed control and signal obedience supervisory systems is nowadays considered to be a given. Most of the systems/lines realised in the last 25 years do have such a system and many older systems have been or are being upgraded. Even more, with the drive for fully automated systems, speed control becomes even more important as it is the basis for automated driving. CBTC systems, where most of the control system elements have been transferred from wayside to on-board, cannot exist without proper speed control and movement authority supervisory systems. Such systems, intended to be used in an unmanned mode of operation Grade of Automation 4 (GoA4), rely on technology for driving and supervising at any moment of the journey to ensure that the train is always at the intended position and travelling at the appropriate speed.

### *ATO for main line railways*

Similar to what is happening in the mass transit world, several recent initiatives have sprung up to trial and later implement automatic train operation (ATO) on main line railways. Network Rail, DB and SNCF are some of the major operators in Europe to do so; the Shift2Rail initiative, funded by the European Union and the sector, also includes a subproject with the same goal. Although for the time being only GoA2 is intended, the requirements for speed control are similar as for CBTC. As is usual when employing ATO, the driver will be less attentive to the speed of the train even though the ATO system normally is not developed to require the speed function to be a SIL4 function. The associated ATP element will provide the required SIL4 protection measures.

## Conclusions

Several factors can be identified that have pushed for a more proactive approach to the implementation of speed control, but we still see a mixed approach, some proactive and some reactive, the latter mostly in the aftermath of an accident with multiple casualties.

The proactive approaches have a threefold basis: i) the foresight of the engineers and politicians, like in the case of the North America cab signalling, ii) the public pressure on politicians to improve the safety by legislative approach, and iii) as a result of modern electronic systems where track information can be easily transmitted to the train and therefore more easily supervised.

It is clear that speed control is nowadays considered a must even if the business case is not totally clear. The only thing still missing sometimes is the recognition by parties that times have changed. Speed control is now a de facto norm and that taking for granted that systems of the past provide sufficient protection is not sustainable.

But, even if the approach might be different (overlay versus new system; a decision often related to brownfield versus greenfield), the importance of having a proper approach to speed control is clear. Without protection many risks on the railway are left unmitigated; something not accepted by the public nowadays.

## References


[1] ***irse.info/y4on9***.
[2] ***irse.info/eyt8a***.
[3] ***irse.info/i2luq***.