

BENEFITS OF MODERN TRAIN DETECTION SYSTEMS

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Introduction

The modern railway industry uses mainly two proven train detection systems: track circuits and axle counters. Whereas yet a wide range of comparisons of various aspects of these technologies has been made, this article wants to focus on special details and discuss facets of both approaches. This will then lead to a closer look on specific opportunities which are enabled by modern solutions that include software interfaces, communication possibilities via open networks and the generation of additional information besides the occupancy status of a track section.

1. METHODS OF TRAIN DETECTION

Train detection systems constitute the backbone of railway signalling and safety of train operations. Since its invention in 1871, the track circuit has been providing safe and reliable train detection data to several generations of railway signalling and control systems. In order to keep up with the changing railway environment, the track circuit has evolved from a simple electric circuit, using the rails as conductors, to a complex digital signal processing system. However, the benefits of further developments are beginning to be outweighed by the growing demands for higher availability and the need for reducing trackside maintenance work, as well as by the restrictions and costs track circuits impose on permanent way design and traction current return path. This fact has paved the way for an alternative form of train detection technology, known as axle counters, which have confidently been working along, and increasingly take over track circuits, even on main lines.

However, the choice between track circuits and axle counters is being made on the basis of their specific features, advantages and disadvantages, with reference to the requirements of the specific application.

1.1 Facets Of Proven Train Detection Systems

Both track circuits and axle counters provide fail-safe information about the fact that a given section of track is free of vehicles or alternatively, occupied. They are both passive forms of train detection, i.e. the train does not

play a role in the detection process other than by being present or absent. While track circuit operate based on the principle of direct and continuous detection of the presence or absence of 'train shunt', axle counters detect trains indirectly, by keeping track of the train axles entering and leaving a track section.



Fig. 1: Optimum railway operation requires reliable technology

1.1.1 Broken rail detection

When suitably designed, track circuits have the inherent ability to detect rail breaks and bonding failures although rail breaks, which do not result in a full vertical transverse rail break can remain undetected. On the other hand, the fact that axle counters do not detect rail breaks leads to the implementation of new and improved methods of rail break detection and track maintenance.

1.1.2 Design features and limitations on application

Track circuits are based on a simple principle – the presence of a train on a section of track is detected through the shunting of the running

rails by the low electrical resistance of the wheelsets. However, for this principle to work, the track circuit design has to achieve a fine compromise between a number of parameters: track ballast resistance (in general, resistance of the leakage path from rail to rail), train shunt resistance, track circuit length, tail cable lengths, type of electrification and earthing. Some of these parameters (the ballast resistance and the shunt resistance) depend on the weather, geographic location, type and use of the railway line, and are difficult to control. The design can be complicated even further by the need to implement additional

requirements, such as demarcating the boundaries of the train detection section by physical or electrical insulating joints or the requirement to implement broken rail detection, EMC, etc. As a result, track circuit parameterisation imposes a number of limitations on their application. Axle counters, on the other hand, do not suffer such limitations, which make them a very versatile and flexible means of train detection. The table below presents a comparison between track circuits and axle counters limitations, with reference to the specific design features.

Design parameter	Track circuits (TCs)	Axle counters (ACs)
Ballast resistance	TCs cannot operate on track with steel sleepers, metal bridges, wet tunnels, etc., where the running rails are not isolated from each other or where the minimum allowed ballast resistance cannot be guaranteed	Axle counters are independent of ballast conditions and are therefore ideal for use in long wet tunnels and in locations where ballast may become saturated by salty water.
Wheel shunt resistance	Loss of track circuit shunting capacity is a serious hazard and may lead to wrong-side failures. The electrical wheel-to-rail contact may be permanently compromised by excessive sanding, dust, fallen leaves or contaminants. Lightly used passenger vehicles on infrequently used lines may also fail to provide an adequate shunt. To avoid safety hazards, track circuits in such problematic areas need closer monitoring and often, special technical measures.	ACs are not affected by the value of the train shunt and provide highly reliable train detection on infrequently used lines and in the presence of intensive leaf fall.
Track circuit length	TC length is restricted. Long block sections can be equipped with multi-section track circuits, which is a costly solution.	ACs can cover much longer block sections. In this way, one single AC system can replace many track circuits, giving improved reliability and cost effectiveness.
Train detection sections in switches and crossings areas	TCs can only monitor track sections with relatively simple configuration, having maximum 3-4 extremities. Moreover, certain types of TCs are not suitable for use in S & C areas.	A modern AC system can monitor the free/occupied status of sections with complex configuration and a high number of extremities. In this way, one single AC system can potentially again replace many track circuits.
Type of rail	TCs can operate with any type of rail, provided rail characteristics (resistance and inductance) are taken into account in the parametrisation of the TC	ACs can operate with practically all widely used rail profiles.
Installation of Insulated Rail Joints (IRJ)	Jointed TCs require the installation of IRJs in one or both rails so as to ensure electrical separation one track section from another. IRJs are the least reliable and most maintenance consuming TC component. It has been	ACs do not require electrical isolation of track sections from one another. This means that ACs can be applied on tracks with steel sleepers but also that they are free of a very

	reported that in the Hunter Valley, glued IRJs have a relatively short life. 120 MGT equates to a life span less than 3 years and substantially less in tight radius turnouts. This means that signalling failures due to short circuiting of GIRJs are frequent and maintenance expenses are high.	critical and low reliability component, compared to track circuits. In addition, the removal of the need to insulate track sections gives flexibility in the choice of sleepers and scope for improvement in the design.. In Hunter Valley, ACs offer the solution to eliminate greatest source of signalling failures in turnouts.
Type of electrification	Some types of TCs are not compatible with AC or DC traction.	ACs can operate with any type of traction.
Bonding	TC bonding is essential to ensure that any short circuit or disconnection in the track circuit is indicated as apparent presence of a train. Bonding is a weak and maintenance consuming TC component.	Bonding is no longer required leading to less maintenance and greater reliability due to the elimination of a weak component compared to TCs.

Table 1: Application areas of track circuits and axle counters

1.1.3 Influences by electromagnetic interference

Both track circuits and axle counters are installed trackside and operate in the harsh railway environment, abundant with electromagnetic interference. Track circuits share the running rails as transmission medium with the traction return current, which could potentially energise the track circuit relay, causing a wrong side failure. For a long time, track circuit immunity from the traction return currents was satisfactorily managed by generally, using AC track circuits in DC electrified areas and vice versa. However, the introduction of modern rolling stock changed the situation. The electronic traction drives used on modern traction units have the potential to generate electrical interference signals right across the track circuit and axle counters frequency spectrum.

Ensuring and demonstrating compatibility between train detection systems and the rolling stock is a complicated and very costly process. It requires two-fold measures, aiming at ensuring a safety margin between emissions of rolling stock and susceptibility of train detection, which inevitably leads to more complicated and costly designs. In terms of track circuits, this has led to the development of audio-frequency track circuits, implementing complex digital signal processing algorithms. As for the axle counters, it is expected that the CENELEC standardisation, which is currently being drafted will set up a standardised measuring method and harmonised values of susceptibility of wheel sensors. This would allow independent assessment of rolling stock and train detection systems and facilitate the implementation of interoperability.

1.1.4 Reset procedures

Track circuits do not require a reset procedure after every power down or operation of the signalling system in degraded mode. Accordingly, there is no risk of an unauthorised reset of the train detection system and no risk of stabled stock being "lost" (e.g. due to a change of shift of signaller).

In certain circumstances axle counters needs to be reset. Reset procedure is required after power-up of the system, track maintenance or after a miscount due to a hanging metal parts for example, resulting in a free track section, being detected as occupied. Modern axle counters enable the customisation of the reset procedures according to the specific requirements. Reset procedures are safety critical operations involving the human factor as they present the risk of a track section being reset (cleared) while still occupied by a train. To eliminate this risk, reset procedures include specific technical and organisational measures, e.g. running a sweep train at restricted speed to check that the section is clear, before the aspect restriction is removed and the section is restored for operation. To reduce to the minimum the negative effect on availability some axle counting systems implement self-correcting methods.

1.1.5 Generation of additional information for further functionalities

In addition to the information about the free/occupied status of a track section, the wheel sensors used as counting heads can provide positive information about the passage of the train via a specific point. Such information can be used to indicate the

approach of a train and trigger a specific function.

When required, wheel sensors can also provide speed and wheel diameter information and axle counters can transmit non axle counting related vital or non-vital digital data between two locations along the track, etc. Apart from those basic functions modern signalling systems provide far more beneficial opportunities and advantages to system integrators and operators.

1.2 RAMS

While both track circuits and axle counters meet the requirements for safety integrity level SIL4, axle counters have better availability. It has been reported that on the West Coast Mainline the axle counters MTBF is 3.4 years, while on the more modern Edinburgh Waverley system axle counters MTBF is in excess of 10 times better. Based on the Edinburgh Waverley experience and a MTBF of around 6 years for TI21 track circuits the reliability of axle counter systems can be up to 5 times that of track circuits on an electrified railway.

Axle counters require much less on-going maintenance than track circuits, especially compared to bounded track circuits. They benefit from facilities as for instance remote adjustment and extensive diagnostic aids.

2. OPPORTUNITIES WITH MODERN SIGNALLING SYSTEMS

Modern signalling systems in the railway industry must be able to provide functions and options that go far beyond the clear/occupied indication. An increasing field of possible and required applications, such as level crossings or trigger functions, expands the application area of axle counters and wheel detection systems more and more. Therefore appropriate components also have to be integrable into existing systems – which means that flexible interfaces are more important than ever in order to enable hardware- as well as software-based communication, centralised or decentralised architectures and more.



Fig. 2: Modern Signalling systems guarantee high reliability and enable flexible architectures

Regarding these new and increasing requirements, modern train detection systems, such as the Frauscher Advanced Counter FAdC, provide a wide range of possibilities and benefits to both system integrators and operators. Besides ensuring fail safe train detection the modular and scalable architecture of this axle counter enables additional options whose full potential is not utilized yet, as the following chapters will show.

2.1 Maximum track availability and reliability

The aim of using highly available components and systems in the railway industry is to ensure that operation is as smooth as possible. In the event of an error or problem occurring, the degree of availability of a system quantifies the probability that a system will not fail, but can instead continue to be used without direct human intervention. Accordingly, high availability refers to the capability of the system to ensure unrestricted operation if a component fails.

2.1.1 Remote diagnostic possibility for preventive maintenance

Comprehensive diagnostic options can also make an additional contribution towards increasing the availability of a system. If trend analyses are evaluated and regular service diagnoses are used to schedule maintenance work, system failures can also be cut by means of preventative measures. Of course, compliance with prescribed maintenance cycles and specifications also plays an important role in all three segments.



Fig. 3: The Frauscher Diagnostic System is accessible on various devices

A comprehensive diagnostic system helps to minimise the time spent on-site carrying out periodic maintenance. Important information, such as the quiescent current of the wheel sensor, can be read from a central service area. The possibility of faults occurring is already identified in advance and prevented by means of preventative measures. This implies that additional maintenance work can be avoided through:

- Unrestricted online access to the data from the axle counting system
- Fast and efficient troubleshooting
- Extensive diagnostic and statistical data
- Simple data management and archiving
- Connection to customer-specific diagnostic management systems via XML interface

All current and archived diagnostic and statistical data can be called up using an Ethernet interface. In addition to implementing customer-specific interfaces, a simple connection via an XML interface forms another available option. These options enable all information to be called up using a web browser at multiple locations within an interlocking and across rail stations.

2.1.2 Partial redundancy

Speaking about increased availability, the focus in signalling technology is generally on implementing various redundancy strategies. As a matter of principle, a distinction can be made between partial duplication of specific components and fully-redundant design of whole system components or of the complete system. The latter, in particular, is of course bound up with significant additional costs.

Basically, partial duplication aims on increasing availability with a comparatively lower

additional financial outlay than full redundancy. For decades the use of axle counters and wheel detection systems in the field of signalling has demonstrated that the majority of faults with an impact on system availability have origin in the outdoor equipment. Triggers are frequently and unavoidable external factors such as lightning strike, flooding, traction, vandalism and mechanical influences.



Fig. 4: Frauscher Wheel Sensor after flooding

In case the concept of partial redundancy is pursued to increase a system's availability, the outdoor equipment components that are at particular risk of being affected by these factors must be duplicated. However, given the wide range of different types of unavoidable influences, a permanent increase in availability is not guaranteed even then.

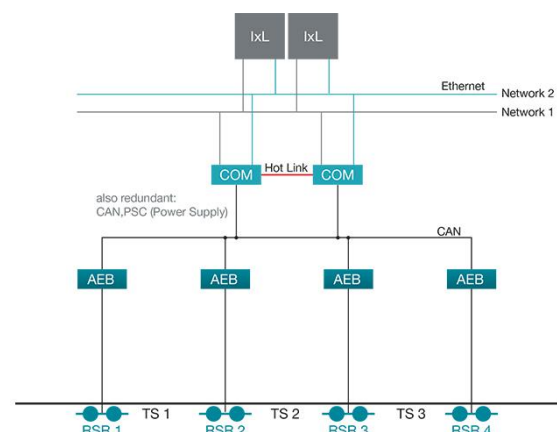


Fig. 5: Partial redundancy of indoor equipment

Intelligent, fault-tolerant functions can provide an effective solution to handle those influences. Using these functions, only parts of the indoor equipment, such as communication units, power supply boards etc., have to be duplicated in order to increase a system's availability significantly as these components would have a major impact on the whole system's functionality in case of an error.

In the following section, two innovative functions that Frauscher can provide with the new axle counter are used as practical examples.

2.1.3 Increased fault tolerance

Raising fault tolerance inherent to the system by means of activating intelligent functions in order to maintain operation without noticeable limitations in the event of a fault – particularly one caused by external influences. In many cases, this enables the required level of availability to be achieved.

Such features allow achieving the aim to further increase the availability of the complete system in a cost-effective manner, even though there are extreme environmental conditions and interference. To activate these functions no additional equipment is needed as these are in-built and ready to operate on a virtual level. Two different approaches are taken to achieve this.

2.1.3.1 Suppression of faults

The Counting Head Control principle (CHC) is used for fundamental avoidance of errors caused by unavoidable influences. When used correctly, the patented functionality satisfies the requirements in line with SIL 4.

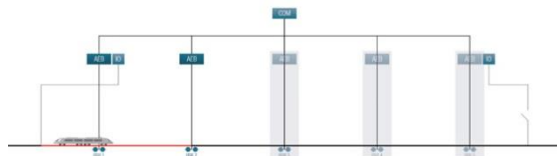


Fig. 6: Counting Head Control in use

If the adjacent track sections are clear, the counting head is switched to a stand-by mode. In this idle state, a freely configurable number of undesirable instances of damping, caused by e.g. tools, people, trolleys etc. can be suppressed. This means that no fault or occupied indication is generated by a short-term influence; no reset is required.

Approaching vehicles switch off the stand-by mode, meaning that they are detected and the occupied indication is output in a fail-safe manner.

2.1.3.2 Automated fault correction process

The intelligent Supervisor Track Section process (STS) corrects unavoidable, external

interference in a fully automated manner. By observing the general reset conditions, it is possible to further optimise availability without any negative effect on safety.

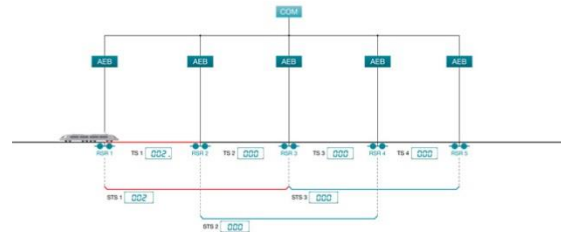


Fig. 7: Supervisor Track Section in use

For example, every two track sections can be overlaid by a virtual supervisor section. Consequently, it is possible for a faulty track section to be reset automatically, without manual intervention, if the corresponding supervisor section is clear. Similarly, a faulty supervisor section is reset if the two corresponding track sections are clear.

Correction of short-term interference without integration in the interlocking

Thanks to the STS process operating method described above, the system is able to correct short-term, external interference. This reduces the number of reset procedures that have to be carried out by the traffic controller. For this it is not necessary for the supervisor sections to be integrated in the interlocking. Examples of typical, short-term interference are:

- Lightning strikes
- Impact on the cable system
- Extreme electromagnetic interferences EMI

Correction of ongoing faults with integration in the interlocking

Particularly in track areas that are difficult to access, alongside interference caused by factors outside the system, even the failure of individual components can lead to ongoing faults with huge impacts on the timetable.

By integrating the supervisor sections in modern, high-performance interlockings, even ongoing errors can be tolerated. In place of the two faulty track sections, the associated supervisor section is automatically processed for train detection within the interlocking. In such cases, the STS procedure therefore enables maintenance of operations with only very slight restrictions. Rectification of the

cause of the error or replacement of a component can be carried out in parallel, with no time pressure. Examples of typical, longer-term interference are:

- Component errors
- Cable faults

2.2 Flexible Architecture

Due to the scalable and modular design an axle counter, combined with a software interface, both centralised and decentralised architectures can be configured, as can a mixture of the two types. Since the system is optimised for open networks, the savings on space, energy and investment costs increase with project scale thanks to state-of-the-art communications technologies.

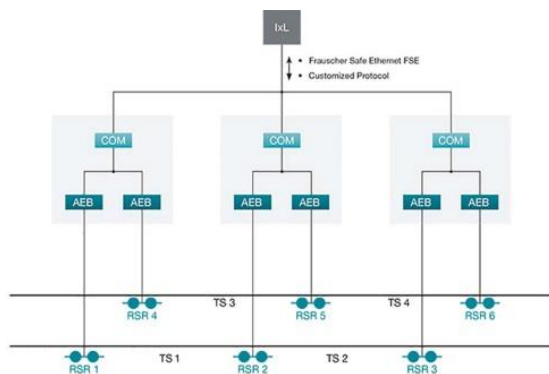


Fig. 8: Flexible architectures are possible when using modern axle counters

This enables the conception of cost-effective and modern signalling systems. Yet a modular signalling project based on a decentralised approach was realised, where the control circuits for the field elements such as axle counting systems, points and signals are positioned along the line in 'object controller cabinets'. Communication with the central interlocking is via a fibre-optic network.



Fig. 9: Object controller cabinet

This concept was influenced by the network-compatible interfaces of the axle counting

system and a software configuration offering both great adaptability for projects with a decentralised architecture and very economical implementation: In order to ensure the communication with the interlocking is as efficient as possible, a customer specific protocol was implemented to the system.

2.2.1 Solar powered systems

High network compatibility of an axle counter also enables combination of communication options if necessary. When modernising the line between Spencer Junction and Tarcoola, the Australian Rail Track Corporation (ARTC) chose radio as one of the methods of transmitting block information. This project saw the existing track circuits replaced with state-of-the-art axle counters. ARTC chose the FAdC based on the need for network compatibility. The primary means of transmitting block information is a fibre optic network.

This is associated with high transmission rates, low costs, and easy integration. In remote areas with no fibre optic connections, ARTC decided to use a radio network. Decentralised located cabinets communicate via this network using a secure VPN tunnel. Power supply for these cabinets is ensured by solar panels.



Fig. 10: Power supply in remote areas is ensured by solar panels

Using modern signalling systems enable the operator to improve the efficiency of rail traffic, while supersede the need to lay costly cables in the sections fitted with wireless communication facilities.

2.3 Communication Through Open Networks

The need of flexible architectures underlines the importance of a modern axle counter's ability to use open networks, such as railway Ethernet, fibre optic cables, 2-copper wires, ADSL or UMTS for communication. In the area of axle counting technology, the types of

communication required essentially consist of the connection between the axle counter itself and the connections established with a higher-level system, such as an interlocking.

There are as well systems in which the internal communication of the axle counter is carried out using state-of-the-art networking technology and the connection to the higher-level system being provided by means of relay technology. In many cases, this applies mostly to smaller systems, in which the expense of the implementation of a safe protocol would be higher than the cost of installing additional hardware to enable relay-switching.

2.3.1 Infrastructure requirements

Depending on the protocol and the individual protective measures used, the network will be required to comply with a specific category in accordance with EN 50159.

Category 1	The maximum number of users and the properties of the transmission system are known and fixed. Unauthorised access is not possible.
Category 2	The maximum number of users and the properties of the transmission system are not fixed. Unauthorised access is not possible.
Category 3	The maximum number of users and the properties of the transmission system are not fixed. Unauthorised access is possible.

Table 2: Network categories according to EN 50159

Category 1 defines a closed transmission system. Open transmission systems are allocated to Category 2 or Category 3.

When configuring the transfer protocol, a maximum network delay will be assumed or established. If a delay in the network is measured by the transfer protocol, the round-trip time is decisive.

The network which is used must be capable of providing the required bandwidth at all times. In the case of event-oriented protocols, the data rate will be related to the frequency of the events and a (heartbeat) interval. As for the cyclical protocols, on the other hand, the data

rate will not be affected by the frequency of the events but will depend on the transfer interval. The timeout that can be achieved will depend upon the maximum permitted delay and upon a (heartbeat) interval.

The availability required of the transmission system network is specified based on the level of availability which the axle counting system should achieve. As it is often the case, the required level of availability cannot be achieved with a single network, therefore, a redundant data transfer network needs to be included during the planning process.

Railway Ethernet

Most major infrastructure operators of main lines have their own internal network. Typically, this is a Category 2 network, in accordance with the EN 50159 standard.

In any case, when using such a network, it is important to ensure that the necessary degree of access protection is guaranteed. The benefit of this type of network is that no costs will be incurred for separate lines. Furthermore, it is possible to ensure that the properties required for the operational purposes, such as the bandwidth and the delay, are provided.

2.3.2 Serial connection of axle counters to higher-level systems

In comparison with hardware-based interfaces, a modern interface using a serial protocol allows the exchange of a range of additional information. For instance, besides the clear/occupied or reset status, the interface can additionally handle information as direction, diagnostic, speed, etc. The network connection and the flexible configuration of the axle counting system offers almost unlimited opportunities for data transfer. What is more, interfaces of this type enable cost savings to be achieved when networking interlocking and axle counting systems. Indeed, serial interfaces require fewer hardware components, consequently the space needed and the applicable wiring costs would be significantly lower. [1] (Figure 1)

As the transmission system is generally exposed to a diverse range of threats, it is necessary to detect the information errors listed in EN 50159 by means of a suitable protocol. In the past, countless protocols were developed which contain the corresponding safety features. In that regard, there is a clear distinction between standardised and proprietary protocols.

The standardised protocols (such as UNISIG Subset-098 or RaSTA) are mostly very complex - as a result their implementation gives rise to considerable effort.

Proprietary protocols are available both in simple and complex forms. Originally, many of these protocols were developed for a different transmission medium and only later adapted for Ethernet use. This "growth" frequently gives rise to unnecessary overheads that are carried forward. Another disadvantage of proprietary protocols is that although specifications are in fact available, it is necessary, when carrying out an implementation, to take into account items that have not been documented yet. The main problem, however, relates to the entitlement to implement these protocols in the first place and then to use them.

If a system integrator has implemented its own safe protocol, which he employs for interfacing between interlocking or for communication with the field elements, the connection of an axle counter via that very same protocol would be the simplest and most effective solution for the system integrator concerned.

2.3.3 Wireless Communication

Even radio- or satellite-communication via the networks of public operators or railway operators represents an interesting alternative to a system having its own cable networks along the train line and to the significant costs and servicing this entails. All the parameters such as modem delays, delay periods and time-outs can be set quickly and easily by changing the axle counter's configuration.

2.3.4 Software protocol solution

Small and medium-sized enterprises that are active in the area of system integration, but do not have their own protocol, will not find it cost-efficient to develop a protocol or to implement a standard protocol. As an independent provider of wheel detection systems and axle counters, it is of strategic importance to Frauscher to be able to communicate signalling data with all system manufacturers and integrators via software interfaces in a safe and reliable manner. Therefore the company developed a safe protocol which fulfils the communication requirements between axle counters and the higher-level signalling system. This protocol is called the Frauscher Safe Ethernet FSE.



Fig. 11: FAdC with Ethernet interface

This freely available protocol has been developed especially for a very wide range of applications in the field of wheel detection and axle counting. It enables communication between various systems without excluding the option to transmit additional information.

Besides fulfilling basic requirements relating to safety (SIL 4) the FSE provides a series of significant benefits for system integrators without their own standard protocol when it comes to realising a variety of projects.

3. CONCLUSION

Modern signalling systems provide more than the basic information for track vacancy detection. By using flexible interfaces a wider range of information can be provided for controlling level crossing systems and a field of switching tasks or trigger functions. This technology is established throughout the world for standard gauge railways and is increasingly replacing track circuits.

It is clear that the benefits of the axle counting systems outweigh those of track circuits in terms of life cycle costs, safety and availability. Negative effects as a result of isolation shocks, isolation problems, dirt, leaves, salt, flooding etc. are not an issue in axle counting technology. What is more, any track architectures (cross overs, diamonds, turn outs, level crossings etc.) can be achieved. The critical factors or possible disadvantages can now be overcome thanks to innovative and high quality wheel detection components. Modern wheel sensors and intelligent analysis software also open up a range of added functions.

Based on the possibility of realizing flexible architectures, axle counters can be overlaid (installed, tested & commissioned) onto track circuits still in service which enables the implementation of the axle counters in stage-

working, rather than one big commissioning. The axle counting system can be installed prior to commissioning and be operated in shadow to the existing track circuits. This would enable monitoring the correct operation of the AC system prior to commissioning.

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