WHITE PAPER

Fast Track Integration for Wayside Condition Monitoring and Preventive Maintenance

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Executive Summary

The high financial and reputational costs of railway accidents and long delays have led railway infrastructure managers to adopt increasingly sophisticated preventive maintenance procedures. However, the ability of railway operators and maintenance engineers to prevent costly system failures and optimize resource allocation depends on myriad wayside condition statuses provided by separate monitoring systems. These data acquisition systems are often comprised of many sensors, transducers, and remote terminal units running on different platforms and closed communication protocols, which can make maintenance more challenging and costly.

To ensure journey reliability and reduce expenditures, infrastructure managers and system integrators for railways should use a single, integrated condition monitoring platform that provides railway operators with ready access to all relevant statuses for predictive maintenance and asset management. This paper will discuss how railway operators are adopting increasingly sophisticated condition-based maintenance procedures to control costs and improve track performance, some of the key difficulties system integrators need to overcome when deploying wayside condition monitoring systems for railway preventive maintenance, and how using a single condition monitoring platform can save time and costs for deployment and maintenance.

Overview

In the coming years, system integrators for railways around the world will need to provide innovative solutions to help infrastructure managers curb maintenance and renewal costs, and also ensure high track performance and safety at the same time. In addition to performing schedule-based preventive maintenance, condition-based maintenance procedures are becoming more robust and increasingly used by infrastructure managers to preempt future failures. As a result, system integrators for railways can better serve the needs of infrastructure managers and railway operators by noting the following budgetary and performance concerns when integrating a cost-effective wayside monitoring solution for preventive maintenance.

Grabbing RAMS by the Horns

Reliability, availability, maintainability, and safety (RAMS) have become the principal concerns of infrastructure managers around the world, especially in Europe. At the same time, infrastructure managers across Europe are also spending a whopping **15 to 25 billion euros**

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each year on track maintenance and renewal alone.[1] Responding to these astounding maintenance costs and the 2002 European Commission (EC) white paper on sustainable transportation for a single European transport area, infrastructure managers have been working with contractors through the **INNOTRACK** project to develop a **competitive and resource efficient transport system.** More specifically, the EC white paper has challenged the continent's railway operators to

- double passenger traffic and triple freight traffic by 2020,
- increase travel time by 25–50%,
- cut life cycle cost (LCC) by 30%,
- reduce noise pollution to 69 dB for freight and 83 dB for high-speed rail,
- improve safety and reduce fatalities by 75%, and
- capture 15% of freight and 12% of passenger markets.

As European infrastructure managers have pledged to work towards achieving these targets, it is clear that the dual objectives of improving RAMS (i.e., track performance and safety) while reigning in unnecessary maintenance costs will be their top priorities for the next decade.

Assessing the Costs

European countries are not the only ones looking to improve the reliability, availability, maintainability, and safety of their national railway infrastructure. Even the Chinese government, which received a great deal of criticism for overlooking safety in its push to develop the world's largest high-speed rail network, has begun investing in safety-related monitoring improvements in the wake of the deadly 2011 Wenzhou high-speed train collision.

According to the official Wenzhou accident investigation report, a piece of signaling equipment was severely damaged by a lightning strike just before the deadly accident. As a result, the railway signaling system erroneously informed the control center that an occupied section of track was clear.[2] Besides killing 40 passengers and injuring over 200 others, the Wenzhou derailment was also extremely costly for China and negatively affected the economy.

Ultimately, Wenzhou highlights the importance of remote monitoring systems and maintenance procedures in ensuring reliability and controlling costs, financial and otherwise. As railway operators around the world have come to realize, **having the right information at the right time** is not only essential for preventing accidents, but can also lead to help optimize asset management and track performance.

Tracking the Future of Railway Maintenance

Costly system repairs following deadly derailments are not the only the reason why railway operators and infrastructure managers spend so much on track maintenance and renewal each year. As the old adage goes, "an ounce of prevention is worth a pound of cure." That is why in addition to **corrective maintenance** taken to restore failed equipment to operational use, railway operators have also adopted several **preventive maintenance** procedures over the

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years to preempt system failures. The term "preventive maintenance," as used in this white paper, includes both **schedule-based (planned) maintenance** and **condition-based (predictive) maintenance** procedures. Although both kinds of preventive maintenance are commonly used in railway applications, increasingly sophisticated predictive maintenance procedures are on track to becoming best practice. Specifically, as the remote monitoring technologies used in condition-based maintenance procedures become more advanced, railway infrastructure managers will be able to employ increasingly sophisticated **risk-based maintenance** tools to optimize asset management and ensure journey reliability.

Schedule-based vs. Condition-based Preventive Maintenance

Figure 1

Schedule-based Planned Maintenance

Since the 1980s, preventive maintenance procedures have been used in the railway industry in the form of **schedule-based maintenance** (also called **planned maintenance**). The goal of planned maintenance is to improve equipment life by preventing excess depreciation and impairment through scheduled service visits. Although schedule-based maintenance is still better than waiting until disaster strikes to perform corrective maintenance, and offers infrastructure managers easier maintenance planning and budgeting, traditional planned maintenance is far from optimal as costly system failures can easily emerge before scheduled service visits.

The problem with purely schedule-based maintenance, however, is that maintenance tasks and intervals are determined according to component manufacturers' recommendations and, more crudely, minimum legal requirements. Naturally, changing environmental conditions and intensity of use can shorten the useful life of a system component. In addition, hidden and unresolved damages or design defects can manifest in system failures before scheduled service visits or the average end-of-life wear-out stage begins.

Condition-based Predictive Maintenance

In addition to using schedule-based preventive maintenance, railways are also turning to **condition-based maintenance** (also called **predictive maintenance**) in which operators keep an eye on critical indicators that provide warnings about possible equipment failures. To optimize resources and efficiency, maintenance engineers need a clear and comprehensive picture of all railway equipment statuses in order to determine which parts to replace and when to perform service visits. As a result, infrastructure managers have been adopting predictive maintenance where maintenance tasks and service schedules are based on the real-time condition of system equipment instead of manufacturers' recommendations or minimum legal requirements. In particular, condition-based maintenance can help improve maintenance responsiveness and agility, increase operational availability, and reduce life cycle costs of total ownership by

- focusing maintenance on essential requirements,
- reducing excess equipment, and
- eliminating unnecessary service visits that waste time and resources.

More recently, **risk-based maintenance** has taken condition-based maintenance to the next level by incorporating sophisticated data analysis software that apply improved asset knowledge to quantify the most cost-effective levels of reliability and risk. For example, more granular knowledge about the resilience of assets gathered by improved remote condition monitoring systems can help railway operators execute targeted campaigns to improve resilience to weather events or identify hidden damage mechanisms like metal fatigue.

As technologies for remote monitoring and data acquisition become more advanced, railway operators will be able to predict the likelihood of future equipment failures according to active and potential damage mechanisms.[3] In fact, Network Rail, the primary railway operator in the United Kingdom, has made risk-based maintenance and the deployment of remote condition monitoring technology the cornerstones of its strategy for improving asset management and journey reliability.[4] Although the predictive capabilities of various preventive maintenance procedures continue to vary, increasingly sophisticated condition-based maintenance procedures, such as risk-based maintenance, are on track to becoming best practice for the railway industry. As a result system integrators will need to integrate remote monitoring systems to supply continuous asset information for front-end data downsizing and back-end data analysis.

Towards an Integrated Wayside Monitoring System

Increasingly sophisticated condition-based maintenance procedures are clearly becoming best practice in the railway industry to guarantee system reliability, availability, maintainability, and safety. At the same time, infrastructure monitoring for railway preventive maintenance includes many different subsystems that monitor myriad wayside conditions including, but not limited to, railroad turnouts and crossings, track geometry, and rolling contact fatigue. Each of these parameters provides information necessary for railway operators to prevent costly system failures and maximize efficient use of assets and equipment.

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Challenges of Integrating Wayside Condition Monitoring Systems

Unfortunately, **no single data acquisition system is currently available** that is capable of monitoring of all these critical phenomena. As a result, infrastructure managers must often contract with system integrators to integrate their own monitoring systems from a hodgepodge of different hardware platforms and proprietary software solutions. However, bringing together disparate parts in this fashion presents a number of challenges for system integrators tasked with integrating a comprehensive wayside condition monitoring system for preventive maintenance in railways. In particular, the following concerns need to be addressed:

- **Managing multiple asset types**
  Typically, condition monitoring systems in preventive maintenance must cover various assets in the field, such as point machines, turnouts, tracks, tunnels, and bridges. If system integrators deploy a different platform to monitor each type of asset, maintenance will be more complicated and cumbersome.

- **Difficult deployment and messy maintenance**
  Deploying a different platform for each asset type not only wastes the limited space available at wayside locations, but also exacerbates difficulties for maintenance engineers when they need to access hardware components during service visits. As a result, valuable time and money will be unnecessarily spent on initial hardware installation and inefficient maintenance thereafter.

- **Developing software to create add-on value**
  Besides hardware installation and deployment, system integrators are also responsible for developing front-end and back-end software to make sense of all the monitoring information fed back from the field sites. More specifically, **front-end data downsizing** programs need to be developed for the RTUs at the remote field sites to process raw data into a manageable form for **back-end data analysis** software and SCADA integration. However, proprietary software and closed protocols not only give rise to interoperability issues, but also make it more difficult for system integrators to develop software for centralized management and data analysis, thereby hindering the system integrator’s ability to create add-on value for infrastructure managers.

Using One Platform for All Condition Monitoring Subsystems

Integrating a wayside condition monitoring system for railway preventive maintenance can be a herculean challenge. Although system integrators still need to combine myriad condition monitoring subsystems to help infrastructure managers reduce maintenance costs and ensure journey reliability, **using one hardware and software platform** can alleviate much of the headache. More specifically, reproducing a single platform with the following characteristics for each condition monitoring subsystem can make it easier to manage multiple asset types, deploy and maintain wayside monitoring equipment, and develop HMI software for SCADA and data analysis.

- **Modular hardware design** enables system integrators to connect different interface inputs and outputs to a single **remote terminal unit (RTU)** for front-end data downsizing and easy deployment. Besides the convenience and efficiency of supporting multiple asset types with just one piece of equipment, some hardware vendors also provide a compact design to save even more space at wayside locations.

- **Hot-swappable I/O modules** provide plug-and-play simplicity for easy maintenance. Particularly, the ability to replace component modules without shutting down the system saves time for maintenance engineers. Moreover, modules that do not need to be replaced or serviced can stay online during maintenance visits, improving overall system availability.

- **Open standards and programming languages**, such as C/C++ and IEC 61131-3, allow system integrators to design their own programs and provide more add-on value. Although propriety software and protocols may be sufficient for specific components in isolation, these closed platforms ultimately make it more difficult for system integrators to develop new programs tailored to end-user needs and manipulate data to support increasingly sophisticated analysis software and risk-based inspection tools. In contrast, both C/C++ and IEC 61131-3 are open standards that are commonly used for RTUs and offer unrestricted access for system integrators to develop software for front-end data downsizing and back-end data analysis.

In summary, modular RTU controllers with hot-swappable I/O modules can connect different interface inputs and outputs to support multiple asset types, and some even come with API libraries and software tools—such as an open standard OPC server and database gateway—for easy integration with the back-end SCADA system or data analysis software. Although one size does not fit all, using a modular, hot-swappable hardware design with an open software platform as **a template for each wayside monitoring subsystem** can be a time-saving and cost-effective alternative to rigid proprietary systems.

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Integrated Wayside Condition Monitoring Platform

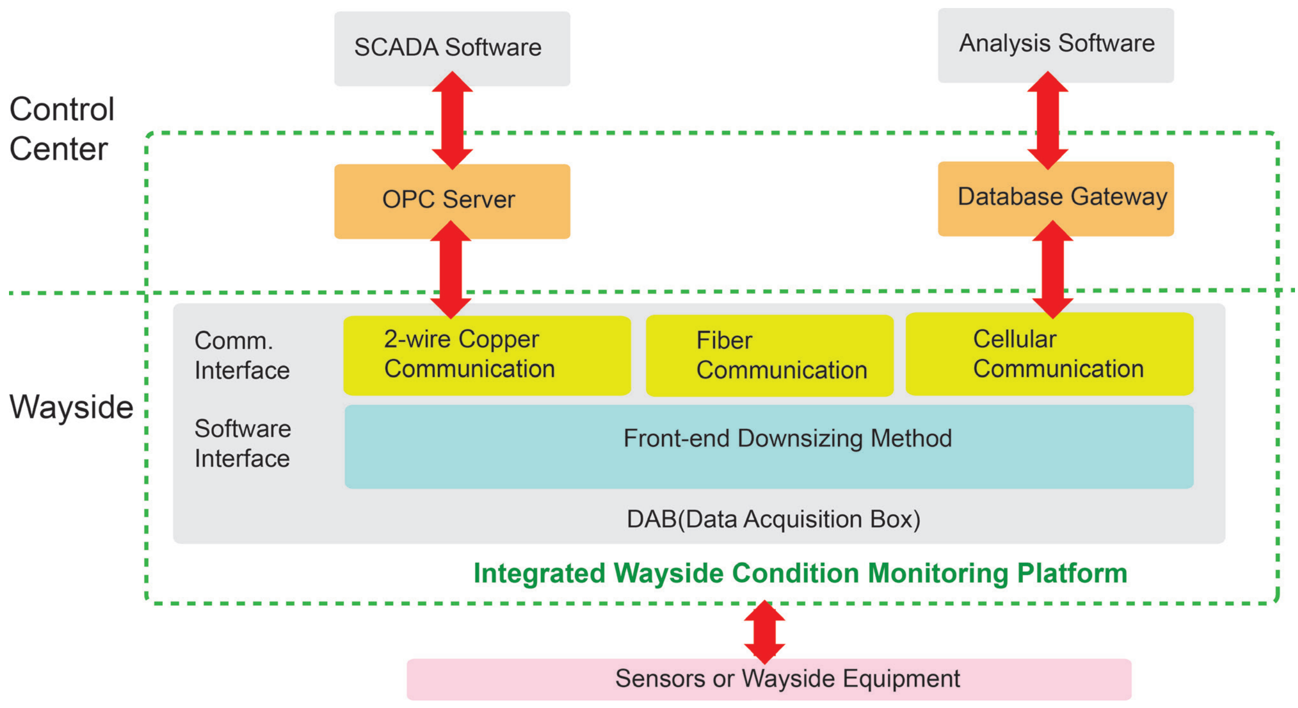

Figure 2
Each remote monitoring subsystem (e.g., turnouts, track temperature, railroad crossings, etc.) can be integrated by connecting different interface sensors at each field site to a modular RTU controller (inside a DAB) that supports different I/O types and communication interfaces, and also provides easy data integration software based on open standards (e.g., OPC server and database gateway) to mitigate hardware and software interoperability issues.

Wayside Condition Monitoring Example

According to a recent high-level performance and cost study conducted by the International Union of Railways, **turnout** monitoring systems have the lowest reliability and availability—but the highest maintenance costs—among all the critical monitoring subsystems used in railway preventive maintenance.[5] Thus, the following discussion will use turnout condition monitoring to illustrate the potential benefits of deploying a single, integrated monitoring platform from a hardware vendor that provides easy data integration software tools.

One of the most vital components of all railway infrastructures, railroad **turnouts** are basically mechanical installations that guide moving trains from one track to another. Also called a **railroad switch** in North American terminology, a turnout is comprised of a set of **points** (two linked tapered rails, also called **switch blades** in North America) inside the diverging **stock rails** (i.e., the outer rails). The fact that turnouts have movable parts and a motor to move the points to the desired position while accommodating tight curves, lateral forces, and impact loads at transitions, necessitates a highly demanding maintenance schedule.

Integrated Turnout Condition Monitoring Topology

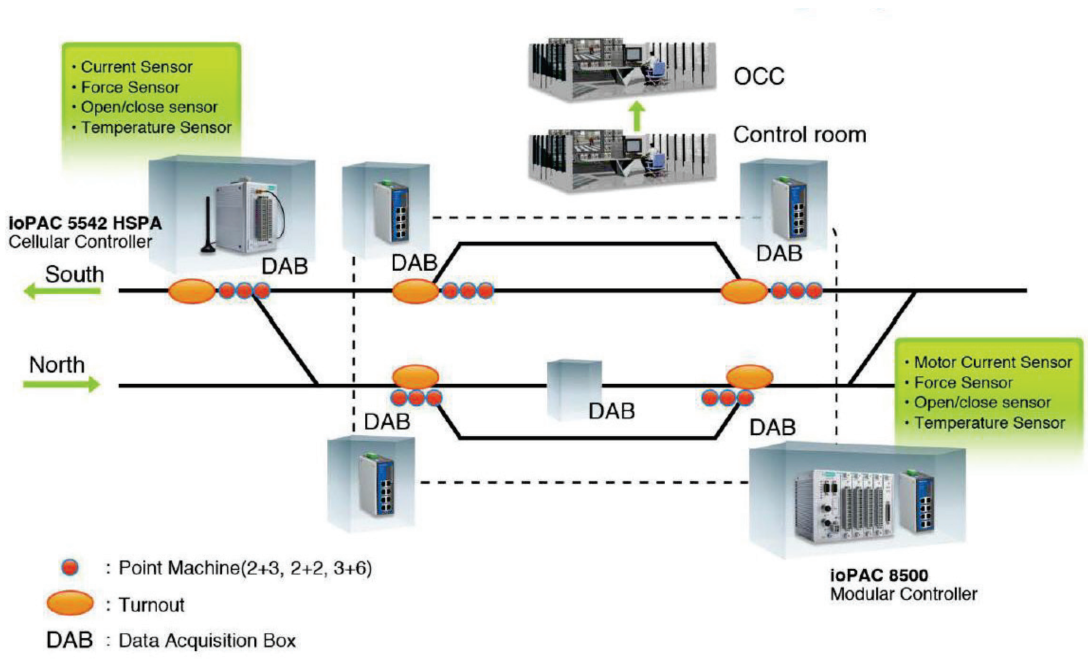

Figure 3
Railway operators rely on monitoring information from many different conditions and remote subsystems that can be integrated into a single Ethernet backbone or cellular network for centralized control.

When used in turnout condition monitoring applications, a modular RTU controller can connect an array of digital and analog sensors—such as motor current sensors, force sensors, and open/close sensors at a turnout—and record real-time measurements. Although precision instruments used to measure each parameter still need to come from highly specialized manufacturers, system integrators can mitigate interoperability issues by connecting all the sensors at each monitoring site to a single hardware and software platform. For example, Ethernet switches running on the same platform can be deployed to connect the RTU controllers to an Ethernet backbone for the entire railway, continuously transmitting critical asset information to a remote control center for centralized monitoring and analysis. For network redundancy or locations where laying physical wires is impractical, cellular controllers from the same vendor can also be deployed to transmit monitoring data wirelessly from the RTU controller to the operation control center.

Although currently available railway monitoring solutions cannot be used out of the box for advanced risk-based maintenance, system integrators can still save valuable deployment time, effort, and costs by taking advantage of hardware components (e.g., modular RTU controllers and Ethernet switches) and easy data integration tools (e.g., OPC servers and database gateways) from the same vendor. By converting raw data from myriad sensors into a more manageable form for SCADA and data analysis software, using a single, open platform can even provide a flexible foundation for integrating next-generation data analysis software in the future. Even though the aforementioned turnout example focused on just one wayside monitoring subsystem, the integrated approach advocated still applies to all the other subsystems that support the overarching railway wayside condition monitoring system. Thus, deploying an integrated monitoring platform, like the solution above, at each field site not only reduces excess equipment that need to be maintained, but also improves system-wide

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responsiveness through the elimination of unnecessary service visits and the provision of readily available asset information.

Conclusion

Recognizing the benefits of increasingly robust condition-based maintenance, infrastructure managers are willing to invest in remote monitoring and data acquisition technologies to provide maintenance engineers and railway operators with readily available asset information to predict and preempt future failures. At the same time, exorbitant track maintenance and renewal costs are also putting pressure on infrastructure managers to eliminate unnecessary expenditures, improve efficiency, and optimize resource allocation. Accordingly, system integrators employed or contracted by infrastructure managers and railway operators will need to keep these performance and budgetary concerns in mind when integrating condition monitoring systems for railway preventive maintenance.

Yet the system integrator’s task is far from easy. Traditional wayside condition monitoring systems for railway preventive maintenance often piece together hardware and software from different platforms that may succumb to interoperability issues and make maintenance more difficult. Moreover, system integrators need to figure out how to manage multiple asset types, deploy and maintain a highly complex and distributed system, and develop programs that deliver add-on value. Instead of using multiple hardware platforms and proprietary software solutions for different wayside monitoring subsystems, system integrators should use a single, open platform that supports multiple interfaces and provides easy data integration software. In particular, using a modular, hot-swappable hardware design with an open software platform as a template for individual wayside monitoring subsystems can save time and deployment costs compared to rigid proprietary systems. More importantly, such platforms will not only simplify the arduous task of integration, but also help infrastructure managers reduce maintenance costs without sacrificing track performance.

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