LEVERAGING TECHNOLOGY TO FACILITATE PREDICTIVE MAINTENANCE PLANNING

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ABSTRACT

With the promise of High Speed Rail and an increased focus on intercity passenger rail in the U.S., there will be increased pressure on freight railroads to collaborate with public transportation agencies in the establishment of “shared use” corridors. Shared track infrastructure in these corridors will need to be maintained to higher track maintenance standards consistent with FRA Classes 5-7 track and passenger operating speeds in excess of 79 mph.

Adding passenger trains, to already busy corridors coupled with stringent on-time performance metrics, will likely prompt the need to develop more effective maintenance strategies than historically required to accommodate freight-only operations. Maintenance programs which tolerate slow orders and unplanned service interruptions will compromise passenger train schedules, discourage ridership and ultimately impact the bottom lines of both the Passenger and Freight-host operators/owners. Ironically, maintaining consistent passenger service will likely lead to increases in ridership, train frequencies, and potentially even train speeds; these service and performance gains will further reduce available maintenance windows. The so-called “robustness” of the railroad schedule diminishes as capacity is consumed and the “heterogeneity” of trains on a given line increases.

Typical sources of high maintenance will require innovative “intelligent” wayside systems to supplement separate track geometry vehicle and/or autonomous inspections and to assist in predicting developing defects or imminent failures to prevent or minimize the impacts of service disruptions and interruptions. Wayside systems designed to interrogate, monitor, log and report on the health of critical systems may include:

a) Turnout point throw force monitoring systems;
b) Rail stress monitoring systems;
c) Track surface deterioration detection systems;
d) Signal health monitoring systems;
e) Level crossing health monitoring systems.

The information collected from wayside systems will, in turn, need to be analyzed by an appropriate data management system to derive maximum maintenance planning benefits.

This paper will focus on different types of wayside systems and how effective data management may be leveraged to enhance maintenance strategies.

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INTRODUCTION

Railroad operations personnel have the unenviable task associated with planning corridor operations. Such planning becomes more difficult as corridor lengths increase and the number of different type of trains increases. Clearly, the introduction of higher speed passenger trains into a mixed freight corridor presents a formidable challenge for operations planners. Even after elaborate train operating model simulations have been used to determine where capacity needs to be added to accommodate newly introduced passenger trains, the challenges associated with planning operations remain. Actual operations almost never correspond with study assumptions.

Railroad engineers and track maintenance people, who have been around long enough, know something about how the number of sidings, siding lengths and spacing of signals affect available maintenance windows. Unfortunately, they are also all too familiar with the urgency which is placed on making unplanned repairs to tracks which are temporarily slow-ordered or removed from service in capacity constrained corridors.

Higher passenger speeds will require tracks to be maintained to tighter tolerances and potentially command greater attention by ordinary expense maintenance personnel; service disruptions become increasingly intolerable with increasing passenger service levels. The afterhours calls to track maintenance managers and/or supervisors to send out personnel to investigate reports of “broken rail”, “rough track”, “signal indication” and “switch-throw issues” remain commonalities among all U.S. and Canadian Class 1 freight railroads. Clearly, adding trains to any railroad corridor reduces the total length of windows available for personnel to perform routine inspections and maintenance. With the bulk of passenger trains expected to be scheduled to accommodate commuters, the available daylight maintenance hours is expected to decrease and potentially contribute to an increase in the burden on after-hours maintenance staff.

A great deal of research has been devoted in the past two decades to developing more effective maintenance strategies. From relatively recent developments involving the use of sophisticated video surveillance and digital imaging systems to earlier developments related to asset management systems, technological enhancements aim to improve maintenance planning through the application of greater objectivity and maintenance prioritization. Some of the more elaborate systems also consider information gathered from wayside train movement detectors to further assist in the development and optimization of track maintenance plans. The data collected, processed and analyzed by virtually all systems today is derived from rolling inspections of the track structure by equipment and/or periodic detailed inspections of components. Few, if any, systems used by railways in the U.S. or Canada today gather information from wayside installations designed to monitor track superstructure.

More stringent track maintenance standards, a lower tolerance for service disruptions, reductions in available maintenance windows and shifting of maintenance windows to non-daylight hours all point to a need for a more predictive and efficient maintenance strategy. The normal routine sweeps by track inspectors and automated track geometry inspection vehicles may need to be supplemented by additional wayside and remote processing systems collectively referred to as “intelligent” track systems.

Building a business case to justify the investments required to deploy an effective “intelligent” track system represents a formidable task as the benefit costs and analyses are often quite subjective. The
discussion which follows focuses on different applications where the use of current technology may be leveraged to best facilitate preventative maintenance planning primarily from the perspective of the track maintenance professional.

In practice, infrastructure maintenance concerns between track and signal maintenance professionals often overlap. Any implications of potential maintenance planning benefits, from a purely signaling perspective and included in the following discussion, are unintentional.

**NOMENCLATURE**

CWR – continuous welded rail (elimination of all rail joints through plant, in-track or field welding)  
FRA – Federal Railroad Administration  
MPF – Moveable Point Frog  
RFD – rail flaw detection (equipment designed to locate internal rail defects which may result in service failures)  
ROW – Right of Way (corridor railroad property)  
WMATA – Washington Metropolitan Area Transit Authority

**TURNOUT POINT THROW FORCE MONITORING SYSTEMS**

The performance of power (remote) operated turnouts represents a major maintenance concern for both track and signal forces. The deployment of an effective turnout monitoring system is not intended to replace or reduce the need to perform inspections mandated by the FRA by either the track or signal departments. Monitoring systems which make use of information collected at switch and MPF throw devices and/or the associated articulated components, promise more effective maintenance planning and, consequently, fewer track and signal related service disruptions.

Failures in turnouts may be generally subdivided into three different groups:

a. Failures due to malfunction of moving parts such as switch machine or drive mechanism;  
b. Failures that cause components to loosen resulting in geometry exceptions;  
c. Failures due to the wear (or damage) of a switchpoint or moveable frog-point.

The most significant and, arguably, the most revealing types of measurements which may be made in switch or frog point throw systems include the direct measurement of the throw force and information related to the time required to complete a cycle. Additional measuring points within turnouts which may be used to complement throw force measurements and facilitate more detailed analyses include:

a. Stock-rail/switchpoint contact;  
b. Monitoring of switch operating rods;  
c. Monitoring of the position of the detector rods;  
d. Longitudinal forces in the rail;  
e. Rail and ambient temperatures.
In existing systems, data is collected by appropriately designed sensors and is normally pre-processed at the sensor location before being prepared for transmission. Data includes working pressure of electro-hydraulic switch drives or the current draw of the electric switch machines. While these systems are not designed to diagnose a fault to component level, they offer a level of intelligence to identify abnormal behavior. The systems are customized using input from both the signal department and the equipment supplier. Envelopes related to pressure or current, defining normal operations through the various stages of a point throw, are developed and used to establish triggers signifying abnormal behavior. (A graphical example is shown in Figure 1 - Typical Remote Condition Monitoring References). The data may be analyzed in a number of different manners. Introducing several different trigger levels may offer the enhanced benefit of a more preventative approach to maintenance scheduling. The greatest benefit is derived from the collection, processing and “intelligent” interpretation of data collected from multiple, time-dependent data feeds.

A typical set-up may also include the installation of sensors to detect switchpoint to stockrail or moveable point to wingrail positions as well as sensors which measure rail and ambient temperatures. Data processing may include the generation of trend curves which may subsequently be used to:

- Identify worn or defective components;
- Proactively schedule the need to service or adjust turnout components;
- Predict imminent service failures;
- Prioritize capital replacements.

The data collected from turnout monitoring systems offers additional insight related to the effectiveness of maintenance activities and component performance. An example related to maintenance adjustments may include surfacing work throughout a ballasted track turnout. Measurements made by turnout monitoring systems may be used to compare moveable component performance before and after surfacing operations to confirm program effectiveness and ensure, where necessary, additional adjustments are made before the (capital program)surfacing gang demobilizes. On the component performance side, the effectiveness of switch point roller systems and/or applications of slide plate lubricant may be objectively evaluated and compared. Intelligent turnout monitoring systems are not suitable replacements for the routine inspections and testing carried out by track and signal personnel. Instead, the deployment of this type of technology offers the maintenance planner a tool which may be used to prioritize inspections, routine service, capital replacements and objectively assess service and component performance.

**RAIL STRESS MONITORING SYSTEMS**

Track maintenance personnel must always keep a wary eye on the longitudinal rail stress in CWR. The ability to accurately discern the stress level in the rails of the track structure, without invasive procedures (removal of fasteners) and/or destructive testing, represents a formidable task for even the most experienced inspector.

In the warmer months as rail temperatures reach levels well above their so-called “stress-free” or “neutral” temperatures, the potential for track buckles (“thermal misalignments” or “sun kinks”) increases significantly. Lateral track buckles are typically characterized by half-wave lengths greater
than 15’ and include alignment deviations that will not permit safe passage of rolling stock at any speed. Typical tell-tale signs of so-called “tight-rail” conditions (high compressive forces in rail prior to buckling) include the appearance of localized perturbations in individual rails that rarely escape the trained eye of the inspector.

In mainlines constructed of the older cut-spike, cast plate and rail anchor system, evidence of tight-rail is somewhat easier to spot than in the more modern concrete tie track systems. The more modern track systems include a much more robust fastening design which is less prone to display local alignment anomalies. Furthermore, the more modern designs with elastic fastenings and their positive toe loading offer more consistent rail restraint and are better suited for use in CWR. It’s somewhat ironic then that the track system which is better suited for use in CWR installations is the same system which offers fewer hints of pre-buckle tight rail conditions.

Concerns with longitudinal rail stresses and differences between actual and “stress-free” rail temperatures don’t go away in the cooler months. The number of rail breaks and the related “signal indication” service disruptions as well as the potential for related derailments increase significantly as the climate and the rails exposed to the elements cool. While tell-tale signs that indicate running rail is in a relatively high tensile state exist, these are not usually treated with the same level of concern as rail in compression. While some northern climate railroads do occasionally apply blanket slow orders during periods of extremely low temperatures, rail break concerns persist in more moderate climate territories.

A compounding problem which arises in CWR locations subject to large annual temperature swings is related to the temporary repairs to rail service failures. Service failures in this context are not limited to breaks but include rails installed to mitigate internal rail defects (identified by periodic inspections by RFD equipment), worn rail, rail damaged in derailments, temporary joint bolt-hole cracks and other types of failures. A typical repair involves the removal of defective rail and replacement with a so-called, “rail plug”. These repairs are most commonly made on an urgent basis and most conveniently while the actual rail temperature is below the “stress-free” temperature. Without taking additional steps to adjust rails adjacent to the repair location, these temporary repairs have the net effect of adding rail to the CWR string; rail which must later be removed prior to periods of significant rail warming to ensure track buckling potential is adequately mitigated.

Today most railroads rely on collected database information related to logged rail “cut-ins” and “cut-outs” and the experience of track maintenance personnel to locate and prioritize the repairs to CWR. The so-called “tight rail” conditions are most often corrected by having maintenance forces cut CWR strings to allow the rail to run and achieve a state of lower compression. Similarly, adjustments for locations where rail may be in a state of high tension most often include repairs which involve adding CWR to the affected string. While this system of tracking repairs and relying on experienced personnel to plan remediation has historically served the railroads, the work prioritization remains rather subjective.

Several different commercial systems are available that include the installation of wayside sensors designed to measure longitudinal rail strain and compute the corresponding stress levels. (An example of a typical installation of a sensor designed to monitor rail strain and compute pertinent information related to the stress state of the rail is shown in Figure 2 – Typical Remote Condition Monitoring References). The information gathered from wayside sensors may be analyzed by rail engineers and maintenance staff to determine locations where rail stress levels are approaching
previously established threshold or trigger levels. Railroad engineers and maintenance staff may
choose to install such sensors at specific or generic locations. For example, locations near the
bottom of long grades, large civil structures, road crossings or special trackwork represent typical
locations where rail tends to accumulate. Alternatively, maintenance staff may elect to have sensors
installed at specified intervals along the track in an attempt to monitor the entire system.

The greatest utility expected from installations of this type of technology is derived from features
which facilitate rapid collection, processing and analyses of data. Systems which include historical
data logging offer the prospect of an additional level of interrogation, further enabling the
development of algorithms and prediction models for violations of pre-set threshold or trigger
levels. Furthermore, historical data may prove useful in assessing the performance of specific track
systems and monitoring the impact of routine and planned maintenance programs.

While identifying locations in the rail under extreme stress (tension or compression) before
imminent service failure represents a fundamental objective, this technology promises more
numerous benefits. The stress state in CWR is affected by numerous factors including, but not
limited to, maintenance work, train traffic, weather, proximity to fixed points and location on grade
or curve. Monitoring and analyzing the stress state in CWR on a continuous basis should lead to the
development and deployment of a more proactive and effective maintenance program. The ultimate
benefit to be derived from the deployment of rail stress monitoring systems is minimized operating
disruptions and interruptions attributable to rail stress concerns or service failures.

**TRACK SURFACE DETERIORIZATION DETECTION**

Calls from operations personnel relaying reports of “rough track” to maintenance managers and
supervisors are always difficult to interpret. More often than not these reports are related to track
conditions which have deteriorated in a relatively short period as opposed to progressive types of
failures. And while track surface deterioration is more representative of progressive defects,
information related to track surface may still be considered useful in identifying locations with a
higher propensity for rapid failures.

Typical causes of “rough track” vary based on the characteristics of the particular railroad territory
and may be attributable to any of the following root causes:

a. Misaligned track in transition section on approach to open-deck or ballasted deck
   bridge;
b. Misaligned track immediately adjacent to at-grade road crossing;
c. Misaligned track in transition section near tunnel portal;
d. Misaligned track adjacent to special trackwork section;
e. Railhead defect which has resulted in the loss of a significant portion of the running
   surface of the rail;
f. Broken rail which has not separated sufficiently to trigger a signal indication;
g. Stripped joint which has not resulted in a signal indication;
h. Collapsed shallow-depth culvert;
i. Track ballast washout;
j. Sub-grade failure within or immediately adjacent to the track section.
Arguments may be made to relate every single one of these defects to an earlier deterioration of track surface. Railway engineers and maintenance personnel are well acquainted with the cascading influence of poor track surface. Track surface significantly affects the ability of the track superstructure (rail, tie plates and ties) to maintain proper alignment of both the track system and individual rails. Variations in track support and, in particular, those which include large cross-level differentials often lead to higher lateral loads on the low rail side of the track. Components of the track superstructure which performed adequately under balanced loading may deteriorate quickly into track defects when higher concentrated loads are applied. In this respect, track surface monitoring systems may prove useful in predicting locations which are prone to the development of other forms of defects.

Clearly, automated track inspection systems represent an indispensable means of accurately measuring and assessing complete track geometry. Some railroads are now comparing successive geometry car runs to identify progressive failures. In addition to track geometry measurements, some systems today include ground penetrating radar systems to assess track sub-grade. While these types of inspections are being performed with increasing frequency, they generally may not be considered an active continuous monitoring system. In practice, “rough track” defects frequently occur in the periods between inspections made by automated equipment.

While it may be impractical and unnecessary to consider installing a system of sensors which would effectively monitor an entire corridor, the installation of an effective system of sensors at specific locations may be warranted. Typical high surface maintenance sections include locations adjacent to sub-structure changes including approaches to bridges (open-deck and ballast deck), tunnels and road crossings and at track transition locations such as approaches to special trackwork and tie design changes.

Additional locations and events along the ROW where sensor installation may make economic sense include:

a. Geologically unstable regions;
b. Landslide prone areas;
c. Washout susceptible areas;
d. Sections adjacent to large excavations;
e. Tunneling under or adjacent to ROW;
f. Groundwater level fluctuations.

Installations of sensors designed to detect settlement and disturbances have been used in the past to monitor the effects of neighboring construction or boring. An example of a system that was used to monitor railway tracks during the installation of a large storm drain serves as a useful demonstration of how technology may be used to monitor track position. In late 2001, WMATA orchestrated a plan to ensure that their passenger line operations would not be impacted by the installation of an 82” storm drain (by tunnel boring machine) approximately 15’ below their railway. The plan called for the installation of sensors and a data collection system to effectively monitor track vertical position in real time as tunneling works progressed and trains were permitted to run at normal speeds. The instruments used were electrolytic tilt sensors mounted on brackets anchored in the ballast. While in this particular case additional measures were taken to essentially compensate for boring activities, the role of the sensors to monitor track position is of particular relevance to the current discussion. (A section illustrating the arrangement used by WMATA and a graph of continuous
monitoring measurements are included in Figure 3 – Typical Remote Condition Monitoring

References)

With the exception of specific designs to monitor the effects of adjacent construction works, few, if any, installations have been deployed to monitor track superstructure surface conditions on an ongoing basis.

The continuous monitoring of track superstructure disturbances including cross-level, profile and twist along key sections of the corridor may prove particularly valuable during significant weather events. While several railroads rely on ROW slide detection instrumentation (linked to the signal system) to protect train movements through mountains, track safety patrols or sweeps are often used to verify safe track alignment during or immediately following significant weather events.

Aside from serving as real-time monitors of immediate disruptions, the “intelligent” analyses of historical data may prove useful in identifying:

a. Progressive sub-grade failures;
b. Ballast pockets;
c. Locations requiring ditch or culvert cleaning;
d. Locations with fouled ballast requiring undercutting;
e. Locations which may benefit from the introduction of a new transition design.

Experienced railroad engineers and maintenance personnel know the problem areas of their respective corridors. Their familiarity with their particular territory provides them with an intuitive sense of where and when problems are most likely to occur. The development of an effective wayside track superstructure settlement monitoring system will assist maintenance personnel in prioritizing additional inspections and planning associated maintenance efforts. Effective placement of wayside installations and an “intelligent” analysis of the collected data aim to reduce the number of required additional inspections and ultimately enhance the serviceability and safety of the corridor.

SIGNAL HEALTH MONITORING

The busiest railroad corridors in the U.S. and Canada employ some form of wayside signal system to guide the safe operation of trains. In its simplest form, the signal system relies on track circuits (in blocks ranging in length) to indicate the presence of trains. Because the signal system relies on the running rail to carry electrical current, the signal system and the condition of the track superstructure are intimately related.

The health of the signal system relies heavily on the ability to maintain a continuous electrical path through the rail and through bonds at rail joints. The signal system also requires track blocks or sections to be effectively separated by insulated joints. The presence of a train referred to as “signal indication” or “track occupancy” is indicated when the electrical current in a track block is compromised by a short-circuit between opposing rails or the electrical discontinuity in one or both rails.

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The need to investigate so called “signal indications” or “track occupancies”, when no train or other shunting track vehicle is known to be occupying the affected track, occurs frequently on today’s freight railroads. Different railroads and their train traffic controllers or central dispatchers have their own protocols for handling these types of system anomalies. In some cases, the protocol for remedial action involves a call out to the signal and track departments to commence with a field investigation. The protocol may include the interruption of train service or a reduction in operating speed until such time as the root cause of the failure is determined.

Typical track infrastructure failures or disturbances which may contribute to signal indications on clear track include the following:

- A broken rail;
- A stripped rail joint and broken rail bonds on temporary joint in CWR;
- A failed insulated joint;
- Rail flow across the end-post of an insulated joint;
- A failed insulated plate or a migrated steel plate under an insulated joint;
- Excessive switch point movement;
- A failure in an insulated gauge plate in a turnout;
- Turnout switch rod insulation failure;
- Failed steel crosstie insulators;
- A piece of wire or other form of electrical conductor between opposing rails or adjacent to insulated joint causing a short-circuit.

While most of the track superstructure failures noted above are not considered progressive types of failures that lend themselves readily to monitoring systems, related intermittent failures may also be recognized. Intermittent signal system failures represent those which are often the most difficult to diagnose. The latest generation of signal monitoring products may be used as a proactive tool to trace and rectify signaling glitches before problems arise. While signal monitoring systems are better suited to detecting progressive types of failures which typically do not involve track superstructure failures, they still offer some track maintenance benefit. The ability to isolate the type of failure through the “intelligent” interpretation of monitoring data may either point to a pending track superstructure failure or narrow the scope of the problem to exclude track infrastructure as a point of failure with a reasonably high level of confidence.

Several commercial systems are available today to log events and essentially monitor the signal system. Information may be stored locally or sent to a remote server for further analyses. (An example of a “track circuit flicker” event is shown in Figure 4 – Typical Remote Condition Monitoring References)

**LEVEL CROSSING HEALTH MONITORING**

Approximately 40% of today’s at-grade railroad crossings include signalized gates and/or flashing lights. Current design active warning systems rely on the track signal system to detect approaching trains. The root cause of active crossing protection failures may occasionally be related to failures in the track circuit, and more specifically a failure that involves the track superstructure as described in the preceding section. As crossing protection systems are designed to function as “fail-safe”, track superstructure failures sufficient to cause track circuit failures often lead to “false activations”.

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The FRA defines a “false activation” as follows:

“The activation of a highway-rail grade crossing warning system caused by a condition that requires correction or repair of the grade crossing warning system. (This failure indicates to the highway user that it is not safe to cross the railroad tracks, when, in fact, it is safe to do so.)”

Again, different railroads may have different protocols for handling false activations at road crossings but maintaining public safety remains paramount. Where a credible report of false activation has occurred, the FRA requires the railroad to ensure that the crossing is protected by flag person or law enforcement before permitting normal train speed operations through the crossing.

Crossing malfunctions related to a track superstructure failures (as described in the preceding section) may not be recognized as progressive types of failures by event monitoring systems. As with the more general signal monitoring systems discussed previously, these types of systems appear to offer more significant value to signal maintenance personnel. A hidden benefit to track maintenance personnel may become evident as signal engineers become proficient at analyzing and interpreting event data. The ability to rule out track superstructure failure as a root cause may go a long way to reducing unplanned call-outs or investigations by track personnel.

Different types of commercial systems are available today to essentially perform event monitoring and data logging at crossings. As with signal monitoring systems discussed in the preceding section, information may be stored locally or sent to a remote server for analysis by a centralized asset management system.

On corridors where higher speed passenger service is being introduced, an increasing number of crossings with no active warning protection may require upgrading. Given the potential advantages related to the ability to identify track superstructure defects before they result in “false activations” and the associated service disruptions, consideration should be given to the deployment of an effective level crossing monitoring system at the time of crossing system renewal or upgrade.

**TRACK DATA MANAGEMENT SYSTEM**

As the number and complexity of different wayside (sensor, detector) installations increases, the management of large volumes of data becomes an increasing concern. Also, the data in and of itself offers very little value in the way of providing information related to the effective monitoring of wayside infrastructure. The greatest benefit associated with the data collected from wayside installations is derived from “intelligent” interpretations. An example of a simple algorithm which may be developed to analyze data collected involves the overlay of successive data sets. Similar types of analyses are currently being performed by rail systems with data that is collected at discrete intervals commonly tied to autonomous types of inspections. While these types of analyses have been demonstrated as effective, a concern which is likely to arise is related to the condition of the infrastructure during the periods between these inspections. In addition, the response of the infrastructure to extreme conditions not prevalent during the time of the out-of-face autonomous and/or scheduled maintenance inspections poses another potential concern.
Examples of extreme conditions include weather, rolling stock malfunctions, vehicular trespass, improper train handling and sub-grade failure.

While different types of sensors will generally require individual analyses and the development of individual triggers or alarms, correlations between the different data sets may lead to the generation of additional trigger mechanisms. For example, data correlation may indicate that internal rail stress is a leading indicator to track structure movement. An effective track data management system uses a database approach to capturing, storing and analyzing data from a wide range of rail-based monitoring systems. Remote web-based access to all monitoring systems including data analyses, alarm management and configuration and management reporting maximizes maintenance planning effectiveness.

**CLOSING REMARKS**

With a recently renewed focus on passenger rail and an anticipated increase in freight demand, today’s railroads should prepare for tighter track maintenance standards, higher operating speeds, fewer maintenance windows and a lower tolerance for service disruptions.

While recent advances in geometry cars, rail flaw detection systems, and other forms of autonomous inspection have contributed significantly to enhancing maintenance and capital planning efforts, unexpected service failures persist. Even with recent developments related to using data from successive inspections made by rolling equipment and correlations to train traffic data, unexpected track infrastructure component failures result in service disruptions and demand unplanned maintenance attention.

This discussion has purposely refrained from attempting to quantify the costs associated with service interruptions and disruptions and postulating any form of cost-benefit analysis. Benefit costs may vary considerably from railroad to railroad and from corridor to corridor and are often quite subjective. The most tangible benefits expected from the deployment of the systems discussed herein include fewer track superstructure related service disruptions and interruptions.

The installation and effective management of wayside track superstructure monitoring systems represent a radical shift from current U.S. and Canadian maintenance practices. Continuous monitoring and the development of custom interpretation models present a significant leverage of current technology to better facilitate predictive maintenance planning.

**REFERENCES**


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5. Pennington, Steven M. “Real Time Monitoring of Trackways During Continuous High Speed Rail Operations.” Circa 2001, Facility Engineering Associates, Fairfax, Virginia


**Figure 1.** Segmentation of (switch throw cycle) profile into ON, UNLOCK, (THROW), LOCK and OFF sections\textsuperscript{10}

**Figure 2.** Typical installation of a CWR longitudinal rail stress sensor
Figure 3. Cross-section showing use of sensors to monitor settlement during culvert bore (Top). Continuous recorded output showing track position measured by sensors (Bottom).  

Figure 4. Track circuit flicker shown schematically (Top). Track circuit flicker shown in event browser (Bottom).
Leveraging Technology to Facilitate Predictive Maintenance Planning

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Overview

Introduction
Turnout Point Throw force Monitoring
Rail Stress Monitoring
Track Surface Deterioration Detection
Signal Health Monitoring
Level Crossing Health Monitoring
Track Data Management
Closing Remarks
FRA sub-divides High Speed Rail (HSR):

“Express”, “Regional”, “Emerging”

“Express” HSR systems should leverage decades of international experience!

“HrSR”

Involve FRA Class 6-7 passenger speeds on shared freight tracks

No Freight
### Freight train schedules:

*Historically, the majority of maintenance work is scheduled around highly variable operating schedules.*

Reasonable track availability to perform ordinary expense maintenance and inspection activities during the day.

### Passenger train schedules:

*Need to plan maintenance work outside of established tactical train schedules.* Very limited track availability to perform unscheduled maintenance inspections and repairs during peak operations, including daylight hours.
Net effect of adding passenger trains to freight lines is to move existing levels of service to higher grades.

### Freight Capacity Classifications

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<td>Low to moderate train flows with capacity to accommodate maintenance and recover from incidents</td>
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<td>Heavy train flow with moderate capacity to accommodate maintenance and recover from incidents</td>
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<td>Very heavy train flow with very limited capacity to accommodate maintenance and recover from incidents</td>
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<td>Above Capacity</td>
<td>Unstable flows; service breakdown conditions</td>
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Source: Cambridge Systematics, Inc.
Turnouts represent the most maintenance intensive component of track infrastructure.

Typical failure modes in power switches include:

- Failures due to malfunction of moving parts such as switch machine or drive mechanism;
- Failures that cause components to loosen resulting in geometry exceptions;
- Failures due to the wear (or damage) of a switchpoint or moveable frog-point.
Turnout throw force monitoring systems - 2

Inductive Sensor

Current Sensor installed in Termination Box of Switch Point Machine next to the turnout
Turnout throw force monitoring systems - 3

Envelope of acceptable values, user-established

Example of recording outside of envelope
Rail Stress Monitoring – track buckles

Real-time continuous rail stress monitor alternative to periodic visual inspections promises to reduce service disruptions when temps first drop.
Rail Stress Monitoring – sensors

- Locations prone to the accumulation of rail
- Removes subjectivity associated with reconciling “cut-in” and “cut-out” repairs
- Greatest utility derived from ability to collect, process and analyze data in rapid and continuous fashion

Sensor dimensions:
- L 12.00 in. (29.4 cm) x H 2.10 in. (5.1 cm) x D 1.45 in. (3.6 cm)
- Sensor weight: 1.1 lbs (500 g)
Surface Deterioration Monitoring - 1

- Track transitions;
- Collapsed culvert;
- Track Ballast migration;
- Landslide prone areas;
- Washout susceptible;
- Geologically unstable base.

Source: TTCI Annual Review 2012
Source: Pennington, Steven M. “Real Time Monitoring of Trackways During Continuous High Speed Rail Operations.”
The system is "fail-safe", or "vital" as it is sometimes called, because any break in the circuit will cause a danger signal to be displayed.
Signal indications – track superstructure failures

Typical types of track superstructure failures which may lead to “track occupancies” or “signal indications” include:

- Broken rail;
- Stripped rail joint (broken rail bonds on temporary joint in CWR);
- Failed insulated joint;
- Failed insulated plate or a migrated steel plate under an insulated joint;
- Excessive switch point movement;
- Failure in an insulated gauge plate or switch rod insulation in a turnout
Signal systems monitoring – circuit flicker

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The FRA Part 234-A defines a “false activation” as follows:
“The activation of a highway-rail grade crossing warning system caused by a condition that requires correction or repair of the grade crossing warning system. (This failure indicates to the highway user that it is not safe to cross the railroad tracks, when, in fact, it is safe to do so.)”
On corridors where higher speed is being introduced, crossing protection upgrading is a likely requirement; consideration should be given to the deployment of an effective level crossing monitoring system at the time of upgrade or renewal.
As the number and complexity of different wayside (sensors, detectors) installations increases, the need for management of large volumes of data becomes an increasing concern;

Greatest benefit associated with the data collected from wayside installations is derived from “intelligent” interpretations
Closing Remarks

Passenger trains and an increased freight demand will require railroads to prepare for tighter track maintenance standards, higher operating speeds, fewer maintenance windows and a lower tolerance for service disruptions;

The installation and effective management of wayside track superstructure monitoring systems present a significant leverage of current technology to better facilitate predictive maintenance planning.
End of Presentation

Questions?

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