Railway Association of Canada Association des chemins de fer du Canada

Leveraging Technologies and Data Processes To Advance Safety Beyond Regulations

1. Background

The Canadian Regulatory framework consists of numerous safety regulations and rules in effect under the Railway Safety Act (RSA), the Transportation of Dangerous Goods (TDG) Act, and other legislation[1]. In addition to these rules and regulations, Transport Canada added a requirement under the Railway Safety Act in 2001, for railways to implement Safety Management Systems (SMS) which exist in parallel and add to the robust regulatory regime.

SMS regulations have enabled railways to advance beyond minimum compliance, by instituting processes and a corporate culture focused on risk identification and mitigation, whether or not they are covered by Act, rule, or regulation. As a result, Canadian railways have taken proactive actions by developing and implementing innovative processes and advanced technologies which in many cases exceed Regulations.

The thrust by railways to leverage processes and technologies to strengthen safety stems from an unwavering commitment to safety and the recognition that running a safe operation is the right and responsible thing to do. Safety also makes good business sense by supporting service, efficiency and cost control. Indeed, the reasons for railways, as transportation companies, to exceed Regulations are compelling when one considers that derailments result in multiple undesirable impacts on key business aspects such as servicing customers, asset utilization, increased cost, as well as a negative impact on employees and the company's reputation.

This report is intended to demonstrate the ways in which Canadian railways have actively led the development and implementation of innovative processes and advanced technologies, which have been powerful forces in reducing risk.

1. '*Canada's Railway Safety Regime'* - Railway Association of Canada 2013

2. Technologies – Background

Over the years, railways have progressed from performing track and rolling stock inspections carried out by people using vision, hearing and smell, to the wide-ranging use of sophisticated technologies which greatly increase detection capability and reliability.

The use of advanced technologies by railways is not apparent to those who are unfamiliar with their deployment, because such equipment is typically distributed along thousands of miles of track, mostly in remote locations. As well, railways are sometimes inaccurately perceived as an old industry which makes little use of technology – this perception is understandable because of the industry's long history, and also since little technology can be seen from the outside. In effect, what most people see from the outside are large railcars and locomotives moving on steel rails, and railway employees manually operating switches or providing manual protection at level crossings.

However the reality is that railways are progressive in their efforts to leverage technologies to reduce risk and have made significant advancements for decades. The report prepared by the 2007 Railway Safety Act (RSA) Review[2] Panel states:

> *"Science and technology have been used extensively throughout the railway industry to improve operating conditions and advance the safety of Canadian railways."*

As well, a report[3] submitted to the RSA review secretariat concluded that technology has made a positive impact on safety, and will continue to do so:

> *"Technology and research findings have been used to advance the safety of Canadian railways in the past, and there will be ongoing opportunities to advance safety in the future"*

Technologies have been particularly effective in reducing main track accidents which are caused primarily by track and equipment (i.e. rolling stock) conditions; this is also mentioned in the 2007 RSA report:

> *"Main track derailments are generally associated with track and equipment failures. …*
> *..There have been significant technological advancements related to track and equipment safety issues, many of which are newly emerging. The Canadian railway industry has been adopting various types of technologies that have been developed to specifically target equipment and track-related derailment causes.*
> *The Panel is confident that the railways are investing responsibly to develop new technologies for track and equipment and that these have, and will continue to have, a positive impact on safety"*

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2. *'Stronger Ties – A Shared Commitment to Railway Safety – A Review of the Railway Safety Act, November 2007'*
https://www.tc.gc.ca/media/documents/railsafety/TRANSPORT_Stronger_Ties_Report_FINAL_e.pdf

3. *'Railway Safety Technologies'* submitted to Railway Safety Act Review Secretariat by T.W. Moynihan, G.W. English - Research and Traffic Group - July, 2007
https://www.tc.gc.ca/media/documents/railsafety/Technologies.pdf

Since the 2007 RSA review, the pace of innovation has accelerated with railways continuing to implement numerous technologies and processes which have sustained continued safety improvements.

The table below shows that TSB (Transportation Safety Board) main track derailments have decreased substantially from 2007 to 2016. The data underscores that while equipment (i.e. rolling stock) and track continue to be the principal factors of main track derailments, they have decreased by 66% and 71% respectively over the last 10 years:

Table 4b. Main-track derailments (assigned factors) 2007-2016

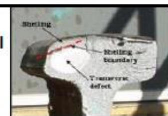
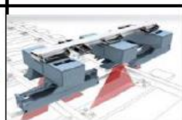
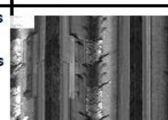
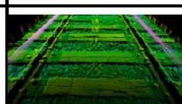
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total number of assigned factors	**182**	**153**	**81**	**91**	**126**	**68**	**95**	**111**	**82**	**67**
Environmental	17	12	6	1	6	4	5	11	3	4
Equipment	61	42	23	27	48	19	33	27	23	21
Axle	14	11	5	7	11	6	8	4	6	6
Brakes	8	3	6	3	7	3	3	4	4	5
Draft system	10	4	4	4	4	4	2	5	5	1
Superstrucure	8	5	0	2	3	2	7	3	1	3
Truck	5	5	1	5	7	2	5	6	2	1
Wheel	16	12	7	6	16	2	8	5	5	5
Track	59	62	34	33	45	28	30	49	32	17
Geometry	25	23	12	16	18	14	10	11	8	7
Object on track	1	1	1	2	2	0	2	1	0	0
Other track material	2	6	5	2	4	2	0	7	2	1
Rail	18	27	7	7	12	8	12	17	11	4
Roadbed	3	4	5	2	6	4	4	5	7	2
Switch	0	1	2	2	1	0	0	6	1	3
Turnouts	6	0	0	1	1	0	1	0	0	0
Actions	20	20	10	24	19	15	25	18	16	20
Failure to protect	4	8	3	2	5	5	5	4	3	5
Failure to secure	0	0	1	0	0	1	1	0	0	0
Failure to use equipment properly	6	6	5	10	7	2	9	6	6	9
Improper loading/lifting	3	1	1	3	0	2	2	3	2	1
Improper placement/position for task	2	1	0	4	2	2	6	3	1	4
Inadequate/Inappropriate maintenance of equipment	1	3	0	1	1	0	0	0	1	0
Operating at improper speed	1	1	0	3	3	2	2	2	3	0
Vandalism	2	0	0	0	0	0	0	0	0	1
Other actions	1	0	0	1	1	1	0	0	0	0
Other assigned factors	25	17	8	6	8	2	2	6	8	5
Derailments by number of assigned factors	**160**	**129**	**67**	**82**	**110**	**67**	**84**	**102**	**77**	**63**
One factor assigned	146	117	58	74	98	66	73	96	72	55
More than one factor assigned	12	12	9	7	12	1	10	6	4	5
No factor assigned	2	0	0	1	0	0	1	0	1	3

Data extracted March 31, 2017.
Federally regulated railway occurrences.
TSB does not investigate all occurrences; therefore, assigned factors may not represent TSB findings. Occurrences are normally only reported to TSB with one assigned factor. The TSB may assign additional factors.
Some factors are assigned by highest category (e.g. Equipment or Track), therefore the breakdowns may not sum up to the category total.
New TSB regulations came into effect on July 1, 2014. Under the new reporting requirements all derailments are reportable.

This significant improvement, in the midst of increasing rail traffic volumes, is in large part attributable to the substantive investments made by railways in technologies and data processes to effectively address main track derailment factors.

3. Technologies and Data Processes – Fundamental for Safety and Reliability

Canadian railways have left no stone unturned in finding innovative ways to deploy and leverage technologies and data processes to enhance safety. Of particular interest is the fact that many technologies used by railways are not required by Regulations, yet the thrust to increase deployment and seek even newer technologies continues relentlessly. The figure below, although not an exhaustive list, provides examples of some key technologies used by Canadian railways to enhance safety, as well as a comparison of Regulatory requirements against railway practice:

CATEGORY	SUB CATEGORY	TECHNOLOGY TYPE	IMAGE OF TECHNOLOGY	DESCRIPTION	INSPECTION FOCUS	REGULATIONS - CANADA	RAILWAYS IN CANADA
Track	Rail	Ultrasonic sensors		Identify defects below rail surface to prevent derailments / service disruptions		1-4 times / year	Canadian railways meet or exceed Regulations. In specific instances, ultrasonic rail inspections are performed up to 18 times per year.
	Track Geometry	Lasers and cameras		Inspect track geometry parameters such as lateral distance between rails, alignment, rail profile etc. Prevent derailments / service disruptions.		1-3 times / year	Canadian railways meet or exceed Regulations. In specific instances, track geometry inspections are performed up to 7 times per year.
	Slide and Rock Fall Detectors	Electrical and mechanical technologies		Detect slides or rock falls to prevent derailments		Not required	Technology used extensively in mountainous areas
	Rail and Track Geometry	Acceleration Detectors (ie vehicle track interaction - VTI)		Identify movements resulting from track geometry or rail joint issues. Prevent derailments / service disruptions.		Not required	Canadian railways have implemented more than 40 units
	Optical Track Inspection	Imaging systems		Inspect track components such as tie plates, tie fasteners, joint bars, bolts and ballast. Prevents derailments / service disruptions.		Not required	Initiated in 2015
	Tie Inspection	Imaging systems		Assess track tie condition. Prevent derailments and support focused capital investments.		Not required	Initiated in 2015
	Track and Bridges	Drones (unmanned aerial vehicles)		Enhance and supplement inspections to strengthen prevention.		Drones not required	Technology in inception phase
Rolling Stock	Wayside Detectors	Infrared and other sensors		Detect warm and hot bearings / wheels, as well as dragging equipment. Used for preventive trending. Prevent derailments, service disruptions or damage.		Spacing of 60 miles, or 40 miles for Key routes (ie high volume dangerous goods). Trending not required.	Class 1 railway spacing 12-25 miles on core routes. Canadian railways meet or exceed Regulations. Trending used actively.
	Wheel Impact Load Detectors	Force Measurement Gauges		Detect high wheel-rail impacts and imbalanced railcars. Prevent derailments, damage or service disruptions.		Not required	About 50 wheel impact load detectors in Canada.
	Truck Hunting (stability) Detectors	Force Measurement Gauges		Measure lateral forces on the track indicating unstable bogie which can result in derailments, damage or wear.		Not required	Truck hunting detectors installed in several locations in Canada
	Machine Vision	Advanced imaging systems and algorithms		Detect missing, damaged or worn rolling stock components which can result in derailments or service disruptions.		Not required	Deployed in several locations for wheel and coupler inspections

The scope and diversity of technologies continue to advance[4] on multiple fronts, including collaborative efforts in research and development between Canadian and U.S. railways working in cooperation with the Association of American Railroads (AAR) and the Transportation Technology Center Inc., as well as universities such as the Canadian Rail Research Laboratory (CaRRL – university of Alberta) and Research and Innovation Laboratory (RAIL - university of Illinois).

It is also important to note that technology deployment continues to reduce safety risks because:

- Railways continue to increase the numbers and density of detectors. For example, the 2007 RSA report references how a railway nearly tripled its number of wayside hot bearing detectors[5], from 250 to 683, in approximately a decade. Recent documentation confirms that the railway has increased the number of detectors in its network to 910, representing a further increase of 33% since the last review.
- New technologies have emerged which increase inspection visibility to further reduce risks – examples include advanced imaging systems which inspect rolling stock and track, allowing the identification of defects which would have been previously difficult or impracticable to detect.
- Railways are using data and supporting analytical processes to enhance their inspection and detection technologies thereby focusing on potential safety risks.

To elaborate on the last point, railways have recognized for some time the value of leveraging data to further strengthen prevention[6]. For example, one Canadian class 1 railway pioneered the use 'warm bearing trending' to detect and monitor bearings before they reach high temperatures. This process successfully reduced burnt-off bearings, which historically were a leading cause of main track derailments related to rolling stock. This process is now used by many railways across North America with similar positive results.

Furthermore, North American railways have been collaborating for many years to share detector data with the objective to enhance safety and reliability for the entire industry. Using data collected by wayside detectors situated throughout the North American railway network, information systems currently collect and monitor data, and use automated algorithms which send preventive alerts[7] to participating railways. This has the net effect of extending the effectiveness and reach of technologies while simultaneously sharing information about risks and creating opportunities for assessing lessons learned and the identification of further technology deployment.

Data sharing, data management and predictive analytics are significant areas of focus that drive railway investment on account of the exceptional opportunity to further reduce risk. There are currently several initiatives being advanced by the industry and individual railways, supported by research facilities, major information technology companies, as well as suppliers[8].

Collectively, advanced technology and data initiatives work in unison to effectively reduce risk by producing multiple means for preventing accidents. For example, the following processes mitigate risks associated with rail integrity by supplementing visual inspections, monitoring and regulatory compliance:

- Ultrasonic rail inspections are performed by specialized vehicles to detect defects below the rail surface, which the human eye cannot see.
- Specialized railcars measure and monitor key aspects of track geometry and rail wear.
- State-of-the-art cameras record images of joint bars – the metal bar that is bolted to the ends of two rails to join them together in a track. Images are recorded and reviewed to validate joint bar condition and automated systems identify defects.
- High-rail vehicles, which use automated systems and are highly mobile, increase the reach and frequency of mechanized track inspections.
- VTI (vertical track interaction) technology is mounted on locomotives to monitor dynamic accelerations which can pinpoint rail or joint defects.
- Automated tie inspections are performed with high-resolution digital imagery, enabling focused tie maintenance and capital programs to adequately support rail.
- Wheel impact load detectors, which measure wheel-rail forces, enable railways to identify and remove high impact wheels before they cause rail damage.
- Wheel profile detectors monitor individual railcar wheels with high resolution digital cameras identifying defects or conditions which may require action.
- Rail wear data is collected and monitored for preventive and maintenance purposes.
- Technologies monitor longitudinal rail stress to prevent rail or joint failure.
- Field processes are used to control rail length during field installation to mitigate forces generated by changes in temperature – both compressive forces which can cause buckling and tensile forces which can result in failure.
- Information systems are used to log, prioritize and monitor rail issues from detection to resolution, for both visual and mechanized inspections.

This multi-layered approach to risk mitigation greatly reduces the likelihood or risk of a failure. As explained by James Reason[9], the use of multiple lines of defense working in unison, and complementing each other, bring about a significant reduction in risk.

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4. 'AAR Strategic Research Program to Improve Safety and Efficiency' – report by Transportation Technology Center Inc. (TTCI): https://www.aar.com/standards/DPLS_2016_ConferenceInfo/Presentations/Main/09-Semih%20Kalay.pdf

5. Page 170 of the 2007 RSA report mentions:

"… in 1994, CN had about 250 hot bearing detectors spaced approximately every 25 miles along its track. …that network has expanded to 683 hot bearing detectors with spacing of 12-15 miles over the core network".

Over the past few years, the company has allocated a special capital technology fund which increased the number to 910 such detectors in 2016 (CN 2016 *'Leadership In Safety'* brochure (https://www.cn.ca/en/delivering-responsibly/safety)

6. AAR Technical Services Update 2017

http://www.amf.org.mx/images/archivos/exporail2017/semmec16/JPG1-AAR.pdf

7. Equipment Health Monitoring System

https://www.railinc.com/rportal/equipment-health-management-system

8. CP Corporate Sustainability Report 2016 – page 19-20

http://www.cpr.ca/en/about-cp-site/Documents/cp-csr-2016.pdf

CN 'Leadership in Safety 2017' – page 22

https://www.cn.ca/-/media/Files/Delivering.../Safety/2017-leadership-in-safety-en.pdf

9. Reason J. "Managing the Risks of Organizational Accidents". Aldershot, UK, Ashgate; 1997

4. Opportunities to Further Leverage Technologies and Data:

As put forward earlier, technologies and data processes have been instrumental in supporting a remarkable risk reduction journey for Canadian railways. Nevertheless, there are further opportunities to sustain and extend the improvements as follows:

Research and development:

Advanced inspection / detection technologies require substantial research, development and testing. As explained earlier, railways have been actively progressing and funding technologies in collaboration with research facilities, as well as universities and numerous suppliers. Nonetheless, considering the strong potential for further benefits, this area would be well suited for government involvement and support. This notion was noted in the 2007 RSA report, as follows:

> Page 174:
> *"Even though the railway industry has a significant impact on the Canadian economy, there are limited public resources available to initiate research and development (R&D) that could improve railway safety."*
>
> *Page 175:*
> *Recommendation 49: "In view of the importance of railways to the Canadian economy, the Government should strengthen its contribution to innovation and technological advancements in railway safety."*

Although there are joint industry-government initiatives, such as the Railway Research Advisory Board (RRAB), the funding is relatively small, and the results so far have not been significant in terms of producing substantive risk-reduction initiatives. Additional research and development would be beneficial to advance technologies associated with broken rail and wheel detection, both of which are significant factors in main track accidents. Although significant progress has been made in these areas over the past few years, the complex and diverse failure modes require further work and would benefit from new technologies to increase detection visibility.

Regulations:

In order to support and encourage railways to invest in new technologies, regulations need to be reviewed and updated to allow such technologies to be implemented with minimal bureaucracy, while also providing railways with the ability to demonstrate through risk assessments how such technologies can substitute antiquated or redundant processes. A good example can be found in section 2.5 of the Track Safety Rules[10] which allows technologies to be used for joint bar inspections, in lieu of walking inspections.

This same approach could apply to a number of other prescriptive rules which currently do not provide the opportunity to leverage technologies through a risk-based approach. Section 10.2 of the 2007 RSA report noted the challenges of implementing new technologies as a result of current regulations:

> *"Once new technologies have been developed and tested, commercially viable options may require regulatory change. ….. Further, attempts by railway companies to implement new technologies can be delayed or result in additional costs because of the need to obtain regulatory exemptions to outdated provisions.*

Facilitating the introduction of new technologies would support the risk reduction journey while avoiding redundancy and providing a business incentive for further investments.

The Regulatory exemption process[11] can be further leveraged to support new technologies by allowing for field testing, risk assessments and /or scientific information to demonstrate the safety and effectiveness of such technologies. This approach has been used successfully in the past and can be expanded to support new technologies through a strong collaboration between railways and regulators.

Recommendations relative to strengthening research and development, and regulatory reform that supports innovation, have been put forward by the railway industry for years. In fact, Canadian Pacific's submission[12] to the 'Review of Federal Support to Research and Development' provided recommendations which continue to be relevant today:

> • "*Transport Canada should implement a review of all regulations with the goal being removal of regulations that represent impediments to innovation.*
> • *The Rail Safety Branch of Transport Canada should develop a plan in consultation ith the rail industry to increase the deployment of new technologies by reducing redundancy in the inspection burden on railways.*
> • *The Government of Canada should increase funding for railway research in Canada through the Transportation Technology & Innovation Directorate of Transport Canada.*
> • *The Government of Canada should use the tax system to promote the utilization of new technologies*

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10. *'Rules Respecting Track Safety' – section 2.5 'Walking Track Inspection':*
    " If joint bars are inspected electronically including the use of camera or other technology capable of detecting joint bar defects, a Walking Track Inspection of tangent track and curves less than 4-degree curvature in jointed track territory is not required"

11. *Subsection 22.1(1) of the RSA makes provision for railway companies to file a notice of exemption for the purpose of conducting testing related to rail transportation or for an immediate exemption of short duration, in order to be exempted from the application of any provision of standards formulated under section 7, regulations made under subsections 18(1) or (2) or 24(1), or rules in force under sections 19 or 20 of the RSA.*
    https://www.tc.gc.ca/media/documents/railsafety/guideline-applying-exemption.pdf

12. 'CANADIAN PACIFIC SUBMISSION TO THE REVIEW OF FEDERAL SUPPORT FOR RESEARCH AND DEVELOPMENT'
    http://rd-review.ca/eic/site/033.nsf/vwapj/sub125.pdf/$file/sub125.pdf

Human Performance Initiatives:

The table in Section 2 of this report shows that main track derailment factors related to equipment, track and environment have decreased substantially over the past decade, in large part due to the advancements in technology and data processes made by railways.

On the other hand, this table shows that main track derailments relating to human factors, or 'actions', have remained relatively flat over this time frame. Recent announcements made by the Minister of Transport to require video and voice recorders will certainly be valuable by enabling a better understanding of risk factors such as crew resource management and fatigue management, thus enabling more effective risk mitigation initiatives within the safety management system framework.

As well there are several training technologies, such as locomotive simulators and remote control locomotive simulators, which are being used successfully to strengthen railway employee skill and proficiency. This is an area where support for railways would be beneficial to expand such technologies and make them more broadly available.

Short Line Railways:

Short line railways play a critical role in the Canadian economy, with nearly a quarter of shipments originating or terminating from such railways. Short lines are relatively numerous, with over 60 such railways in Canada, which are typically small in size, with light density lines, and operating ratios over 85%.

Therefore, it is understandable that short line railways have limited resources and capital to develop or deploy advanced technologies. This was noted in section 10.1 of the 2007 RSA report:

> *"The Panel learned, however, that short line railways may have difficulty implementing technological innovations due to a lack of financial capital."*

Before enumerating the opportunities to bolster technology for short line railways, it should first be recognized that many inspection and detection technologies produce preventive benefits for the broader railway network by extending technology beyond traditional inspection points; this is particularly true for rolling stock that moves across multiple railways.

As an example, wheels inspected by impact detectors or imaging systems would typically not deteriorate at such a rapid rate that they would represent a high risk to connecting partners spanning relatively short distances. The same would apply for rolling stock inspected with technologies such as truck (i.e. bogie) hunting detectors or imaging systems for couplers. Nonetheless, there are opportunities for short line railways to further reduce risk through government funding to deploy technologies such as:

- Wayside detectors in specific higher risk locations, which can be pinpointed using a route risk assessment which considers parameters such as population density, volume of dangerous goods and environmentally sensitive areas.
- High rail vehicles with specialized technologies to increase track geometry and rail related inspections
- Ground penetrating radar vehicles in vulnerable topographies subject to permafrost, water conditions, muskeg etc.

Such technologies would help to reduce main track accidents, which are caused mostly by track and equipment (i.e. rolling stock) factors. Although it is recognized that preventive actions need to encompass people, process, technology and investment, it stands to reason that strengthening technology would be a positive risk reduction step.

5. Summary

In summary, this report shows the ways in which Canadian railways have actively led the development and implementation of innovative processes and advanced technologies to reduce risk.

Government support would be valuable in key areas such as the review of regulations to facilitate the implementation of new technologies, research and development, as well as funding of specific technologies for short line railways. This would build on the substantial risk reduction benefits achieved thus far, while supporting current efforts and initiatives, thereby sustaining a journey which will continue to elevate safety from strength to strength.