

# **Railway Association of Canada, Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of the Railway Safety Act (RSA)**

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# Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

1.	Introduction .....	1
1.1	What are SMS and their role in rail safety? .....	1
1.2	SMS in Canada’s Railway System .....	2
2.	Performance-Based Enhanced Safety Regulation .....	6
3.	Regulatory Regime for Successful SMS.....	7
3.1	Safety Policy .....	8
3.2	Safety Risk Management .....	8
3.3	Implementation .....	9
3.4	Safety Performance Indicators for Railways .....	10
3.5	Recordkeeping .....	11
3.6	Safety System Application and Promotion .....	11
3.7	Safety Assurance and Auditing .....	12
3.8.	Successful implementation of risk-based regulation for UK railways .....	14
3.9.	Summary of SMS Elements .....	14
4.	Safety Risk Management Process .....	16
4.1.	Establishing the Context .....	16
4.2.	Hazard identification and prioritization.....	16
4.3.	Risk analysis .....	17
4.4.	Risk evaluation .....	18
4.5.	Risk control.....	19
4.6.	Monitoring and review .....	20
4.7.	Communication and consultation.....	21
4.8.	Summary of Safety Risk Management Process Elements.....	22
5.	Conclusion.....	24
6.	Limitations and Disclosure .....	24
	Appendix A – Summary of Railway Safety Management System Regulations (RSMRS) SOR/2015-26.....	25

# 1. Introduction

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. As early as the 1940's the importance of safety management systems have been reviewed and discussed. In addition to their rules and regulations, Transport Canada added a requirement under the *Railway Safety Management System Regulations* (RSMSR) in 2001 for railways to implement Safety Management Systems (SMS) which complement regulatory regimes. This was initiated to promote operational improvements in Canada's rail safety performance<sup>1</sup> by enhancing safety culture, better managing safety risks, and demonstrating compliance with rules and engineering standards in day-to-day operations, while also reflecting on their processes and becoming more innovative.<sup>2</sup>

Thus, the RSA rests on two complementary pillars. The first is regulatory oversight; a traditional inspection, enforcement, and compliance regulatory regime. The second is the requirement for each railway operator to have an effective SMS, making SMS itself a regulatory requirement, subject to review and audit.<sup>3</sup> Both pillars are overseen by the regulator, Transport Canada.

## 1.1 What are SMS and their role in rail safety?

The introduction of SMS resulted in confusion within the railway industry and public, leading to a misunderstanding that SMS were a form of industry self-policing to replace government regulatory oversight.

However, despite this misunderstanding, SMS regulations have enabled railways to advance above the minimum regulatory requirements by instituting processes and a corporate culture focused on risk identification and mitigation, whether or not they are covered by act, rule, or regulation.<sup>4,5</sup> As a result, Canadian railways have taken proactive actions by developing and implementing innovative processes and advanced technologies which in many cases exceed regulations. Rather than being a competing system of 'self-regulation' to Transport Canada's oversight, SMS are complementary as shown by the following:

“Traditional approaches to safety management—based primarily on compliance with regulations, reactive responses following accidents and incidents, and a “blame and punish” philosophy—have

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<sup>1</sup> <https://www.scribd.com/document/187293997/2013-Fall-Report-of-the-Auditor-General-of-Canada-Oversight-of-Rail-Safety>

<sup>2</sup> Winfield, M. (2016). The Lac-Mégantic disaster and transport Canada's safety management system (SMS) model: Implications for reflexive regulatory regimes. *Journal of Environmental Law and Practice*, 28(3), 299-332. Retrieved from <http://login.ezproxy.library.ualberta.ca/login?url=https://search-proquest-com.login.ezproxy.library.ualberta.ca/docview/1816873385?accountid=14474>

<sup>3</sup> Locomotive video and voice recording (LVVR) systems: A proposal for access and use of LVVR information, updated December 2016. Personal communications with Paul C. Miller, 22 August 2017.

<sup>4</sup> Cheng, Y-H. (2017). Railway safety climate: A study on organizational development. *International Journal of Occupational Safety and Ergonomics*, forthcoming.

<sup>5</sup> Morgan, J.I., Abbott, R., Furness, P. & Ramsay, J. (2016). UK rail workers' perception of accident risk factors: An exploratory study. *International Journal of Industrial Ergonomics*, 55: 103-113.

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

been recognized as being insufficient to reduce accident rates (ICAO, 2008). SMS was designed around evolving concepts about risk management and safety culture, including the research into High Reliability Organizations, which are believed to offer great potential for more effective safety management. A successful SMS is systematic, explicit, and comprehensive...it becomes part of an organization's culture, and of the way people go about their work.”<sup>6</sup>

Canada's *Railway SMS Regulation* was updated in 2015. It lists 12 specific requirements and processes each railway company's SMS must identify and deliver, including such items as an Accountable Executive; employee involvement; and processes for risk assessment and mitigation; compliance with regulations, rules, and procedures; and continuous safety improvement. A summary of the RSMSR is included in Appendix A. Railway companies and unions have worked with Transport Canada to develop and promulgate “clear language” best practices for successful development and implementation of SMS for the 2001 but not the 2015 revisions.

At this time, a review of SMS is seen by business, government and regulators as means of enhancing safety performance, productivity, and profitability and “just good business”.<sup>7,8</sup>

### 1.2 SMS in Canada's Railway System

Canada has one of the largest railway networks in the world. Currently, 73 railways are required to establish SMS (Local railways must comply with SMS requirements when operating on federal rail tracks). The industry demonstrates considerable diligence for continuously maintaining and improving the overall safety of Canada's railway network and transportation of call commodities, including dangerous goods.

Safety performance trends (see Figure 1) demonstrate a continuous improvement in passenger and freight rail safety in Canada over the past ten years. In an analysis of Canadian train derailments from 2001 to 2014,<sup>9</sup> the amount of dangerous goods carried by rail has increased due to a rise in oil production in western Canada. Nevertheless, there was a decreasing trend in derailments resulting in a dangerous goods release. It is noted that in mid-2014 the reporting requirements changed such that all derailments became reportable as opposed to previous years. Therefore data for 2014 and after includes additional accidents that would not have required reporting in previous years, resulting in a leveling off of rail safety performance after 2014.

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<sup>6</sup> Fox, K. (2013). Speech given by Ms. Fox, Chair of the TSB and recognized expert in SMS for all transportation modes.

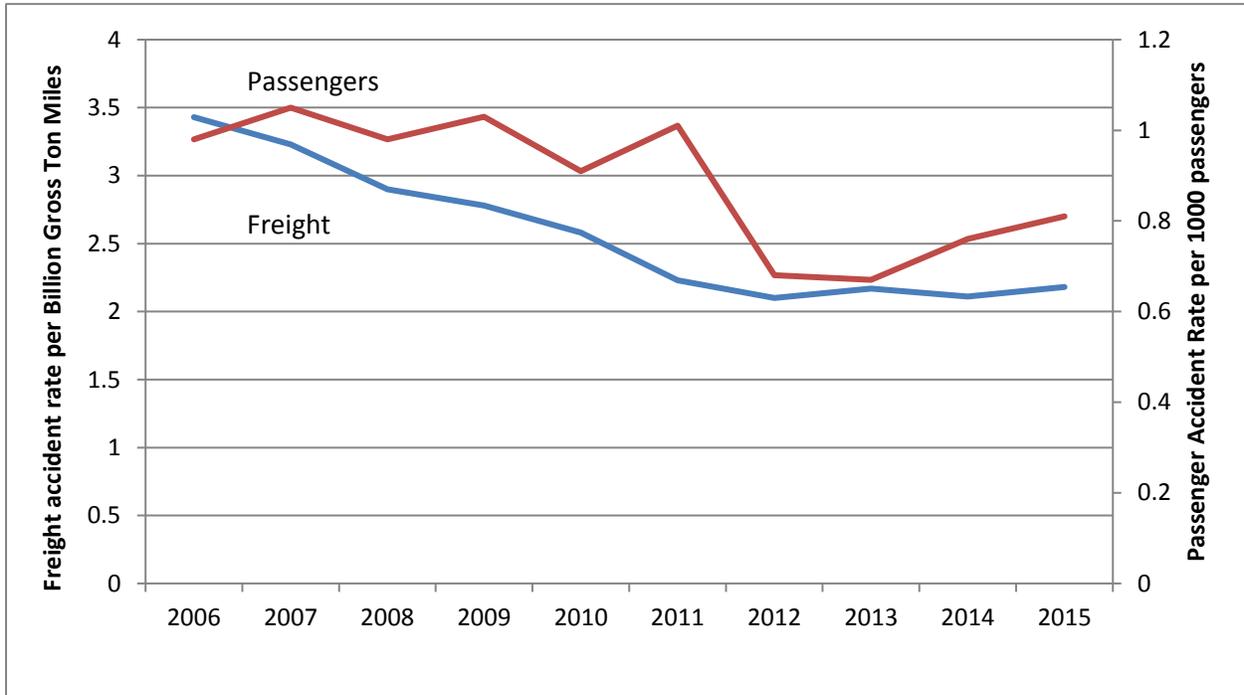
<sup>7</sup> Venkatraman Narayan, (2012) "Business performance and maintenance: How are safety, quality, reliability, productivity and maintenance related?" *Journal of Quality in Maintenance Engineering*, 18(2): 183-195. doi: 10.1108/13552511211244210.

<sup>8</sup> Kontogiannis, T., Leva, M. C., & Balfe, N. (2017). Total safety management: Principles, processes and methods. *Safety Science*, forthcoming.

<sup>9</sup> Leishman, E. M. (2016). *Analysis of Canadian Train Derailments from 2001 to 2014*. University of Alberta, Civil and Environmental Engineering. Edmonton: University of Alberta.

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

About 32% of the trains involved in rail accidents in 2016 were freight trains, 6% (69 trains) were passenger trains and 61% were mainly single cars or cuts of cars, locomotives, and track units. In the same year, there were 108 accidents involving dangerous goods; a decrease when compared to 145 for 2015 and below the five year average of 141. One accident involved the release of dangerous goods in 2016; a decrease from 6 in 2015 and a five year average of 4 per year. Railway fatalities increased from 46 in 2015 to 66 in 2016; down from the five year average of 76. Most fatalities are associated with crossing accidents and people trespassing, with only two or three per year associated with other rail operations (with the exception of 2013 when the Lac-Mégantic derailment led to 47 fatalities).



**Figure 1. Freight and Passenger Accident Rates in Canada<sup>10</sup>**

SMS in Canada’s rail system have had some success. However, better communication of the SMS approach to all stakeholders, and more extensive internal and external auditing would further improve railway performance.<sup>11</sup>

<sup>10</sup> RAC. (2016) Rail Trends. [www.railcan.ca](http://www.railcan.ca). Rail Trends safety data reflects the performance of RAC’s federally and provincially regulated freight and passenger member railways. These data come from the Transportation Safety Board of Canada (TSB) and RAC. The TSB maintains a database of safety performance statistics on federally regulated railways, as well as provincially regulated railways that voluntarily report their data. Each organization uses the same safety definitions, and the data reflects railway operations in Canada only.

<sup>11</sup> Winfield, M. (2016). The Lac-Mégantic disaster and transport Canada’s safety management system (SMS) model: Implications for reflexive regulatory regimes. *Journal of Environmental Law and Practice*, 28(3), 299-332. Retrieved from <http://login.ezproxy.library.ualberta.ca/login?url=https://search-proquest-com.login.ezproxy.library.ualberta.ca/docview/1816873385?accountid=14474>

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

While there have been audits and inspections of railways' SMS, it is not clear whether TC's oversight activities are targeting the higher-risk railways and the most significant safety risks.<sup>12</sup> Due consideration is required for strengthening oversight of non-federal railways using federal railway tracks and shortlines and contract operators compliance with safety standards and regulations.<sup>13</sup> TC has completed or substantially completed a total of 14 audits, over three years, for eight federal railways; 26% of what its policy requires. There have been concerns that audits have been narrowly focused and provided assurance on only a few aspects of SMS rather than whether the whole system has been adopted.<sup>14</sup> At the rate at which TC is conducting its audits, it will likely take many years to completely audit all the key components of SMS regulations, including key safety systems of the 73 railways that are currently required to have a SMS<sup>15</sup> unless additional resources are applied to expedite audits of SMS and traditional inspections.

In summary, although there have been substantive safety improvements in Canada's railway industry, a more sustainable and effective approach to implementing and regulating SMS can provide additional opportunities for improving safety .

In this report, we discuss and propose the adaptation of an enhanced SMS implementation, within clearer performance-based regulation, and safety-risk management methods. We draw from other jurisdictions and research to demonstrate how this would improve and encourage continuous improvement and innovation by railway operators and in concert with partners and relevant stakeholders. This is outlined in Figure 2 and discussed in the next sections. The first block in Figure 2 (left side of the figure) summarizes the principles of performance-based, enhanced safety regulations, which numbers the desired characteristics of each component of the SMS. The central block describes the cyclic nature of the safety management system framework, which requires consistency with the organization's safety policy. The third block (right side of Figure 2) shows the safety risk management process and components, and the required monitoring, communication and consultation with all relevant stakeholders.

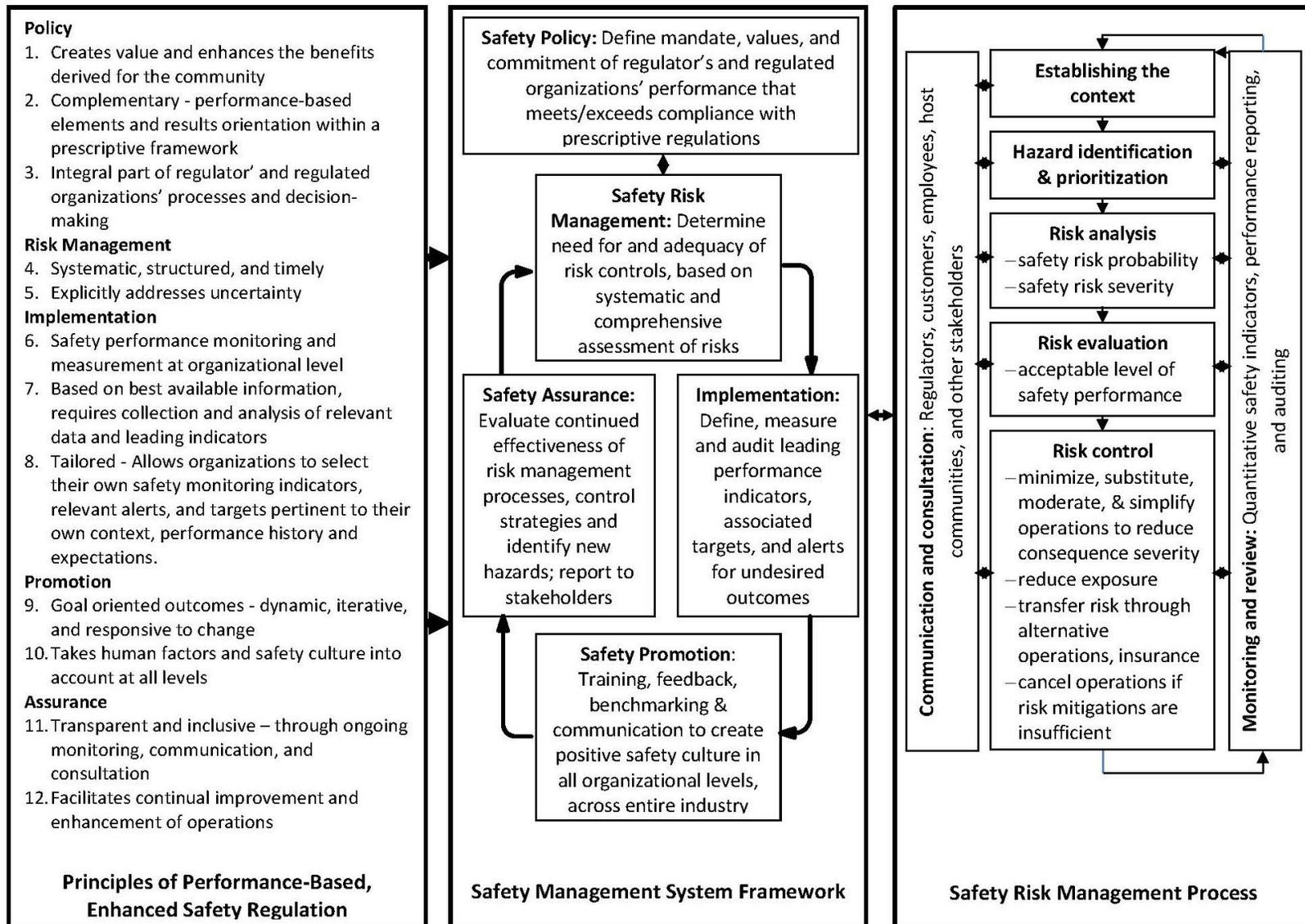
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<sup>12</sup> <https://www.scribd.com/document/187293997/2013-Fall-Report-of-the-Auditor-General-of-Canada-Oversight-of-Rail-Safety>

<sup>13</sup> [http://www.oag-bvg.gc.ca/internet/English/parl\\_oag\\_201311\\_07\\_e\\_38801.html#hd5k](http://www.oag-bvg.gc.ca/internet/English/parl_oag_201311_07_e_38801.html#hd5k)  
<https://www.scribd.com/document/187293997/2013-Fall-Report-of-the-Auditor-General-of-Canada-Oversight-of-Rail-Safety>

<sup>14</sup> Ontario Auditor General (year) and <https://www.scribd.com/document/187293997/2013-Fall-Report-of-the-Auditor-General-of-Canada-Oversight-of-Rail-Safety>

<sup>15</sup> <https://www.scribd.com/document/187293997/2013-Fall-Report-of-the-Auditor-General-of-Canada-Oversight-of-Rail-Safety>



**Figure 2. Relationships between the principles of performance-based enhanced safety regulation, SMS framework, and safety risk management process**

## 2. Performance-Based Enhanced Safety Regulation

In this section, we outline the principles of performance-based safety regulation (in bold) and the accompanying rationale. The purpose of regulation is to improve organizations' and individuals' behavior to **increase social benefit while minimizing harms**. Prescriptive compliance-based regulation specifies the designs, technologies, or processes that must be used by regulated organizations to achieve compliance, such as requiring use of the American Railway Engineering and Maintenance-of-Way Association (AREMA) *Manual for Railway Engineering*. Performance-based regulation is **goal-oriented**; it defines the required outcomes, while allowing regulated organizations to determine how they will comply with these outcomes, such as *Locomotive Emission Regulations* under the *RSA* (i.e., refurbish or buy new, if a locomotive is pulled out of service).

Beyond performance standards for regulated organizations, performance-based regulation has implications for the regulator, how it regulates organizations within its jurisdiction according to tailored standards, and how the regulator itself is evaluated. More generally, performance-based regulation is a regulatory system that uses performance as:<sup>16</sup>

1. the basis for the legal commands found in regulatory standards,
2. a criterion for allocating enforcement and compliance resources,
3. a trigger for the application of differentiated (or tiered) regulatory standards, and
4. a basis for evaluating regulatory programs and agencies.

The *Railway Safety Act* defines a SMS as “a formal framework of integrating safety into day-to-day railway operations and includes safety goals and performance targets, risk assessments, responsibilities and authorities, rules and procedures, and monitoring and evaluation processes”.<sup>17</sup> The *Railway Safety Management System Regulations* (2015) are an interesting hybrid; they prescriptively specify the processes that operators must include in their SMS, including processes for establishing performance targets and initiatives, risk assessment, and implementing and evaluating remedial actions. Yet, they do not specifically define “safety performance”, “improvements”, or even “acceptable level of safety performance”. Indeed, expanding the regulator’s obligations to points 2-4 above, have been raised by the Auditor General<sup>18</sup> and others.<sup>19</sup>

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<sup>16</sup> Coglianese, Cary, Jennifer Nash, and Todd Olmstead. (2002) “Performance-Based Regulation: Prospects and Limitations in Health, Safety, and Environmental Protection,” Regulatory Policy Program Report No. RPP-03 (2002), p. 3.

<sup>17</sup> Railway Safety Act - R.S.C., 1985, c. 32 (4th Supp.) (Section 4). Available URL: <http://laws-lois.justice.gc.ca/eng/acts/R-4.2/page-1.html?txthl=management+systems+syst%C3%A8me+system+safety#s-4>

<sup>18</sup> Auditor General of Canada (2013). Fall Report of the Auditor General of Canada, Chapter 7 – Oversight of Rail Safety – Transport Canada. Office of the Auditor General of Canada. Available URL: [http://www.oag-bvg.gc.ca/internet/English/parl\\_oag\\_201311\\_07\\_e\\_38801.html](http://www.oag-bvg.gc.ca/internet/English/parl_oag_201311_07_e_38801.html)

<sup>19</sup> Winfield, M. (2016). The Lac-Mégantic Disaster and Transport Canada's Safety Management System (SMS) Model: Implications for Reflexive Regulatory Regimes. *Journal of Environmental Law and Practice*, 28(3), 299.

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

Conversely, the International Civil Aviation Organization's (ICAO)<sup>20</sup> hybrid approach is a performance-based, enhanced safety framework, whereby certain performance-based elements are introduced within a **complementary** prescriptive, administrative control framework. This allows the compliance aspects of regulation to be **flexibly tailored**, risk-based (and hence more dynamic) performance of the safety-sensitive aspects of an organization's operations. For simpler operations, such as a simple one-person operation, the risk mitigation process may involve the use of a one-page checklist. For complex, multi-disciplinary processes (e.g. operations on track with rock falls, avalanches, and washouts) it may involve using risk mitigation software to perform a systematic, comprehensive safety and mitigation assessment. This highlights an opportunity for enhancement of the railway SMS regulations, aiming towards flexibility to accommodate diverse rail operations and sizes, improving the efficiency of reporting, developing meaningful safety performance metrics and criteria, and strengthening oversight of SMS implementation for enhancing rail safety.

Unlike auditing of prescriptive requirements, assessment within a performance-based process requires internal and external (regulatory) auditors to be aware of the context of that process/element within the overall regulatory framework, the complexity of organizations' operations, and **decision-making criteria**, such as simple go/no go or pass/fail criteria.

Defining acceptable levels of performance is often through the **monitoring and measurement of safety performance at the organizational level**; using appropriate safety, quality, or other outcomes or deviations; through **best available data** for trending of rates (rather than absolute numbers). Trend analysis will define what is an abnormal or unacceptable occurrence rate as well as the desired target (improvement) rate for an indicator.

Lastly, the assurance processes of performance-based enhanced safety regulation must be **transparent and inclusive**. Organizations' SMS must have an internal review process to ensure that the system is working as intended and meeting its objectives. Furthermore, the regulator and other stakeholders (as required) should review the organizations' operations and initiatives to make sure that it is meeting goals and that issues are being addressed. Regular meetings between the regulator and industry would help in this regard. This ongoing monitoring, communication, and consultation for safety performance will facilitate **continual improvement and enhancement** of operations.

### 3. Regulatory Regime for Successful SMS

The RSA definition for a Safety Management System, as applied to railways, considers different key aspects of the management system and the organization to which it applies: "a formal framework for integrating safety into day-to-day railway operations and includes safety goals and performance targets, risk assessments, responsibilities and authorities, rules and procedures, and monitoring and evaluation processes."

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<sup>20</sup> International Civil Aviation Organization (ICAO) (2013) Safety Management Manual (SMM), Third Edition.

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

In the view of the authors, this definition summarizes some of the main attributes for a successful SMS. The core of the statement is the integration of safety practices and safety culture into the day-to-day operations of railways that ultimately, is the desired outcome of the RSA. Around this core statement, key attributes are included such as accountability (“*responsibilities and authorities*”), auditability (“*formal framework*”), and measurability (“*safety goals and performance targets*”). Also, it highlights the requirement for an explicit understanding of the levels of risk associated with the operation and their tolerability (“*risk assessments*”), implementation of practical tools for risk control (“*rules and procedures*”), and continuous monitoring and assessment of the effectiveness of the system. These are further addressed in Section 47 of the RSA, and detailed in RSMSR.

This section discusses some fundamental characteristics and principles of a regulatory regime that the authors’ work demonstrates to be necessary for successful SMS and the roles of industry and regulator in achieving an effective system (see SMS implementation, relative to principles of performance-based, enhanced safety regulation in Figure 2).

### 3.1 Safety Policy

The RSMSR require SMS to reflect the organization’s safety policy, which is a tangible statement of the company’s commitment to promoting railway safety. A safety policy is considered a living document, which is reviewed and updated regularly, according to the characteristics and needs of the operations at the time. In this regard, it is important that rail operators’ safety policies reflect the multitude of tasks in their operations (i.e., maintrack, yard work, mechanical work, maintenance operations, administrative tasks, etc.).

The safety policy is a plan of action that will influence future decision-making.<sup>21</sup> Moreover, its effectiveness requires: 1) the participation of management and employees in its development (i.e., senior management, crew member representatives), 2) consistency with the characteristics of the rail operations and the business objectives, 3) adequate consideration of the nature of potential hazards associated with the operations, and 4) appropriate weight and importance within the organization. It is important to highlight that points 2 and 3 above are applicable to the development of the safety policy as well as the SMS overall. These two considerations provide the means to scale the extent of the safety policy and SMS processes according to the scale of the operator (i.e., Class 1 railways versus short line operators), while reflecting the potential hazards and exposure associated with their operations.

### 3.2 Safety Risk Management

The RSMSR requires SMS to include (Under *Processes* for Railway Companies and Local Railway Companies): 1) a process for identifying safety concerns, which is the equivalent to hazard identification within a risk management framework; 2) a risk assessment process, which requires evaluating the potential consequences and their likelihood against some evaluation criteria; and 3) a process for

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<sup>21</sup> Canadian Centre for Occupational Health and Safety (CCOHS) (2017) Guide to Writing an OHS Policy statement. Available at [www.ccohs.ca](http://www.ccohs.ca). Accessed August 23, 2017.

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

implementing and evaluating remedial action. These requirements are the basis of a risk management process, which in turn provide a path towards performance-based or risk-based approaches to regulation.

Performance-based regulations were discussed in detail in the previous section. Risk-based approaches to regulation focus on harm prevention and promote safety outcomes that comply with goals and objectives through the adoption of appropriate tools.<sup>22</sup> Conventional compliance-based regulation promotes a rigid and prescriptive approach that requires previous occurrences for controls to be regulated, and is supported by inspections and audits focused on the specific regulated controls to assure compliance.<sup>23</sup> Risk-based or performance-based regulations provide a more flexible and dynamic performance that can be tailored to reflect the conditions of particular railway operations. As stated previously, ICAO (2013) refers to the introduction of performance-based elements within a prescriptive framework that would allow for the compliance aspect of the regulation. Such an approach provides opportunity for innovation, optimization and continuous safety enhancement while complying with regulated safety targets. This would imply that regulatory inspections and audits focus on the adequacy of the SMS and risk assessments to the operations, through field inspection of operations and review of recorded procedures and outcomes. This approach also promotes further collaboration between regulated organizations and the regulator for enhancing safety, which in the authors' experience, is already strong for federally regulated railways in Canada.

A key aspect of performance- or risk-based regulations is the safety risk management process. This process is discussed in Section 4 in the context of rail safety regulations and the implementation and audit of railways' SMS.

### 3.3 Implementation

ICAO (2013) includes a detailed discussion of the requirements for a successful implementation of SMS. Perhaps the most important aspect of implementing a SMS in an effective manner is its integration with the existing operational systems. Such systems can include quality management systems (QMS), operational procedures, and related SMS (within the organization or third parties). An SMS can be developed to encompass the full range of operations within the organization; however, there can be situations where individual SMS, tailored to specific operations (i.e., transloading special dangerous goods), would be better-suited given the diversity of the organization. Arguably, the latter could reflect the case of large railways. Under such circumstances, integration of an overall SMS or developing SMS for particular business units requires a thorough analysis of interphases between units and tasks (i.e., transition between yard work and main line transport). Successful regulation would promote adequate SMS for the overall operation, as one overarching system or a number of systems, emphasizing the requirement for assessing the adequacy of SMS at interphases between different units and tasks.

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<sup>22</sup> Nicholls A (2015) The Challenges and Benefits of Risk-Based Regulation in Achieving Scheme Outcomes. Actuaries Institute 2015 Injury Schemes Seminar, 8-10 November, 2015, Adelaide, Australia.

<sup>23</sup> Nicholls (2015) and ICAO (2013).

Evaluating the success of SMS implementation can only be achieved through evaluation of some indicators identified to represent the operation safety performance, which leads us to our next topic.

### 3.4 Safety Performance Indicators for Railways

Performance indicators are measureable performance outcomes that provide the necessary information to determine if the SMS is enhancing safety or just complying with regulation. Moreover, performance indicators demonstrate to the regulator that the SMS has been implemented, that its performance is adequate (ICAO 2013) and that, in combination with incident investigations, allows regulators to evaluate the its level of success.<sup>24</sup> An earlier evaluation of safety performance measurements in the Canadian railway industry<sup>25</sup> recommended enhancing the existing performance measurements (largely based on incident and accident statistics) and developing new measures to better identify the overall level of risk associated with railway operations. While these statements are still relevant, the report also identified the regulator as the lead for these initiatives. In the authors' view, successful regulation should promote that safety performance indicators be developed by railway operators and their consultants, who hold the detailed knowledge of their particular systems and processes, together with the regulator in order to develop harmonized indicators throughout the industry which reflect the characteristics of the Canadian railway system. For increased efficiency, operators should have the flexibility to adopt all or part of the safety performance indicators as they apply to their processes, systems, and operations. The regulator would evaluate these during inspections and audits of the SMS implementation and adequacy.

Safety performance indicators demonstrate the adoption of regular monitoring schemes and alert levels indicating the need for risk mitigation.<sup>26</sup> In this regard, performance indicators are data trending charts of low-consequence occurrences or factors, in terms of event rates, that indicate an increasing potential for intolerable loss that require mitigation. Within railways - the availability of rail defect data, track geometry measurements, hot wheel detectors, among other data - provide an options for developing a suite of leading safety performance indicators. Moreover, when used to develop safety performance indicators, these provide the means for establishing safety targets and evaluating risk mitigation actions (requirements in RSMSR) at higher operational levels (closer to the root causes) than using statistical data on incidents and accidents. Although federally regulated railways must report all accidents and incidents according to the TSB Regulations (SOR/2014-37), these statistics should be used as validation of the effectiveness of a SMS and not as diagnostic of a deficient SMS. Rather than being reactive like the TSB, Transport Canada is a preventative regulator. Indeed, recommendation 25 of "Stronger Ties" recommended that Transport Canada be responsible for railway safety data collection, which would enable Transport Canada and industry to jointly determine data requirement to adequately measure

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<sup>24</sup> Basso B, Carpegna C, Dibitonto C, Gaido G, Robotto A, Zonato C (2004) Reviewing the safety management system by incident investigation and performance indicators. *Journal of Loss Prevention in the Process Industries* 17:225-231.

<sup>25</sup> QGI Consulting Ltd. (2007) Performance Measurement in Railway Safety - Final Report, Delivered to the Railway Safety Act Review Panel, July 13, 2007.

<sup>26</sup> ICAO. (2013).

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

SMS.<sup>27</sup> The information available through the TSB, however, provides valuable insight into leading incident and accident causes that can be used for developing safety performance indicators.<sup>28</sup> As an example, Leishman (2016) shows the top leading causes of main-track train derailments in Canada include human error, track geometry defects, rail breaks (rail, joint bar and anchoring) and wheel breaks; which are currently the focus of most risk mitigation by federally regulated railways. Another example can be found in the indicators used by the Rail Safety and Standards Board<sup>29</sup> in the UK, based on records of reported track faults, embankment failures, level crossing incidents, signaling failures, brake faults, exceeding speeds, objects on track, among others.

Although it is responsibility of the operator to successfully implement a SMS, the regulatory regime should provide a means for assurance. RSMSR requires that operators have someone responsible for implementation of the SMS, and that monitoring and internal auditing identifies deficiencies in implementation. This highlights an opportunity for regulation to link the effectiveness of SMS implementation with the operator's safety objectives and performance indicators.

### 3.5 Recordkeeping

Recordkeeping and filing are stressed as an essential process in RSMSR for regulatory auditability. Successful regulations would promote adequate documentation to ensure safety, without creating an excessive burden in the SMS process that would hinder its effectiveness. The amount, detail, and method of recordkeeping should be consistent with SMS regulation processes and the scale of the operations, while assuring compliance with safety policies and processes for safety and ease of regulator auditing.

### 3.6 Safety System Application and Promotion

SMS regulation of safety implementation / promotion should focus on assuring training and communication to create positive safety culture in all organizational levels, across the entire operation. The current RSMSR requires that all employees be notified about safety aspects, including the safety policy, reporting procedures, identified risks and remedial actions, safety targets and initiatives, among other items. Successful SMS regulations should go beyond communication and promote engagement of all employees in taking part of the SMS and enhancing safety culture through training. Compliance with regulation through internal and external regulatory auditing can be achieved through systematic interviews, where understanding and implementation of the SMS is tailored to the employees' level within the organizational chart. In this regard, interviews with upper management would target the objectives of the SMS, the processes in place to achieve the safety targets and safety policy, and how are these being measured. Interviews with field employees would target the application of field-level SMS

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<sup>27</sup> Railway Safety Act Review Secretariat. (2007) Stronger Ties: A Shared Commitment to Railway Safety, Review of the Railway Safety Act, November 2007.

<sup>28</sup> Leishman E. (2016) Analysis of Canadian Train Derailments from 2001 to 2014. M.Sc. Thesis, Faculty of Engineering, University of Alberta, Edmonton, AB, Canada.

<sup>29</sup> Rail Safety and Standards Board (RSSB). (2017). Annual Safety Performance Report A reference guide to safety trends on GB railways 2016/17. Available at: <https://www.rssb.co.uk/Library/risk-analysis-and-safety-reporting/2017-07-report-annual-safety-performance-report.pdf>

tools, their perceived effectiveness and employees' understanding of the real benefit of SMS and positive safety culture.

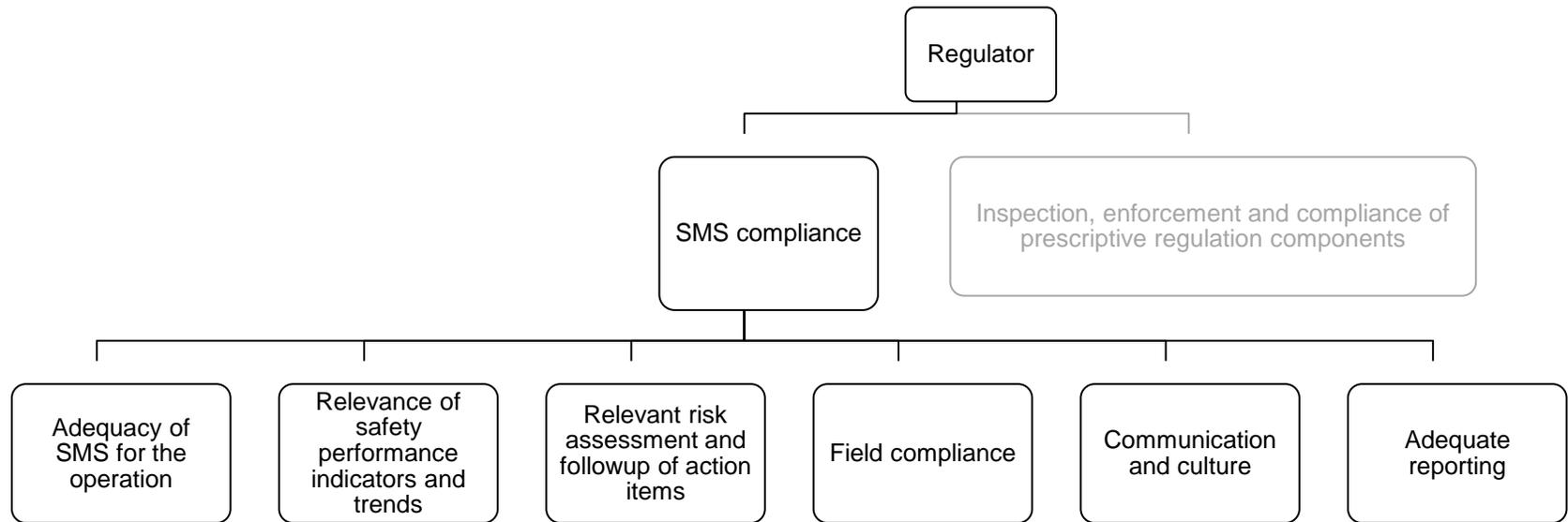
### 3.7 Safety Assurance and Auditing

Auditing has been discussed, to some extent, within the previous sections. Auditing should not only assure compliance with record keeping, it should assure compliance with the adequacy of the SMS to the particular operations. This includes the safety policy, relevant safety processes in place, adequate risk assessments and mitigation strategies, relevant safety performance indicators and follow-up with analyses of their trends (i.e., rail breaks, track geometry defects, impact detectors, hotbox detectors, and other leading indicators the organizations' mitigation of these), completeness of occurrence reporting, safety culture, and overall success of the SMS through analysis of occurrence statistics (incidents, accidents, injuries and other occurrences known as lagging indicators). To this end, auditing needs to focus on the SMS design and how it relates to the railways being audited. This requires integrating the documentation auditing, interviews and field components.

Further, external and internal auditing must be tailored to the particular characteristics and stakeholder needs (companies, unions, regulators) of the operator being audited. This risk ranking will ensure that adequate focus is placed on the most safety sensitive aspects of the operation. This can be associated with increasing challenges in resource allocation for auditing and achieving consistency between audits among different operators; however, it will ensure that audits address that operator's real safety concerns. A way forward is the development of auditing processes in modules that can be applied as they become relevant for the operation, together with adequate training. Auditing should be comprehensive regardless of the size of operation; however, this approach will scale the amount of record keeping and management necessary, depending upon the operation's size, the potential for safety hazards, frequency of occurrence, and the severity of consequences. Railroads carrying chlorine cars through the Rocky Mountains and adjacent to spawning rivers will have greater record keeping and auditing requirements than shortline operators of grain trains on the Prairies.

As previously stated, interviews for auditing purposes must be tailored to the employees' level within the organization and reflect their tasks and levels of responsibility. Interviews with upper management should target the objectives of the SMS, the processes in place to achieve the safety targets and safety policy, and how are these being measured; while interviews to field employees should target their specific application of field-level SMS tools and their perceived effectiveness, associated with their particular tasks.

Figure 3 shows the inspection role of the regulator with respect to safety regulations. These include inspections regarding the current prescriptive regulations and SMS compliance. Figure 3 focuses on auditing and inspection of SMS regulations. The authors consider that a successful regulatory regime requires inspections and audits to assure compliance of each of the SMS aspects shown in Figure 3 (It is noted that Figure 3 represents a simplification of the interrelationships between each block).



**Figure 3. Main SMS aspects for inspection of SMS compliance**

### 3.8. Successful implementation of risk-based regulation for UK railways

One example of successful implementation of safety performance-based regulations for SMS for railways is in the United Kingdom (UK). The Office of Rail Regulation (ORR) has developed a risk-based approach for the regulation of railways in the UK<sup>30</sup> that focuses on identified risk priorities that are reviewed regularly. The intent is to prioritize the regulator's resources on a risk basis while retaining capacity to process permits and other documentation and target reactive investigations into incidents.

The ORR assesses safety performance in terms of indicators that include incidents, near misses, risk indicators, and outcomes. Risk indicators are based on comprehensive risk models developed specifically for the UK railway system and on a Railway Management Maturity Model, which aids understanding the maturity level of an organization in a number of critical areas.

A risk-based approach is also used by the ORR to identify railway operations that represent higher risks. These are then prioritized for higher resource allocation and regulatory attention. Risk priorities are reassessed every two years.

Safety is regulated through the *Railways and Other Guided Transport Systems (Safety) Regulations*.<sup>31</sup> These regulations give operators and infrastructure managers a duty to develop safety management systems, carry out risk assessments and risk mitigation measures, report annually on safety performance, among others. Further, they regulate common safety methods for risk assessments and monitoring based on European guidelines. ORR also possesses tools to enforce safety (if safety enhancement is required and/or for compliance with other regulations).

The successful implementation of ORR's risk-based regulations has been reflected on the UK having the lowest fatality ratio per billion train km across the EU between 2008 and 2012 (1.1 fatalities per billion train-km compared to an average of 23 and a maximum of 149.1 - ORR 2015). Moreover, safety on main line railways has shown constant improvement between 1999 and early 2015 (timeframe of the ORR report).

### 3.9. Summary of SMS Elements

In the authors' opinion, implementing these elements (3.1-3.7) would increase the effectiveness of SMS in achieving improved safety performance, which we summarize in Table 1.

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<sup>30</sup> Office of Rail Regulation (ORR) (2015) ORR's Health and Safety Regulatory Strategy. Available from [www.orr.gov.uk](http://www.orr.gov.uk). Accessed August 23, 2017.

<sup>31</sup> Office of Rail Regulation (ORR). (2014). *The Railways and Other Guided Transport Systems (Safety) Regulations 2006 (as amended) - A Guide to ROGS*. Available from [www.orr.gov.uk](http://www.orr.gov.uk). Accessed August 23, 2017.

**Table 1. Summary of SMS Elements, Key Elements, and Best Practices**

<b>Element</b>	<b>What is it?</b>	<b>Key components for improving effectiveness?</b>	<b>Best practices?</b>
3.1 Safety Policy	A tangible statement of the company's commitment to safety, providing a plan of action that influences future decision-making.	<ol style="list-style-type: none"> <li>1) management and employee participation in its development</li> <li>2) consistency with the characteristics of the rail operations</li> <li>3) consideration of potential hazards</li> <li>4) appropriate recognition of policy within organization</li> </ol>	CCOHS (2017)
3.2 Safety Risk Management	A process for identifying safety concerns/hazards, assessing potential consequences, and evaluating of remedial actions	<ol style="list-style-type: none"> <li>1) comply with goals/ objectives of safety policy</li> <li>2) use hazard identification, analysis, and evaluation tools appropriate to organization's complexity and scope</li> <li>3) support continuous improvement</li> </ol>	ICAO (2013)
3.3 Implementation	A process of adopting SMS performance targets, risk assessment, responsibilities and authorities, rules and practices, and monitoring and reporting into operations	<ol style="list-style-type: none"> <li>1) integrate with existing operational systems (quality, reliability, financial)</li> <li>2) tailor for specific, high-risk operations</li> <li>3) connect operational units (e.g., engineering, mechanical, transportation)</li> </ol>	ICAO (2013)
3.4 Safety Performance Indicators	Measurable performance outcomes that demonstrate if the SMS integration is enhancing safety or adopted superficially for compliance purposes	<ol style="list-style-type: none"> <li>1) adopt harmonized leading indicators (rail breaks, hot wheels) that reflect Canadian operating conditions</li> <li>2) correlate leading indicators to lagging indicators</li> <li>3) evaluate of effectiveness of SMS in improving performance of operators</li> </ol>	RSSB (2017)
3.5 Record keeping	Documentation that allows internal and external auditability	<ol style="list-style-type: none"> <li>1) sufficient for RSMSR</li> <li>2) appropriate to scale and scope of operations</li> </ol>	CSA (2010)
3.6 Safety system application / promotion	Process of integrating SMS across operations to promote a positive safety culture, reinforced by decision-making, aligned with lived values	<ol style="list-style-type: none"> <li>1) engage all employees in the purpose of SMS</li> <li>2) train employees on the elements of SMS relevant to their level in the organizations</li> <li>3) audit employees' understanding and use of these elements in their own terminology and day-to-day activities</li> </ol>	CSA (2010)
3.7 Safety Assurance / Auditing	Internal and external (regulatory) review of practices	<ol style="list-style-type: none"> <li>1) assure appropriate application of SMS to each operations' scope and scale, focusing on safety sensitive aspects (highest priority risks, from risk ranking)</li> <li>2) assure compliance with regulations</li> <li>3) interview employees, tailored to their understanding of operations and level of responsibility</li> </ol>	CSA (2010)

## 4. Safety Risk Management Process

All process components (safety risk management, implementation /promotion and assurance) are integral for a successful system and derive from the organization's safety policy. The lead component, however, is how risk is identified, evaluated and mitigated.<sup>32</sup> This is discussed in more detail in this section.

RSMSR requires that railway companies conduct risk assessments under particular circumstances, including the identification of safety concerns, initiation or modification of the transport regime of dangerous goods, and when proposed changes to operations may affect safety (SOR/2015-26). It has become the consensus that effective risk management requires that risks be assessed in a continuous, iterative manner. This allows for early identification of potential hazards and proactive management of these. RSMSR requires continuous analysis to identify safety concerns, triggering a risk assessment when a concern is identified. A natural step forward would consider regularly scheduled risk assessments together with the continuous analysis for identifying safety concerns. In this section, we discuss the components of the Safety Risk Management Process (right hand box in Figure 2).

### 4.1. Establishing the Context

We previously discussed the importance that the SMS reflect the characteristics of the rail transport operation. This is most important for hazard identification and risk assessment. The context should not only define the boundaries of the rail operation in physical terms (yards, track, shops, loading facilities) but also in terms of the organization's culture, objectives, processes, etc. Moreover, consideration of the external context is necessary, which includes: 1) socio-economic and cultural aspects, 2) regulatory frameworks, 3) environmental conditions (i.e., weather, land use, sensitive areas), 4) technology, and 5) relationships, values and perceptions of external stakeholders.<sup>33</sup>

The context for risk management also establishes the objectives of the risk management process, the methodology, and the criteria for evaluating risk. Here, leading safety performance indicators are identified (i.e., rail breaks, track defects, exceeding speed limits) as well as adequate metrics for railway occurrences (i.e., incidents per length of track, per MGT or combinations; using severity indicators such as number of derailments, injuries, etc.) that allow consistent, normalized measurement and evaluation of risk. These indicators and their trends also constitute part of implementation and safety assurance within the SMS framework (Figure 2).

### 4.2. Hazard identification and prioritization

The objective of hazard identification is to generate a comprehensive list of events with the potential to cause harm to people, the environment, equipment, infrastructure, or operations. Identification must be formal, systematic and continuous; and based on a combination of reactive, proactive and predictive

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<sup>32</sup> Demichela M, Piccinini N, Romano A. (2004). Risk analysis as a basis for safety management system. *Journal of Loss Prevention in the Process Industries*, 17:179-185

<sup>33</sup> Canadian Standards Association (CSA) (2010) Risk management - Principles and guidelines. National Standard of Canada CAN/CSA-ISO 31000-10. Published in 2010, reaffirmed in 2015

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

methods for safety data collection. It must utilize tools and techniques suited to the particular rail operations and the context previously established.<sup>34,35</sup> The RSMSR requires continuous analyses for identification of safety concerns based on reports, railway occurrences, injuries, inspections, audits, perceived hazards, complaints, and data from monitoring technologies (SOR/2015-26).

Tools for hazard identification and prioritization suited for rail transport operations include structured group brainstorming sessions,<sup>36</sup> risk registers, preliminary hazard analyses, task analyses, Failure Mode and Effects Analyses (FMEA), Fault Tree Analyses (FTA), and Event Tree Analyses (ETA), among others.<sup>37,38</sup> The tools selected and their complexity will be driven by the size and scope of the operation. Identification must consider all potential sources of risk such as structure failure (e.g., bridge collapse during extreme river flooding, increase in rail breaks during extremely cold weather), human aspects (e.g., response deficiencies under extreme weather conditions, known areas for trespassers, grade crossings in densely populated urban areas), equipment failures (e.g., distance from closest inspection system, time since last full inspection in the yard), and natural events (e.g., landslides, soft ground, storm events).

### 4.3. Risk analysis

Risk analysis consists on estimating the probability and the severity of the identified safety risks, which involves developing a further understanding of the hazards and processes that would lead to a loss. Such analyses must consider different sources of risk (as previously identified), the multiple consequence scenarios and their likelihoods, as well as those factors affecting the probability and magnitude of the consequences (e.g., track speed, gradient, and curvature; train length; commodities being transported; population density; time of day; season).

The level of detail for the analysis will depend on the size of the operation and the complexity of its systems, the information and data available, and the criticality of the system components (e.g., secondary track at low speeds transporting grain in an unpopulated area versus main line transport of dangerous goods).<sup>39</sup> Tools available for risk analysis include some of the tools used for hazard identification (FMEA, ETA, FTA), refining the estimation of the hazard likelihood and the magnitude of potential consequences. Other tools include risk-ranking techniques based on system modelling and risk factor analyses.

There are risk analysis tools that have been developed for the railway industry. The Rail Corridor Risk Management System (RCRMS)<sup>40</sup> is currently used in the United States. The RCRMS is not applicable for Canadian railway operators as it compares the risk rankings of different route options, as in Canada there

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<sup>34</sup> ICAO (2013)

<sup>35</sup> CSA (2010)

<sup>36</sup> ICAO (2013)

<sup>37</sup> Ayyub BM (2003) Risk Analysis in Engineering and Economics. Chapman & Hall / CRC. pp.571

<sup>38</sup> Ostrom L, Wilhelmsen CA (2012) Risk assessment: Tools, techniques, and their applications. John Wiley & Sons Inc. New Jersey. pp. 392

<sup>39</sup> CSA (2010)

<sup>40</sup> available at [www.railroadresearch.org](http://www.railroadresearch.org)

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

is rarely more than one route option. Other models have been developed at the University of Illinois,<sup>41,42,43</sup> and the Safety Risk Model (SRM) available from the RSSB in Great Britain.<sup>44</sup> These models are comprehensive, quantitative approaches that provide precedence for this application.

### 4.4. Risk evaluation

Risk evaluation provides the required information for identifying which risks need to be mitigated and their prioritization.<sup>45</sup> Risk evaluation requires defining or adopting acceptable levels of safety performance. This requires the definition of safety performance indicators (leading indicators and other occurrences, incidents, and accidents), appropriate metrics, and consensus regarding realistic safety expectations for rail transport in Canadian society. The RSMSR requires a method for evaluating the level of risk that considers the likelihood that a risk will occur and the severity of its consequences (SOR/2015-26) without specifying the approach (qualitative, quantitative), method, metrics or acceptability criteria. While this provides flexibility for railway operators, it becomes a challenge for aggregating or comparing among operators. Successful SMS regulation would promote homogeneous metrics and set realistic safety criteria to be met, based on society's (government regulators', host communities') expectations, constant safety improvement, and sound analyses. The TSB regulations on rail occurrence reporting (SOR/2014-37) and the statistical analyses derived from those records<sup>46</sup> are a good basis for developing common risk metrics. Other source of valuable information is the statistical analysis published by the Railway Association of Canada (RAC).<sup>47</sup>

Comprehensive risk criteria require adoption of diverse metrics that cover the potential types of losses (human, environmental, economic, business, etc.). Potential metrics can be developed based on annualized numbers of employees, passenger and third party fatalities, injuries, number of rail incidents and accidents (or accident groups such as collisions, derailments, crossing accidents), environmental clean-up costs, transport delay time, costs of equipment and infrastructure loss, etc. Safety monitoring can focus on leading indicators such as those previously mentioned.

Criteria could aim at absolute threshold values for each risk metric, which operators are required to adhere to (similar to those proposed by the Health and Safety Executive in the UK)<sup>48,49</sup> or promote

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<sup>41</sup> Kawprasert A, Barkan CPL (2009) Communication and Interpretation of Results of Route Risk Analyses of Hazardous Materials Transportation by Railroad. *TRR Journal*, 2097:125-135

<sup>42</sup> Liu X, Barkan CPL, Saat MR (2011) Analysis of derailments by accident cause – evaluating railroad track upgrades to reduce transportation risk. *TTRR Journal*, 2261:178-185

<sup>43</sup> Liu X, Saat MR, Barkan CPL (2013) Safety effectiveness of integrated risk reduction strategies for rail transport of hazardous materials. *TRR Journal*, 2374:102-110

<sup>44</sup> Muttram R.I. (2002) Railway safety's safety risk model. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit*, 216: 71–79.

<sup>45</sup> CSA (2010)

<sup>46</sup> available at [www.bst-tsb.gc.ca](http://www.bst-tsb.gc.ca)

<sup>47</sup> Rail Trends, available at [www.railcan.ca/publications/trends](http://www.railcan.ca/publications/trends)

<sup>48</sup> Health and Safety Executive, UK (HSE). 1992. The tolerability of risk from nuclear power stations. Her Majesty's Stationery Office, London.

<sup>49</sup> Health and Safety Executive, UK (HSE). 2001. Reducing risks, protecting people. Her Majesty's Stationery Office, London.

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

continuous improvement of rail transport safety performance (i.e., an “equal or better than before” policy) after the operator’s safety performance has met certain minimum requirements.

It is the view of the authors that developing and proposing successful rail transport risk evaluation criteria needs to be a collaborative effort between regulator, industry, and research institutions; as these will bring a comprehensive set of expertise. However, the regulator should ultimately hold the decision-making power and accountability to define such criteria in light of society’s safety expectations and need for a healthy rail transport industry.

### 4.5. Risk control

Risk control refers to a set of actions designed to mitigate risks and constrain them within acceptable thresholds. These can aim to minimize, substitute, moderate, or simplify tasks and operations to reduce occurrence likelihood or consequence severity. Some actions include: 1) reducing exposure (i.e., modifying transport route for dangerous goods to avoid vulnerable populations), 2) reducing likelihood of occurrence (i.e., increasing the frequency of rail inspections, reducing distance between wayside detectors), 3) transfer risks (i.e., through insurance or industry funds), 4) risk avoidance (avoiding certain operations, which is not likely to be feasible given that railroad operators cannot refuse certain traffic as it is key for the economic health of the country), and combinations of these actions.<sup>50,51</sup>

Selecting risk control strategies requires an assessment of the benefits gained from their implementation (in terms of risk reduction), the costs required (both capital and operational costs) and potential risks that can be created by implementing the strategy. Not all controls are equally effective. Elimination of risks is the most effective, following by substitution of less hazardous materials for more hazardous, isolate/separate risks from those vulnerable, engineer controls, implement organizational controls, institute procedural controls and, lastly, require personal protective equipment.<sup>52</sup> The implementation of rock fall management is a good example. Blasting rock faces would eliminate the risk. Rock nets reduce the exposure of operations to falling rocks by isolating/separating the rockfalls from the track. Shotcrete and bolting are engineered controls that reduce the likelihood of rock falls occurring. Contracting-out rock fall controls, tied to performance incentives and penalties, would transfer the risk to others. Reducing speed during higher rock fall times (e.g., following rainfall events) would avoid train collisions.

The RSMSR requires evaluation of the effectiveness of remedial actions follow a risk assessment. Have the identified risks been reduced? This is an important feature of successful SMS regulations, and requires identification of safety performance indicators (leading indicators and occurrences, accidents, and incidents) as discussed earlier. It is worth mentioning that the value of such effort would be increased by assuring consistency between safety performance indicators for SMS monitoring and for risk assessment, as well as consistency across the industry through regulation. Such indicators, associated with particular

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<sup>50</sup> Ayyub (2003)

<sup>51</sup> CSA (2010)

<sup>52</sup> Cocchio J., Lefsrud LM, Nibber N, Winkel G. (2017). *The Handbook for Engineering Safety and Risk Management*. University of Alberta.

railway tasks and operations, would provide a means to scale the SMS to the size of the railway's operations.

Hazard identification, risk analysis, evaluation and control are the core process within the overall safety risk management process. These need constant updating to increase the likelihood that new hazards are addressed in a timely manner that increases in risk are detected and that risk control strategies are effective in reducing risk. Successful SMS regulation would promote this continuous cycle, with participation of the entire organizational structure (in the form of field-level tools, data analysis, reporting, etc.), and with a dedicated team that oversees the process and reports its findings for timely action.

#### 4.6. Monitoring and review

Safety performance indicators are key for evaluating the effectiveness of SMS. Moreover, the RSMSR requires monitoring the effectiveness of the SMS and risk control measures. We cannot understate the importance of relevant leading indicators and occurrences that reflect each operator's particular characteristics and size, as well as the advantages of homogeneous safety performance indicators and risk metrics throughout the industry. We will discuss additional factors the authors consider important for successful SMS regulations.

The railway industry and the regulator already have a strong commitment to allocating resources for monitoring and review. These include leading indicators such as track geometry and continuous track deflection measurements (i.e., MRail system), which are starting to be used for safety performance monitoring,<sup>53,54</sup> rail breaks, and wheel breaks, among others. Monitoring also includes recording incidents such as speeding, exceeding authority limits, inadequate response to signals; accidents such as collisions, derailments, crossing accidents, and their consequences, including fatalities, number of trains involved, number of cars derailed, release of dangerous goods, etc. As previously mentioned, statistical analyses of these are regularly published by the TSB and RAC. This rich database is a solid base to tailor monitoring and review of the relevance and effectiveness of the risk management process (as per Figure 2) and the SMS overall. Trends in leading indicators and occurrences can provide the required information for subsequent iterations of hazard identification and prioritization, risk analysis, and evaluation.

Moreover, monitoring can provide quantitative information for implementation and safety assurance in the iterative SMS framework in Figure 2. An example can be found in the positive impact of improved technologies (rail inspection, hot wheel detectors, wheel impact load detectors) in decreasing the number of derailments due to infrastructure failures (although not a lead indicator, its reduction is a measure of success considering the technologies addressed leading indicators such as rail breaks, brake problems and

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<sup>53</sup> Roghani A, Macciotta R, Hendry M. (2017). Quantifying the Effectiveness of Methods Used to Improve Railway Track Performance over Soft Subgrades: Methodology and Case Study. *Journal of Transportation Engineering, Part A: Systems*, 143(9).

<sup>54</sup> Roghani A, Macciotta R, Hendry M. (2015). Combining Track Quality and Performance Measures to Assess Track Maintenance Requirements. Joint Rail Conference (JRC2015). American Society of Mechanical Engineers. March 23-26, 2015, San Jose, California, USA

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

wheel breaks). However, derailments due to human factors have remained relatively constant and are not decreasing at a rate comparable to other attributes such as infrastructure and track conditions. This shows the potential for updating and enhancing the hazard identification and prioritization based on adequate monitoring and review within a systematic safety risk management process and SMS, following successful implementation of risk control strategies. In this case, updated hazard prioritization could be followed by enhancements to the SMS and risk control strategies by addressing safety culture, risk communication, and other tools to enhance safety associated with human factors.

Monitoring and review also refer to compliance with the safety risk management process and the SMS. This should be done through internal and external auditing, tailored to the specific characteristics of the railway operator. Moreover, auditing should be consistent with the required training of employees at the level that auditing is being performed. Successful SMS regulations would promote these characteristics as well as homogeneous auditing standards throughout the industry.

The monitoring and review processes should encompass all aspects of the risk management process such that it ensures that:

- controls are effective and efficient,
- further information is obtained that will be used to improve the risk assessment process and the SMS,
- it maximizes the knowledge gained from safety performance indicators and railway occurrences and their trends, it is effective in detecting changes in the external and internal context, including the risk criteria, potential hazards and their prioritization;<sup>55</sup> and
- these are consistent with the railway industry's best practices and the current technologies.

### 4.7. Communication and consultation

Risk communication is an interactive exchange of information and opinions between regulators, customers, employees, and other stakeholders. This includes discussion of the nature of risks, safety concerns, opinions, reactions to regulation, among others.<sup>56</sup> An accurate assessment of risk is the basis for appropriate decision-making.

It is important that communication and consultation occurs internally (e.g., with rail managers, risk assessors, crew members, maintenance-of-way personnel), and that communication (e.g., terminology, illustrations, examples) be tailored to individuals' training and skills. External communication includes discussing risks with regulators and the public (say with emergency responders, with appropriate confidentiality controls in place) tailored to their understanding and information needs. It is important to note that the honest disclosure of risks, consideration of stakeholders' socio-economic and political context, and the operator's history with stakeholders are important influences to others' perceptions of the risk. An Engineering Pamphlet of the US Army Corps of Engineers (EP 1110-2-8) on risk communication suggests that risk communication must: 1) be free of jargon, 2) establish consensus amongst experts, 3)

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<sup>55</sup> CSA (2010)

<sup>56</sup> Ayyub (2003)

## Role of Safety Management Systems (SMS) in the railway industry and potential for enhancement of Railway Safety Act (RSA)

use credible sources of cited information, 4) be tailored to the audience, 5) personalize the information as possible, 6) promote discussions stressing a positive approach, and 7) present data in a meaningful manner.<sup>57</sup> As per Figure 2, safety risk communication and consultation is continual and two-way, throughout the safety risk management process.

Communication should be consistent with safety risk management and SMS. Safety policies, the detail and justification for processes, and risk control actions must be communicated effectively. Moreover, successful SMS regulation will promote processes for employee input regarding SMS processes and risk control measures. The RSMSR requires communication, and in some cases consultation, of key components and outcomes of the rail SMS such as safety policy, procedures for reporting railway occurrences, identified risks and remedial actions to be implemented, safety targets and initiatives, among others. Moreover, the RSMS requires a procedure that enables employees to report contraventions of the Act, regulations, rules, emergency directives, orders, or certificates; to the railway company, without fear of reprisal (SOR/2015-26).

### 4.8. Summary of Safety Risk Management Process Elements

Implementing these safety risk management elements (4.1-4.7) would improve SMS effectiveness and overall safety performance. We summarize these elements in Table 2.

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<sup>57</sup> Ayyub (2003)

**Table 1. Summary of Safety Risk Management Process Elements, Key Components, and Best Practices**

<b>Element</b>	<b>What is it?</b>	<b>Key components for improving effectiveness?</b>	<b>Best practices?</b>
4.1 Establish the context	Definition of the railway operations	<ol style="list-style-type: none"> <li>1) define organization’s objectives for risk management process</li> <li>2) scope operations and technology, changing environmental conditions, pertinent regulations, range of internal and external stakeholders</li> <li>3) identify leading safety performance indicators relative to operations</li> </ol>	CSA (2010)
4.2 Hazard identification and prioritization	List of events with the potential to harm	<ol style="list-style-type: none"> <li>1) systematic and continuous identification of hazards to people (employees, public), environment (on/off property), assets (rolling stock, rail, share price), and production (reliability, on time performance)</li> <li>2) use <i>reactive methods</i> to learn from others’ incidents using event tree analysis</li> <li>3) use <i>proactive methods</i> to identify hazards for own operations through field level hazard assessment and/or</li> <li>4) use <i>predictive methods</i> to relate prevalence of hazards (e.g. rail breaks as a function of ambient temperature)</li> </ol>	Ayyub (2003), CSA (2010)
4.3 Risk analysis	Estimation of the severity and probability of safety risks	<ol style="list-style-type: none"> <li>1) based on scope and complexity of operations, consider multiple consequence scenarios and the associated factors (e.g., track speeds, train length)</li> <li>2) estimate probability/frequency based on own operating statistics or others’ (RAC, RSSB)</li> </ol>	CSA (2010), RAC (2016), Muttram (2002)
4.4 Risk evaluation	Identification and prioritization of which risks need to be mitigated	<ol style="list-style-type: none"> <li>1) define and/or adopt criteria for acceptable level of safety performance through leading and lagging indicators for all types of losses</li> <li>2) base criteria on own past performance; others’ performance; consultation with communities, unions, and other stakeholders; and/or regulatory requirements</li> <li>3) evaluate using quantitative methods (numerical frequency X severity data) or qualitative, relative methods (high, medium, low)</li> </ol>	Liu et al., (2011, 2013), CSA (2010), TSB (2017)
4.5 Risk control	Set of strategies designed to mitigate risks and constrain them within acceptable thresholds	<ol style="list-style-type: none"> <li>1) apply risk controls to avoid, transfer or reduce - starting with the most effective to the least: eliminate, substitute, isolate/separate, engineer controls, organizational controls, procedural controls and, lastly, personal protective equipment</li> <li>2) re-evaluate risks to determine if they have been reduced to within acceptable thresholds; continue to apply risk controls until they do</li> <li>3) scale effort to the size of railway’s operations</li> </ol>	Cocchio et al. (2017), Roghani et al. (2015, 2017)
4.6 Monitoring and review	Evaluation of SMS effectiveness	<ol style="list-style-type: none"> <li>1) reassess leading and lagging indicators for operations, relative to industry, for homogeneous auditing</li> <li>2) update hazard prioritization, assess controls, and iteratively improve SMS</li> </ol>	CSA (2010)
4.7 Communication and Consultation	Exchange information and opinions	<ol style="list-style-type: none"> <li>1) discuss nature of risks, safety concern / hazards, prioritization, reactions to regulation with internal stakeholders, tailored to their training and skills</li> <li>2) be consistent with SMS and risk management processes</li> </ol>	Ayyub (2003)

## 5. Conclusion

The purpose of this paper is to examine the role of SMS, as positioned relative to performance-based enhanced safety regulation<sup>58</sup> and safety risk management processes (adapted from ISO/CSA 31000) so that Canada's railway industry improves beyond compliance-based regulatory requirements. In summary, we recommend the following:

- Encourage regulator and industry collaboration, knowledge sharing, and continuous review to improve SMS implementation success and a best-fit approach for Canada.<sup>59</sup>
- Enhance the current regulation to allow SMS to reflect the characteristics, the tasks, and the size of the different rail operators in Canada. This flexibility will require auditing to focus on the adequacy of the SMS to the particular operation as well as its implementation and trends in safety performance indicators.
- Adopt a SMS performance-based regulatory approach, with the development of a suite of leading and lagging performance indicators, from which railway operators may choose, based on the scope and complexity of their operations.
- Regulatory auditing and monitoring of industry processes to close any lapses in the performance-based SMS.
- Application and use of the proposed framework in this report as guide – performance-based SMS principles, SMS framework, and safety management process to encourage enhanced safety culture within industry and operators.

## 6. Limitations and Disclosure

The views expressed in this document are the authors' opinions about key elements of successful Safety Management Systems as they apply to the Canadian railway industry. Discussions are based on literature review and experience with the industry and regulator. The objective of this document is to provide positive input that could potentially aid decision-makers' enhancement of railway safety in Canada, which, in the authors' view, should be considered as a continuous effort.

It is noted that Transport Canada and the Canadian railway industry have been funding safety-related research initiatives at the Faculty of Engineering of the University of Alberta, home of the David and Joan Lynch School of Engineering Safety and Risk Management.

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<sup>58</sup> <http://www.jstor.org/stable/pdf/40712156.pdf?refreqid=excelsior:ad169d083c4dfdda9f5df6aeff9b1d84>

<sup>59</sup> <https://www.youtube.com/watch?v=0ltEU71PJsk&t=87s> <https://www.youtube.com/watch?v=50JSGyS0a-w>

## **Appendix A – Summary of Railway Safety Management System Regulations (RSMSR) SOR/2015-26**

### **Safety Management System Processes, Procedures, Plans and Methods**

**5** A railway company must develop and implement a safety management system that includes

- (a) a process for accountability;
- (b) a process with respect to a safety policy;
- (c) a process for ensuring compliance with regulations, rules and other instruments;
- (d) a process for managing railway occurrences;
- (e) a process for identifying safety concerns;
- (f) a risk assessment process;
- (g) a process for implementing and evaluating remedial action;
- (h) a process for establishing targets and developing initiatives;
- (i) a process for reporting contraventions and safety hazards;
- (j) a process for managing knowledge;
- (k) a process with respect to scheduling; and
- (l) a process for continual improvement of the safety management system.