THEME 4: HUMAN FACTORS

Canadian Rail Research Laboratory (CaRRL)

University of Alberta

a. Railway transportation safety

1. Automated Machine Vision Inspection Systems (AMVIS) in Railways

Transport Canada's Rail Safety, Technology Evaluation and Assessment Group is developing a framework for assessing new technologies and processes in comparison to current manual/visual inspections methods, which includes analyzing the 1) effectiveness of the technology; 2) effectiveness of integration into business processes; and 3) ability to perform a complete inspection using complementary technologies.

Collaborative RRAB research is focusing on the first element of the assessment process, which is aimed at establishing how well the technology or process functions. This approach may include investigating the:

- Probability of detection and ability to effectively measure for certain defects (when applicable);
- Reliability – to remain accurate and calibrated in the operational environment, with minimal down time;
- Repeatability – to identify defects under similar conditions;
- Reproducibility – to identify defects under different conditions; and
- Traceability – to establish a logically-rigorous relationship between the existence of defects that can (and cannot) be detected; and the occurrence of a safety incident whenever a defect goes undetected, or is misdiagnosed, or is ineffectively acted upon.

A task team, including the University of Alberta, has been created from some of the members of the RRAB to focus on and assess the capabilities of Automated Machine Vision Inspection Systems (AMVIS; i.e., automated inspection portals). The task team will act as the steering committee to guide the project and provide data and technical support to investigate, analyze, or improve some aspect(s) of AMVIS technologies that are currently being developed by Canadian railways.

2. Risk Tolerability — Process Model and Development for Occurrences with High Potential for a Release of Dangerous Goods

Large volumes of hazardous materials (hazmat) are transported by railways in Canada. Even with low probability, people may suffer severe consequences due to railway mishaps conveying hazardous materials, particularly when trains pass through highly populated regions. To control and reduce the consequences of railway incidents transporting hazmat, performing risk analyses and risk assessments are necessary. Risk is identified as the relationship between hazard and vulnerability, which shows the degree of influence in an economic, social, and environmental level for a particular location. Risk assessments can provide appropriate information to identify areas at higher risk levels, develop and change land-use planning, and assign adequate emergency planning.

Features of the communities, such as population density, and climate conditions, such as wind direction, are changing over time. Therefore, the risk is not constant, and changing factors should be considered to calculate the risk. The methodology proposed in this study develops threat zones created by hazmat dispersion and combines them with population vulnerability to hazmat release to create risk maps. The method considers scenarios for these factors to capture their changing nature and efficiently calculate risk maps. The methodology considers scenarios of input variables – such as wind speed, cloud cover, and solar radiation, amongst others – to create a hazard map for the most probable and most dangerous meteorological conditions. Type of atmospheric stability and wind speed are two notable factors in comparison to other factors (e.g., cloud cover, temperature, and pressure) related to the dispersion of hazmat release. Therefore, the process used to consider meteorological conditions when creating hazard maps is based on the stability class and wind speed in this study.

A hazard map shows the potential escalation of a rail incident by estimating how a toxic cloud of released hazmat can disperse, potentially leading to fire and explosion scenarios. A hazard map also shows the threat zone in an area in which hazards such as toxic radiation or thermal radiation have exceeded a threshold value. This study is using ALOHA software to determine threat zones and create hazard maps. To model the threat zones in the ALOHA software, the physical effects of crude oil release, including pool fire, vapor cloud explosion, flashfire, toxic release, and boiling liquid expanding vapor explosion (BLEVE) are identified using event tree analysis. The ALOHA software predicts the threat zones for less than one hour after a release starts or for distances less than 10 kilometers (6.2 miles) from the source of release. This is related to the equations that ALOHA uses to predict threat zones. These equations are extracted from a series of experiments in which the gases are dispersed and travel in the direction of prevailing wind.

In these experiments, all calculations were performed within 0.6 miles (1 kilometer) of the release point and, in a few cases, calculations were performed for distances greater than 6 miles. The results showed the threat zones calculated far from the release source by the ALOHA are not accurate. Predicting the dominant atmospheric conditions at the time of the accident is challenging, so all wind directions are evaluated in the hazard map. Though hazmat disperses across the wind direction and covers a specific part of the location, considering all the wind directions and wind rose (how wind speed and its direction are distributed in a specific location) provided adequate information to prepare a hazard map and prevent any probable mistake in risk analysis.

3. Applying Safety Risk Model (SRM) on Canadian Railways, with a Special Focus on Transport of Dangerous Goods (TDG) Occurrences

In the previous research, we identified and ranked the gaps in Safety Management System (SMS) elements. The study's findings revealed that, among those SMS elements that showed the major gaps, there was a mutual cause-risk assessment. Many of these flaws can be avoided if a thorough risk assessment is carried out. Furthermore, the SMS is usually formulated without a quantitative risk assessment as a support, because of its costs in terms of money and time. In addition, sometimes the data required to conduct a quantitative analysis are not available. Therefore, it can be difficult to define the objective of an SMS without a quantifiable risk assessment. To this end, this study focuses on railway risk assessment and quantification of risk by applying an appropriate model.

One of the popular models in this regard is the Safety Risk Model (SRM). The SRM is widely used in the railroad industry of various countries, such as the UK and USA. The SRM is developed in the form of a cause and consequence analysis using Fault Tree Analysis (FTA) and Event Tree Analysis (ETA). This model is based on the quantification of the risk resulting from hazardous events that have the potential to lead to fatalities, major injuries, or minor injuries to passengers, staff, or members of the public.

A review of the literature revealed no comprehensive SRM that aggregates Canadian railway operations (federally regulated). To address this gap and contribute to the continuous improvement of rail transportation safety, this research focuses on risk assessment of railway accidents by applying an SRM customized to Canada. This model would also provide an opportunity to apply risk reduction analysis to determine the effectiveness with the introduction of a new control measure: Enhanced Train Control (ETC). Positive Train Control (PTC) is a well-known control measure that was mandated by the Rail Safety Improvement Act of 2008 (RSIA) for the development of certain Class 1 railroad main lines in the US to improve rail transportation safety. On December 29, 2020, the Federal Railroad Administration (FRA) announced that PTC technology had been implemented on all required freight and passenger railroad route miles. While the railway industry supports this measure, railway operators in Canada and the US have raised several major concerns regarding their experience with PTC implementation in the US, such as expense, complexity, and significant effort requirement to apply it.

A study done by Canada's Advisory Council on Railway Safety in 2016 recommended that the development of a targeted, risk-based, corridor-specific train control approach is the best option for the deployment of this technology in Canada. This suggestion has been the "working assumption" for implementing ETC in Canada. The recent Notice of Intent published in the Canada Gazette on February 5, 2022, revealed that Transport Canada intends to implement ETC in Canada to make Canada's rail transportation system even safer. The current study also aims to assess the impact of ETC implementation on rail transport risk. In this study, the risk is calculated in terms of collective risk (the average number of equivalent fatalities per year) and individual risk (the annual probability of equivalent fatality/year for a particular passenger or staff group using the railway). The risk reduction analysis of ETC implementation would then be applied.

This study focuses on investigating the Transportation Safety Board of Canada (TSB) and Rail Occurrence Database System (RODS) databases for main-track train derailment and collision, Class 1-5 occurrences. The assessment is being performed on the 1,084 reported main-track derailments and collisions in the eleven-year period between January 1, 2007 and December 31, 2017. This time frame was chosen based on databases available for part of the study analysis (FTA analysis). For those accidents that were not reported by RODS, TSB reports were used to collect the required information.

Applying a Canadian-customized SRM will help to predict residual levels of safety risks. It will allow for the identification of areas that need further risk controls. It also provides the opportunity for sensitivity analysis to be carried out to determine the risk reduction from the introduction of new control measures. It also enables cost-benefit and ALARP analyses to be carried out. In addition, it is beneficial in prioritizing areas for safety research. A Canadian-customized SRM will provide the basis for assessing the risk for a particular line of route or for a particular train operating company.

4. Risk Tolerability for the Transport of Dangerous Goods — Enhancement of Safety Performance in Canadian Railroad by the Application of Artificial Intelligence (AI), Machine Learning (ML), and Data Fusion (DF)

The objective of this study is to provide recommendations for risk tolerability strategies for rail transport in Canada, particularly for the transport of dangerous goods. This will be done by employing Artificial Intelligence, Machine Learning, and Keyword Analysis to determine the importance of each contributing factor of SMS/HFACS elements, prioritize them, and map the way they are linked. AI and ML can use various databases as inputs. These inputs can be extracted, processed, and refined to examine various results.

To achieve this objective, we analyze all incidents (Class 1, 2, and 3) that occurred from 2004-to 2019. Based on the causes and contributing factors, as well as reading details about the incident reports, it is possible to use ML to determine the SMS and HFACS elements associated with the incident. Then, AI determines the importance of each contributing factor in the accident rate, prioritizes them, and maps the way they are linked, and as a result, the enhancement of the safety performance of the organization will be achieved. Next, the application of Data Fusion helps to increase the accuracy of the results by combining one qualitative approach with the completely quantitative approach taken in this research.

5. Cognitive Impacts of In-Cab Warning Systems and Train Operator Workload

Automated control systems are increasingly being adopted in various industries to improve safety and optimize operations. They are changing the nature of work and transitioning the role of human operators from manually operating to passively monitoring. Such technologies prevent or reduce known human errors and improve safety; however, they may cause unexpected impacts on human performance and introduce new sources of human risks.

Recently, enhanced train control (ETC) has been developing across Canadian railway operations to automate operations, minimize human errors, and lower risks associated with handling dangerous goods. The proposed installation of ETC technology onto the Canadian railways will potentially change many train operators' tasks when operating a train. It may negatively influence the train operators' performance and increase the potential to make errors. Therefore, this research will evaluate the human factors implications of the introduction of ETC to the Canadian railways and identify the train operators' workload and other factors influencing performance.

In the current phase of research, we are examining the workload level of train operators with an ETC. For this, we answer: What are train engineers'/operators' workload levels at various operational transitions (e.g., locations requiring signal response or speed changes)? What combinations of visual, auditory, cognitive, and psychomotor stimuli are more likely to cause higher workload and/or overload? How may the ETC system impact workload and overload?

6. CaRRL Report on Enhanced Train Control

This project developed a concept of four levels of ETC functionality and a detailed review of the preventability of such levels on previously reported railway reportable occurrences (reportable incidents as per the Transportation Safety Board). The project developed detailed analyses of the potential safety benefits gained from the introduction of ETC technology to the Canadian railway environment. The analysis was based on the Transportation Safety Board Rail Occurrence Database System (RODS) and considered the preventability of the number of occurrences for the different occurrence groups as well as preventability in terms of the number of derailed cars, injuries, fatalities and other severity indicators.

7. Leading and Lagging Indicators for the Safe Transportation of Dangerous Goods by Rail

This project developed a detailed analysis of a railway occurrence database managed by the Transportation Safety Board of Canada. The analysis considered incidents involving the transportation of dangerous goods and utilized process safety techniques to identify leading and lagging safety performance indicators in the Canadian railway industry. Safety risk models were then developed to evaluate the role of human factors in of railway occurrences and by evaluating failures in the Safety Management Systems and through Human Factors Analyses. These allowed identification of those aspects of organizational factors that require strengthening to minimize the likelihood of railway occurrences. From a consequence perspective, human factors were analyzed as they influence the success in mitigating the effects of a rail incident involving the release of dangerous goods. The work focused on population evacuation and the most vulnerable areas based on demographic characteristics.

b. Grade-crossings

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c. Trespassing

d. Training

e. Safety culture

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4. Creative Sentencing Research Grant, Protecting Worker Safety in Alberta by Enhancing Field Level Hazard Assessments and Training for Ground Hazards Associated with Tailings Facilities, Dams, and Systems

Efforts related to the safety and performance of oil sands tailings storage and transportation facilities have traditionally focused on preventing catastrophic failures and are well defined by government legislation and industrial best practices. However, a recent death related to ground hazards near oil sands tailings facilities, dykes, and transport systems signals the need for improved worker safety during daily operations near these facilities. Ground hazards are known and understood by geotechnical experts, but a breakdown in communication occurs with respect to informing frontline workers. This final report serves to provide a thorough review of the research completed as part of the creative sentencing project resulting from that fatality. It represents an unprecedented collaboration and initiative between the oil sands industry, regional contractors, the Province of Alberta, and the University of Alberta.

5. Analysis of the Role of Safety Management Systems (SMS) in the Canadian Railway Industry

The Canadian Railway Safety Act regulations require that railways implement Safety Management Systems (SMSs). The intent of this requirement was to promote companies' safety culture, better management of safety risks, and demonstration of compliance with rules and engineering standards in day-to-day operations, while also reflecting on their processes and becoming more innovative. Yet, the railway disaster at Lac Mégantic in 2013 — which claimed 47 lives — demonstrated that SMSs have been unevenly applied by railroads. A Canadian Pacific railroad derailment on February 3, 2019 with strikingly similar circumstances— which claimed 3 lives— demonstrates these safety issues persist. In this research, we discuss and propose the adaptation of enhanced SMS implementation, within clearer performance-based regulation and risk management methods. We draw from other jurisdictions and research to demonstrate how this would encourage continuous improvement and innovation by railway operators in concert with partners and relevant stakeholders.

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