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SPATIO-PARAMETRIC RAIL RISK ASSESSMENT FOR DEVELOPMENTS NEAR FREIGHT RAIL

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Abstract: Railway operations are a backbone of the Canadian economy. Over the last decade, Canada has experienced an increase both in rail traffic and in the transportation of Dangerous Goods by rail. Due to recent catastrophic events affecting communities adjacent to railways, railway operations in Canada have been subject to increased scrutiny and public awareness, particularly in those areas that are close to urban developments. This increased awareness has led to changes in policy and guidelines for developments in proximity to railway operations. Legislation changes making railway data more accessible to the public have made more customized analysis of the risk of railway operations to adjacent developments possible, yet there are few methodologies available to guide industry in making these assessments. This paper describes a Spatio-Parametric Approach to Rail Risk (SPARR) model that integrates research on rail safety best practices precedents from around the world, input from stakeholders, multiple-substance explosion modeling, failure analysis, and Monte Carlo simulation with site-specific data and geometry. A case study is presented to demonstrate the proposed risk quantification method. The results of the risk assessment show how this comprehensive model can assess the risks to the public along a rail corridor and aid policy-making and industry stakeholders in optimizing development and designs and establishing flexible response strategies.

1 Introduction

To meet the growth needs of communities across Canada, demand for new forms of infill development is growing as cities place greater emphasis on curbing urban sprawl. With increasing urban land value and limited space availability, there is increasing pressure to develop land along urban railway corridors that historically have been used for low-density land uses. However, land development in proximity to heavy railway operations – considered a heavy industrial land use – causes challenges for municipal policy makers, as railway corridors pose unique risks to the adjacent communities.

The risks involved in the transport of Dangerous Goods by rail are clear from the recent Lac-Mégantic disaster, where multiple tanker cars exploded when a train derailed in the centre of town (Transportation Safety Board of Canada [TSB] 2013). The derailment led to the death of 47 people and the evacuation of over 2000 from the area. Another incident occurred in Calgary during the catastrophic flooding of 2013, when a Canadian Pacific bridge collapsed partially while in use: five tanker cars derailed and were teetering over the Bow river (TSB 2013). If any of the tankers been punctured, the oil spill would have been disastrous to the ecosystem of the river. The volume of Dangerous Goods being transported by rail is also rapidly increasing, which further intensifies the impact of these risks. Oil shipments moved by Canadian Class 1 railways increased from 500 car loads in 2009 to 160,000 in 2013 (Railway Association of Canada 2014), and derailments were up nearly 20 percent in 2014, reaching a total of 749 (Railway Association of Canada 2014).

Due to increased attention to railway safety and the implications for development adjacent to railway corridors, municipalities have been urged to review their policies for land use along railway corridors. While globally and nationally there are initiatives to streamline policymaking, to date there has not been a unified approach on incorporating the risks that freight rail corridors pose to adjacent developments in the municipal planning processes. Canadian municipal guidelines for development in proximity to heavy rail operations highlight the importance of robust risk assessment. However, the methodology for that assessment is left open, and while many approaches to risk assessment exist, their application to railway risk tends to be based on high level historical analysis that does not address variances in location-specific risk profiles.

The Spatio-Parametric Approach to Rail Risk (SPARR) model introduces a risk assessment approach that comprehensively addresses risks with a level of granularity that allows for the generation of spatially distributed risk profiles. The SPARR model is based on best practices in rail risk assessments from around the world, developed through an iterative application to rail risk assessments in Alberta. This study introduces the SPARR model for identification and assessment of risks that heavy railway corridors pose to adjacent land uses, allowing the development of effective, site-specific mitigation strategies, and providing a robust methodology for municipalities aiming to optimize policies to ensure sustainable and safe urban development along railway corridors. This paper presents the new SPARR model for rail risk assessment of developments in proximity to rail operations. The model is then applied to a case study to allow for evaluation and identify opportunities for improvement.

2 Background

2.1 Railway Risk and Safety Related Policies

In the Canadian context, all existing railway operations are regulated through several national acts, including the Canada Transportation Act (Minister of Justice 1996) which regulates noise and vibration and the Railway Safety Act (Minister of Justice 1985) which regulates safe railway operations. The transportation of Dangerous Goods is regulated by both the Transportation of Dangerous Goods Act (Minister of Justice 1992) and the Transportation of Dangerous Goods Regulations (Transport Canada 2001). These regulations require Emergency Response Assistance Plans (ERAP) to describe the procedures that are in place for a transportation accident involving Dangerous Goods. In addition, railway companies are required to meet certain operating practices regarding the safety of trains and routes that carry Dangerous Goods through protection and emergency directives. Examples include maximum speeds for operation, inspection frequency, and minimum requirements for track class, as well as the requirement to provide yearly aggregate information on the nature and volume of any Dangerous Goods rail companies transport by rail through a given municipality (Government of Canada 2013).

Following the Lac-Mégantic disaster, and in consideration of the projected growth of the transportation of Dangerous Goods by rail, the Transportation Safety Board (TSB) identified three key safety issues to be addressed to further improve the safety of the Canadian rail system. These include the vulnerability of Class 111 tank cars to damage, route planning and analysis for trains carrying Dangerous Goods, and requirements for emergency response assistance plans. In particular issues with the Class 111 tank cars were addressed, as they are known for their "high risk of product release in case of accident damage" and represent almost 80% of the Canadian fleet, carrying many types of Dangerous Goods (TSB 2014).

In 2003, the Federation of Canadian Municipalities (FCM) and the Railway Association of Canada (RAC) established a Community-Rail Proximity Initiative for the prevention and resolution of issues arising from development near railway corridors and other rail operations. This resulted in publication of the FCM-RAC "Guidelines for New Development in Proximity to Railway Operations" in 2013, to assist municipal governments in developing general policies for developing lands near railway facilities. The guidelines provide a standard set of mitigation strategies involving an earthen berm and building setbacks of 30m from the property line of a freight rail corridor and 300m from rail yards (FCM-RAC 2013). These requirements are depicted in Figure 1. These mitigations are based on historic analysis of aerial photos of train derailments, and do not necessarily account for public safety risks that originate from movement of Dangerous Goods by rail.

In urban areas, where high land values and limited space availability place greater development pressure on sites close to railway corridors, standard proposed mitigations are less likely to be accommodated. In this case, a location specific risk assessment is recommended to determine distances for Individual Risk and Noise and Vibration limits. However, no specifications are provided as to how these risks are to be reviewed.

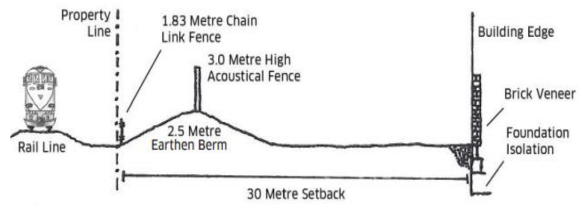

Figure 1: Standard Mitigation Requirements (FCM-RAC, 2013)

The Major Industrial Accidents Council of Canada (MIACC) was formed in 1987 with the goal of reducing the risk of major accidents from activities involving hazardous substances, and developing national standards, guidelines, and tools. MIACC has developed risk acceptability criteria which is reflected in allowable land uses for specified levels of Individual Risk (the annual risk of fatality of an individual) as shown in Figure 2. MIACC suggests that risk acceptability be defined based on the premise that the risk being evaluated should not make a substantial addition to the existing risk of everyday life: “an annual chance of death of 1 in a million is often chosen as a tolerable level, and an annual probability of death of 100 in a million is considered unacceptable” (MIACC 1995).

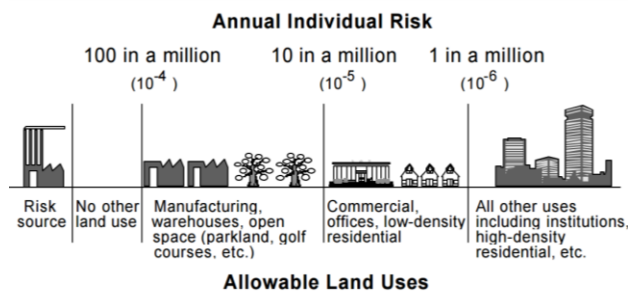

Figure 2: MIACC Risk Acceptability Criteria for Land-use Planning (MIACC 1995)

2.2 Railway Risk and Safety Related Case Studies

Policy makers worldwide are dealing with regulation of development in proximity to rail. In European legislation, a distinction is made between the risk to society caused by railways due to the transportation of Dangerous Goods, and the regulation of nuisance to society (noise and vibration) caused by railway traffic. The risk caused by railways due to the transportation of Dangerous Goods is regulated under the Convention Concerning International Carriage by Rail (COTIF 1980) and under the regulations concerning the international carriage of Dangerous Goods by rail (RID). Under RID, generic guidelines have been established for the calculation of risk for carriage of Dangerous Goods by rail. All member states are recommended to use the guidelines and adjust them to individual circumstances as necessary. The risk assessment methodology identifies event trees as the most helpful structure to classify accident scenarios and risk calculation.

For example, in determining the requirements of both existing and new developments adjacent to railways, Dutch regulations require a structured quantitative risk assessment methodology for municipal planning purposes (Ministerie van Infrastructuur en Milieu, Regeling basisnet 2014). The recommended risk framework includes: (i) quantitative risk assessment, (ii) the adoption of individual and group risk as risk-determining parameters and (iii) risk acceptance criteria. The acceptance criterion Individual Risk (IR) measures the annual fatality probability of one person residing in a certain geographical location for a full year due to hazardous material. Note that IR is characteristic of the location for which it is calculated, regardless of whether people are present at that location or not. The Dutch regulation allows a maximum risk of 1 in a million annual chance of fatality, which is similar to the 1 in a million threshold that MIACC defines as a tolerable risk level.

Several municipalities in Canada have considered a set of land use policies that apply to new developments in proximity to railway operations. Table 1 summarizes the policies that have been implemented. These policies are generally based on the recommendations from the FCM-RAC guidelines and, as such, do not typically account for the risks associated with transport of Dangerous Goods.

Table 1: Summary of Implementation of Mitigations for Developments Adjacent to Railways

Municipality	Municipal Zoning Adoptions
Town of Canmore	27.5-meter setback from centerline of Canadian Pacific Railway right-of-way and noise impact study (Town of Canmore, 2010)
City of Edmonton	Draft Regulations with detailed setback and mitigation requirements for different land uses and noise and vibration studies (generally 15 to 30 meter offsets for commercial and residential development) (City of Edmonton, 2016)
City of London	30-meter setback with berm or 120 meters without development and noise and vibration studies (City of London, 2014)
City of Ottawa	30-meter setback for residential buildings (City of Ottawa, 2016)
City of Windsor	Appropriate safety measures to satisfaction of Municipality and noise and vibration studies (City of Windsor, 2012)

3 Spatio-Parametric Approach to Rail Risk (SPARR)

3.1 Overview

Risk is typically defined as “the exposure to the chance of occurrences of events adversely or favorably affecting project objectives as a consequence of uncertainty” (Al-Bahar and Crandall 1990). As such, risk has an inherent relationship with uncertainty. The outcomes of a risk assessment are dependent on the information available and the experts involved, and are not to be treated as an exact science. To address uncertainty, risk assessments often rely on historical data and trend analysis. However, for assessment of catastrophic risks there are limitations in the use of historical data. Often, not enough data on historic occurrences exists to accurately estimate the frequency of occurrence.

The foundations of the SPARR model are based on a methodology to address uncertainty through the combination of comprehensive data gathering, expert judgement and simulation, to help estimate the identification, definition, probability, and impact of risk events. While available data may provide a range of different or sometimes conflicting information, its review by experienced experts in the field allows for an estimate of the ranges of likelihood of occurrence and impacts to be used in the risk assessment. Expert judgement that based on experience from other locations or disciplines can be evaluated and put into context through data review. Simulation can support analytical data analysis and the final risk quantification.

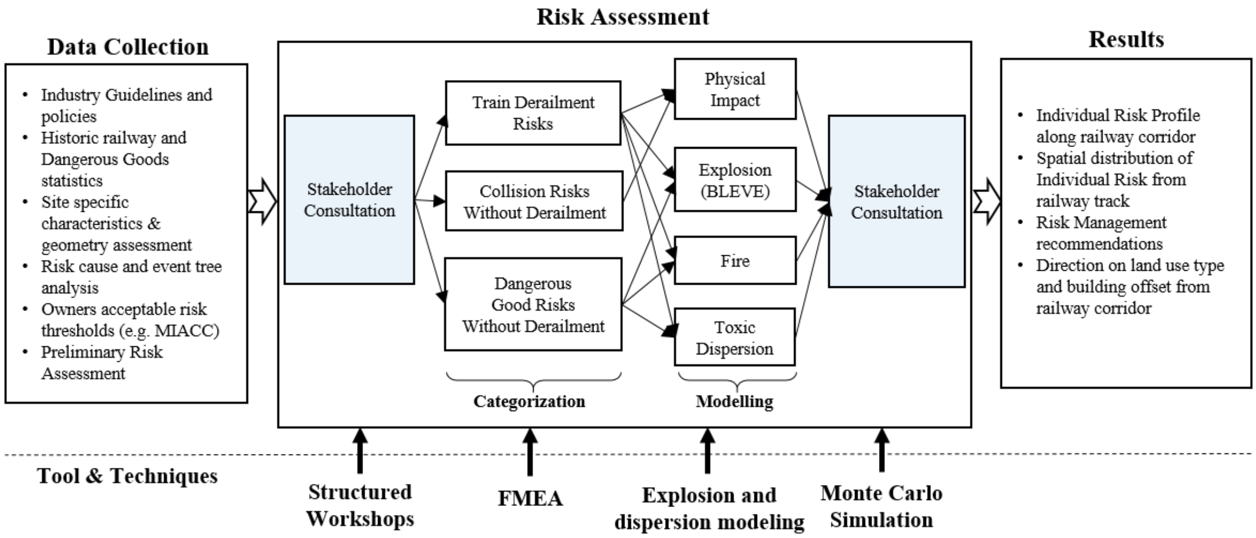

Figure 3: Spatio-Parametric Approach to Rail Risk (SPARR) model

As shown in Figure 3, the SPARR methodology takes a two-pronged approach. Comprehensive data collection, including historic occurrence statistics (i.e. desktop research, online information gathering, stakeholder consultation) are used for the development of an initial risk register. Then tools and techniques are used to assess the data that is used for quantification.

The data collection process begins with review of industry guidelines and polices related to rail risk and safety, including the identification of key risks within the specific project context. The project site is contextualized based on site-specific and geometric characteristics, including track geometry, rail, pipeline corridors, and other items. This is undertaken through site visits and in structured workshop settings with key project stakeholders. The workshop familiarizes stakeholders with industry guidelines and polices, generates an understanding of the potential causes of risks specific to site development, confirm details of all relevant risks in the corridor, discuss assumptions and confirm the initial risk register.

Failure Mode and Effect Analysis (FMEA) is used to assess risk events on the probability of occurrence, impact, and detectability through in-depth review with subject matter experts. FMEA helps to identify potential failure modes based on experience with similar products and processes, and common physics or failure logic. Since a risk event can result from numerous causes that are independent, the probability of a risk event will be the sum of the probability of those causes. The probability can therefore be determined by the (a) probability that there is a train present in the location, (b) probability of the cause occurring, (c) probability of the cause not being detected/mitigated, and (d) probability of the cause leading to a risk event if it occurs. This causal approach is used to complement the use of historic information of railway incidents to identify railway risk, since the frequency of occurrence of a disastrous risk at a specific location typically cannot be estimated accurately from the limited dataset of historic occurrences available.

Explosion and dispersion modeling are used to determine the potential consequences and spatial impacts of Dangerous Goods risks. Relevant risk impact scenarios include physical impact, explosion, fire, and atmospheric dispersion of toxic substances.

Monte Carlo simulation is applied once the risk register is finalized to account for uncertainty in each of the inputs to the model and provide a probability distribution of the model outcomes. This allows for sensitivity analysis of the risk assessment, and determination of the level of risk that is acceptable in a given scenario.

The results of the SPARR model provide a spatial distribution of Individual Risk exposure (annual risk of fatality) for specified intervals of railway track as a function of distance from the track. Based on a predefined acceptable risk threshold, which can be determined as part of the process or identified prior to the risk assessment, these outcomes can be used to provide recommendations on suitable types of development and mitigation measures. The outcome of the SPARR model can be visualized through risk level contours along the rail corridor for relevant levels of risk (e.g. MIACC threshold for various land uses). The contours vary for different sections of the rail corridor depending on the granularity and scale of the risk assessment

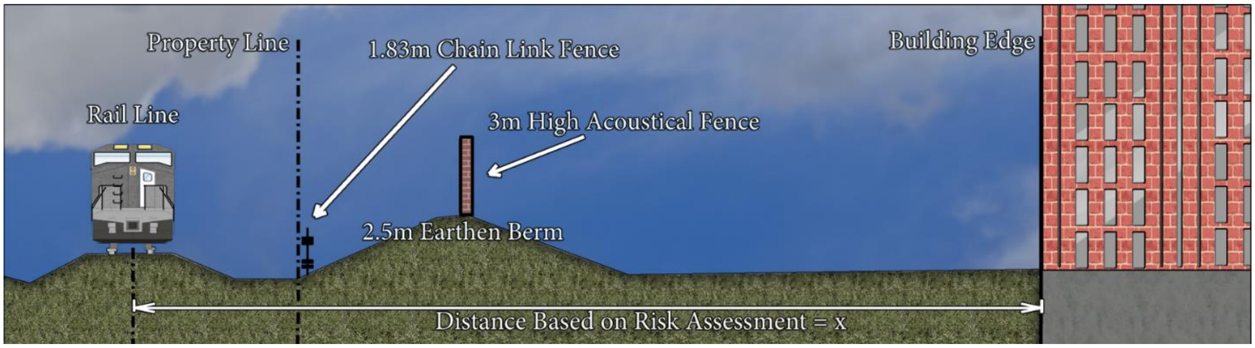

Figure 4: Site-specific risk assessment outcomes from the SPARR model

Figure 4 depicts the site-specific risk assessment outcomes calculated from the SPARR model in context of the recommended mitigations from the FCM-RAC Guidelines (i.e. chain link fence, acoustical fence and earthen berm). As noted, FCM-RAC Guidelines recommend a specific risk assessment be undertaken for sites where minimum offsets can not be accommodated. The SPARR model provides a comprehensive and consistent methodology to provide site specific recommended setback values (*x*) based on predefined risk thresholds for typical land uses. Note that *x* varies for each location and may exceed the 30m setback required by FCM-RAC Guidelines. This difference reflects incorporation of Dangerous Goods risks as well as the risk of derailment. FCM-RAC Guidelines do not account for Dangerous Goods risks.

3.2 Risk Assessment

The primary risks related to development in proximity to freight rail operations are summarized in Table 2. These risks have been identified through in-depth literature review and expert stakeholder consultation.

Table 2: Project Related Risks

Impact Type	Risk Events
Public Safety	Train derailment at development site Dangerous Goods release from car contents Dangerous Goods explosion from train car contents in rail yard Public trespass on rail
Damage to development	Noise and vibrations impacting development infrastructure
Undesirable operations of development	Noise and vibrations impacting development operations Rail restrictions impact construction costs, logistics, safety
Design and Construction restrictions	Damage caused by utility rupture or damage to railway embankment

Public safety is often the major concern of municipalities dealing with land development along heavy railway corridors. Therefore, the primary metric used in the risk assessment is Individual Risk as a function of the probability of an individual fatality. With the impact (i.e. a fatality) being inherently defined the main focus of the risk quantification is to determine the likelihood of an individual fatality as a function of distance from the rail line. What is quantified is the probability in which an unprotected individual standing outdoors for an entire year, will be exposed to a fatal circumstance. Since the risk is quantified for an unprotected scenario (i.e., the preventative effects of buildings and topography are not accounted for), and the assumption is that the individual is present for 24 hours per day, 7 days per week, the risk quantification is conservative.

The risks are identified and characterized into three major categories: train derailment, collision without train derailment and Dangerous Goods release without train derailment. The specific approach for the quantification of these categories in given in the following sections.

3.2.1 Train Derailment

To quantify a risk event, especially one as complex as a train derailment, the root causes and their probabilities must be understood and linked to the physical components of the situation. For a train derailment, numerous sources of uncertainty are involved. These include, for example, the likelihood of a train being present at the site under review, the likelihood of a train carrying Dangerous Goods, the likelihood of a derailment leading to a Dangerous Goods release, and the severity of the train derailment and/or Dangerous Goods release. In addition, the risk quantification incorporates root cause analysis, and reviews whether one or more causes occur, whether the cause is detected (there are mitigations in place during operations to detect defects), and whether this cause leads to the risk event occurring. Event tree analysis is undertaken to ensure a comprehensive review of all causes and risk events in the quantification.

The risk assessment approach differentiates causes that are unique to a given location and those that are consistent across the track network, based on the statistical data available for derailments in Canada. Across Canada, the average probability of a main track derailment per kilometer of track is 1.04 in 1 Million (TSB, Railway Statistics 2017). Intuitively, this average does not mean that all track segments have the same probability of derailment. Some areas of track are more likely to be the sites of derailment than others, e.g. due to differences in track geometry, presence of switches, train speed and other factors. To account for this difference, a review was undertaken to determine how many derailment causes were consistent across all track segments and how many were unique. Using summary statistics of main track derailments, it was determined that any cause of derailment related to train equipment (i.e. failure to load properly, misuse of equipment), could be taken to be consistent across all track segments. These base derailment causes account for 58% of all derailments. The base derailment probability is defined to apply to a main line that is easily maintained and located in an unpopulated, open, flat, rural area with a tangent track, with no crossing, in mild weather. The remaining causes of derailment comprise the other 42% of derailment probability, including track geometry, switches, objects on tracks, vandalism, and crossings, among others. The SPARR model assumes a base probability of derailment for any segment of track and adds additional probability according to other derailment causes. A detectability scale and a relative frequency scale were used to compare local circumstances to the baseline and determine the site-specific derailment probability.

When examining the impacts of train derailments, it is important to look at two primary factors: (1) the physical impacts of the train cars; and (2) the impacts of Dangerous Goods releases. The first of these, physical impacts, is based upon studies of historic train derailments that informed the FCM-RAC guidelines (30m offsets from the rail corridor). The methodology assumes that the physical impact is not expected to extend beyond 30 meters.

Determining the impacts of a release of Dangerous Goods involves breaking down the events that lead to the release. The probability of a train car carrying Dangerous Goods is calculated based upon the total Dangerous Goods train car movements versus total train car movements (based on confidential data provided by Canadian Pacific Railway). However, even if a Dangerous Good is present in a derailment, this does not necessarily mean that a release will occur. Statistically, when a Dangerous Good is involved in a derailment, a release occurs ~2% of the time (Hirschler 1992). The current methodology uses a conservative range of 2% to 3% for this occurrence. Furthermore, a Dangerous Goods release is not always serious. The severity of a release is dependent on the type of container and material involved, and the extent of the derailment. The Nose Creek risk assessment assumes the container to be the common DOT111-A-100 rail car, considered to be the worst-case container.

To understand the risk profile of a Dangerous Goods release, we explore the probability of a Dangerous Good being present and the impact that it could have if it were to be released, explode, or catch fire. The methodology considers the types and quantities of materials that are being transported. An independent explosion and dispersion modelling study was conducted to model certain representative substances, e.g. propane, crude oil and anhydrous ammonia. The methodology assumes that any release could result in one, or a combination, of any of the following: Boiling Liquid Expansion Vapour Explosion (BLEVE), Vapour

Cloud Explosion (Flash Fire), Vapour Cloud Dispersion (Toxic Dispersion), Pool Fire and Torch Fire. For each component, the probability of fatality was determined, considering parameters such as overpressure, fireball diameter and exposure to Vapour Cloud Explosion. The spatial impact of a Dangerous Goods release is determined using the same approach suggested by Hirschler (1992). The spatial probability of fatality from exposure to a Vapour Cloud Explosion is determined by assuming a probability of 99% from the source to half of the total distance of the vapour cloud distance, and a 50% probability of fatality up until 2/3 the total distance, and a drop to 1% after the individual is 85% of the distance away from the source. The resulting approximation of fatal consequences from a vapour cloud explosion (Flash Fire) as a function of distance from the source is shown in Figure 5. The results indicate a 50% probability of vapour cloud explosion at distance between 2-40m from the track centre and 10% probability of occurrence at any distance further than 40m. it also shows that there is zero chance of vapour cloud explosion at a distance further than 225m.

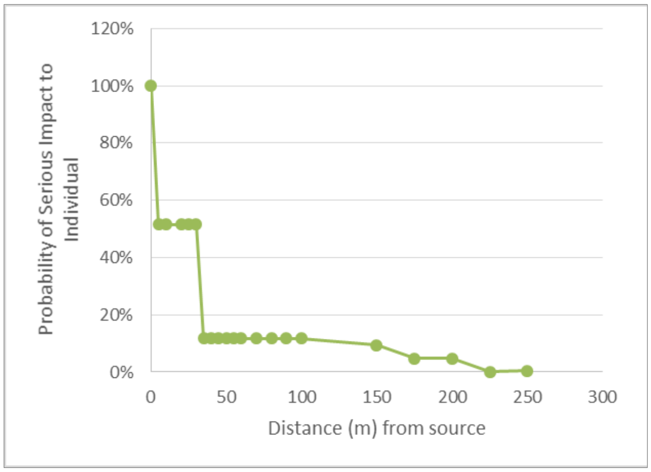

Figure 5: Probability of serious impacts from a vapour cloud explosion versus distance from the source

The relative frequency that is used for each Dangerous Goods release event, shown in Table 3, is based on event trees and assessment of probabilities provided in literature (Ministerie van Infrastructuur en Milieu 2011). The results suggest that if a Dangerous Goods release occurs, the chance of a pool fire is much higher than the chance of a BLEVE event or flash fire.

Table 3: Relative probability of Dangerous Goods impact events

Impact Event	Probability DG is Flammable (A)	Probability Base vs. Worst Case Event (B)	Relative Probability of each Event (C)	Probability of impact event (A × B × C)
BLEVE	75%	90%	1%	2.5×10^{-5}
BLEVE (30m Derailment)	75%	10%	1%	2.8×10^{-6}
Vapour Cloud Explosion	75%	90%	1%	3.0×10^{-5}
Vapour Cloud Explosion (30m Derailment)	75%	10%	1%	3.4×10^{-6}
Pool Fire	75%	90%	98%	3.6×10^{-3}
Pool Fire (30m Derailment)	75%	10%	98%	4.0×10^{-4}

3.2.2 Dangerous Goods Release without Train Derailment

The risk of a Dangerous Goods release without derailment is assessed based on historical data. Two types of risk were addressed: Dangerous Goods events from rail cars while on tracks and Dangerous Goods events from rail cars while in the rail yard. While on mainline tracks, 10 years of records indicate that 18 Dangerous Goods incidents have occurred without a derailment or at an at-grade road crossing; however, none of these events led to a fatality. This works out to an annual probability of an event of this nature occurring per train kilometer of 0.007% (or 0.7 in 10,000 years). This risk event was independently discussed with subject matter experts through the review of failure mode analysis, where the resulting annual probability was 0.05%. This probability was conservatively used in the risk assessment. In the analysis of this risk event, the same Dangerous Goods impact events are applied as discussed previously. The resulting risk does not contribute significantly to the overall Individual Risk.

3.2.3 Collision without Train Derailment

Historically, the leading cause of fatalities around rail lines is trespassing. This is a potential cause of derailments due to emergency braking, but here we discuss the public safety impacts of train-person collisions resulting from individuals trespassing on the tracks. The risk of someone remaining on the tracks when the presence of a train is obvious is not considered in this analysis as it is considered to be an individual choice that cannot reasonably be mitigated as part of the risk assessment. The risk that is quantified in the assessment deals with individuals accidently entering the rail corridor or trying to pass across the corridor. After an in-depth review of literature and in consultation with project stakeholders, this was quantified as an annual probability of 0.3%. This risk does not contribute to offset distances. Mitigation measures for this risk include fencing and controlled, grade separated crossing points.

4 Application and Results

Case Study – Nose Creek Area

The Nose Creek Area Structure Plan covers an area of 679 hectares (1,678 acres) of undeveloped land in northeast Calgary, west of the Deerfoot Trail and north of the Stoney Trail. Nose Creek and a Canadian Pacific rail line run along the eastern edge of the plan area, which has primarily been used for agriculture. The mild terrain, natural area around Nose Creek, and proximity to major transit corridors make it an ideal location for future development. The City of Calgary required a risk assessment related to rail operations to assist in the planning process and to provide information to support development of Nose Creek Area Structure Plan (ASP) Terms of Reference. This allowed developers and landowners to adequately address issues such as offset distances, noise and vibration studies, and other considerations (i.e. drainage impacts and rail operations). A summary of site characteristics for Nose Creek is included in Table 4.

Table 4: Nose Creek Site Characteristics

Site Aspects	Nose Creek Specific Details
Site	Agricultural land adjacent to Queen Elizabeth II (QEII) Highway
Soil geology	Tracks bisect land running north-south
Drainage patterns	East side of tracks contains several residences, is lower in elevation and contains Nose Creek
Topography	
Proximity to rail corridor	West side of tracks is higher in elevation and contains primarily grain fields
Rail	
Track geometry	Tracks vertical elevation consistent along area
Track topography	~10m drop on east side of tracks; at grade with land on west
Speed or changes in speed	12 to 15 trains per day at a maximum train speed of 45 mph
Derailment in area or on other similar areas	Train lengths typically 7000 to 8500 ft
	Development may require rail crossing
Growth and estimate usage of rail	Spur line heading east under QEII – switch is currently removed
Rail contents and frequency	
	At-grade road crossing just north of development area
Development	
Proximity to rail corridor	Commercial/residential development potential
Collision protection	Land on both sides of tracks
Type of development	Land locked areas without rail crossing
Security of rail right-of-way	
Construction Requirements	

Impacts or disruption to rail	Construction will be in close proximity to rail on both sides
Security of rail right-of-way	Storm water management system includes outlets underneath tracks
Services or utility requirements, impacts	Utility construction potentially required near tracks/under tracks
Impacts to track infrastructure	Contains Dangerous Goods pipeline near rail corridor
Temporary storm water	

The risk assessment for Nose Creek focused on key risks caused by the interaction between the existing freight rail corridor and the adjacent area designated for new development. Inputs for the preliminary risk assessment were gathered through data collection, reviewing past studies and industry guidelines, analysis of local and national statistical records from Transportation Canada on rail incidents, review of track usage and commodities transported, among others. This information was used to identify the project risks and to develop an initial risk register, which was reviewed and complemented by focused workshops with subject matter experts on municipal policy, local railway operations, heavy rail and Dangerous Goods operations, infrastructure risk, and emergency services. Site-specific explosion and dispersion modeling was undertaken as input into the risk assessment.

For the Nose Creek case study, the location-specific probability of derailment per kilometer of track was calculated as 1.37 in 1 Million. This was calculated based on 10-15 trains per day, or 4,745 trains per year. Thus, the annual frequency of a derailment at the Nose Creek site is 0.652%: that is, an individual standing near the tracks would likely see a derailment 1-2 times in 200 years.

Risk assessment events and probabilities are put in a Monte Carlo simulation model to assess the possible range of Individual Risk values for various distances from the rail line. This simulation provides insight into the range of values that could be realized based on the uncertainties associated with the input values. For example, the true probability of a Dangerous Good substance being present at the time of an accident is between 10-25%, the number of trains per day is somewhere between 25-30, and the probability of a relevant Dangerous Good accident is between 2-3%. The combined probability that all these values coming in on their maximum likelihood is extremely unlikely. The values at the very far ends of the distributions have very low likelihoods of being realized. Conservative values were chosen for the input for Monte Carlo analysis where there was uncertainty. For this reason, the risk assessment results use the 99th percentile values of the simulation to determine recommended risk mitigation offsets. The 99th percentile represents the value which was not exceeded in the 5000-iteration simulation 99% of the time. Typical deterministic (single value) calculations would calculate the mean value. The percentile of the range estimation used for any risk assessment is determined with the owner based on their needs and requirements.

Figure 7 provides an example of Individual Risk as a function of distance from a railway track. In this example, the 1 per million probability (MIACC threshold for residential land use) is about 47.5 meters from the track, and the 10 in 1 million probability (MIACC threshold for commercial land use) is at 35 meters.

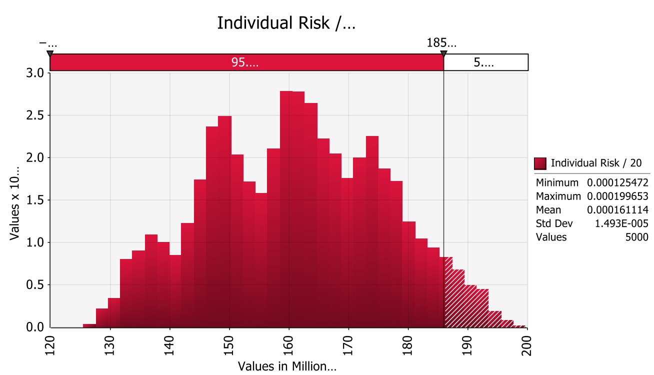

Figure 6: Sample Individual Risk Distribution at 20m from Track

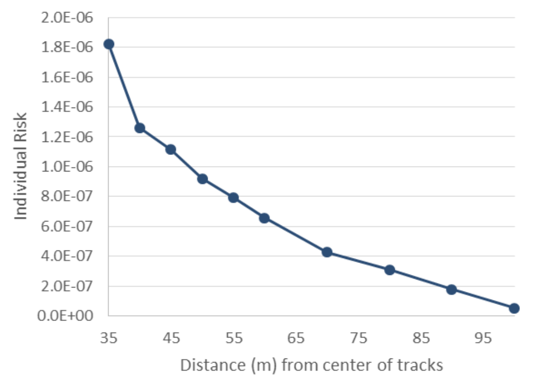

Figure 7: 99th Percentile Individual Risk vs. Distance from Track (35m to 100m)

5 Discussion and Conclusion

In the context of increasing heavy rail operations, the increase in railway transportation of Dangerous Goods commodities, and the increasing value of land in downtown urban areas which are typically dissected by rail, municipalities are reaching out to industry to provide a reliable and robust approach for assessing risk. The risk assessment methodology described in this paper introduces a holistic approach to rail risk for development in proximity to heavy rail corridors, introducing the SPARR model, which attempts to comprehensively address risks with a level of granularity that allows for the generation of spatially distributed risk profiles.

Due to the inherent nature of risk, uncertainty is a key in any risk assessment methodology. Typically, risk assessments often rely on historical data and trend analysis to account for such uncertainties. However, for the assessment of catastrophic risks there are limitations in the use of historical data, as there is often not a large enough dataset of historic occurrences available to accurately estimate the frequency of occurrence. The foundations of the SPARR model are based on a methodology to address uncertainty through the combination of comprehensive data gathering, expert judgement and simulation, to help estimate the identification, definition, probability, and impact of risk events. As such it, the model takes into account the uncertainty in all parameters, allowing for a comprehensive incorporation of data without the need to undertake detailed studies of every parameter. Rather, the use of expert judgement is applied to the wide range of data available, complemented by simulation modeling to address the expected range of uncertainty for each parameter used in the risk assessment. As such, the SPARR model includes what can be described as a sensitivity analysis to uncertainty, something that is often not addressed in risk assessments. In addition, by means of actively including subject matter experts in the risk assessment process, stakeholders are actively involved in the process, allowing for a transparent process that builds trust amongst the stakeholders and confidence among the represented stakeholder groups as to the results obtained. This latter aspect is critical for municipal planning applications.

The application of the methodology to the Nose Creek case study portrayed how the results from the SPARR model apply to a location specific risk assessment, providing spatially distributed risk levels along the railway corridor. This spatial depiction of risk as a function of distance from the railway is particularly useful for municipal planning purposes in combination with a municipal definition of risk thresholds for Individual Risk. With the required thresholds in place, the outcomes of the SPARR model can directly be used to inform decision-making about appropriate land use. Consequentially, the more granular the level of assessment that is conducted, the more that land use along a railway corridor can be optimized.

The results obtained are congruent with the FCM-RAC Guidelines that were developed as generic guidelines for municipalities throughout Canada, although it should be pointed out that the guidelines do not take into consideration the risks related to Dangerous Goods. As such, it is to be expected that the results of the SPARR model generate somewhat larger offset distances than may be required based on the FCM-RAC Guidelines. The trade-offs between the two approaches require a clear understanding of the scope requirements of site specific risk assessments. However, if applied correctly, the appropriate use of both frameworks allows for a comprehensive and robust approach to addressing risk along railway corridors.

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