

Geospatial Analysis of Environmental and Safety Risks of Railways on Vulnerable Land Users in Point Douglas and St. Boniface Communities in Winnipeg, Canada

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Abstract

Train rails are associated with environmental and safety risks, often concentrating industry near their yards and rails. ArcGIS was applied to map the rail network, land uses, and industrial sites in Point Douglas and St. Boniface in Winnipeg, Canada. We identified 123 land uses with vulnerable populations needing assistance in evacuation from hospitals, senior living facilities, schools and early childhood centres within a buffer of two km of the rails and conducted hotspot analysis. About two-fifths of the total population, 39% in Point Douglas and 40% in St. Boniface, are at risk from fire, spill or train derailment involving dangerous goods and requiring evacuations or isolation.

Keywords

Rail Hazard, Rail Lines, Industrial Sites, Vulnerable Land Use, Safety Risk, Rail Relocation

1. Introduction

Railyards and railways near communities pose environmental and safety risks (Federation of Canadian Municipalities & Railway Association of Canada, 2013). When rail lines pass through residential areas, safety risks, pollution, noise, vibration, and traffic hazards are imposed on residents. Significant social, health, economic, and safety challenges from railways occur (Federation of Canadian Municipalities & Railway Association of Canada, 2013). This paper focuses on hazards of rail yards and lines in Winnipeg, focusing on Point Douglas and St. Boniface.

Rail line and industrial operations contribute to various environmental and social issues. These social and environmental issues include air pollution, climate change, noise pollution, injuries, landscape disruption, loss of community cohesion, and heightened stress (Spencer-Hwang et al., 2014). Rail operations also negatively affect quality of life and public health, influencing property values and population density due to factors like traffic congestion, increased crime rates, and pollution (AlQuhtani & Anjomani, 2021). Railways have three main impacts on nearby communities: 1) zoning for industrial land development near rail operations, 2) presenting risks associated from spills and fires from rail operations, and 3) creation of risks at road/rail crossings (Federation of Canadian Municipalities & Railway Association of Canada, 2013).

The Lac-Mégantic train disaster exemplifies the safety risks associated with rail line operations. Forty-seven people were killed, and most of the town was destroyed by fire or spills on July 6th, 2013 (Valiante, 2019). Six million liters of oil were estimated to be spilled with some igniting and approximately 100,000 liters entering the waters of Lac Mégantic and the Chaudière River. Severe social and economic repercussions resulted, including many residents losing their jobs temporarily or permanently and local businesses remaining closed for months (Généreux et al., 2014). The explosion from the train blast reached a height of 30 meters and impacted an area with a radius of 1 square kilometer. Fires ignited by spilled oil during the derailment scorched 11 hectares of land (Northern Lights, 2019). The train disaster was a wake-up call for urban industrial rails in other cities.

A similar disaster to Lac-Mégantic disaster is feared for Point Douglas and South St. Boniface. A derailment or train fire involving dangerous goods in the densely populated Point Douglas and South St. Boniface communities could result in severe consequences. Such an event could lead to widespread fires, explosions, and hazardous material release, endangering both residents and nearby infrastructures. The proximity of rail lines and industries increases the risk of casualties, property damage, and environmental contamination.

This paper examines the environmental, health and safety risks of rail lines and industrial sites. A literature review of the different risks from railways is profiled before the method. The findings identify risk from rail lines and industrial sites in Point Douglas and South St. Boniface for proximate vulnerable land uses with various maps and GIS analysis tools. In the conclusion the potential mitigation strategies are suggested to inform urban planning and policy decisions about rail risks and rail relocation to contribute to improved safety and quality of life for residents in the Point Douglas area and St. Boniface community.

Point Douglas and St. Boniface in Winnipeg

Winnipeg's Point Douglas and South St. Boniface neighbourhoods in Manitoba, Canada, are communities fractured by rail lines and industrial operations. The rail yard and main line divide Point Douglas into south and north neighbourhoods and saddle a main street in St. Boniface. Living on the other side of the

tracks has been an on-going environmental injustice in these communities, despoiling their environment. On July 28th, 2022, the United Nations General Assembly formally recognized the right of every individual to a healthy and sustainable environment (United Nations Environment Programme et al., 2022). Addressing environmental justice in Point Douglas and St. Boniface will require proactive policies and interventions that mitigate these railway risks and ensure that the communities have equal protection from environmental harm.

Residents in these areas frequently contend with environmental pollution, industrial fires and explosion risks due to the nearby industries and rail activities (Solademi & Thompson, 2020; Caporale & Fast, 2023; Solademi & Thompson, 2023). These rail lines increase health and environmental hazards and safety risks for residents. Studies show that the operation of trucks, locomotives, and yard equipment at rail yards negatively impacts community health and quality of life by increasing air pollution, noise, traffic congestion, and industrial pollution, leading to various health problems (Kampa & Castanas, 2008; The Impact Project, 2012; Hoekstra, 2014; Mabahwi et al., 2014).

Point Douglas and St. Boniface residents, who live close to rail infrastructure, feel at risk. These residents advocate for environmental justice to enhance their environment's sustainability (Rutgers, 2023). At the 2023 Manitoba Planning Conference, Catherine Flynn, Chair of the Point Douglas Residents Community, highlighted several railway issues in the Point Douglas area. These railway issues include persistent noise, house vibrations, frequent horn blasts, and diesel fumes from idling locomotives near homes.

This paper discusses the historical development of rail lines in Winnipeg. Tracing their establishment and growth as key infrastructural elements in the city's industrial and economic expansion. The environmental repercussions and safety concerns are discussed. The historical review considers how rail lines and yards have shaped the urban landscape and influenced public health and community well-being. These concerns set the stage for analyzing the risk of rails. Rail lines intersection with industrial sites, vulnerable land uses and the vulnerable population in Point Douglas and South St. Boniface were spatially and statically explored.

History of Rail Lines in Winnipeg

Historical accounts tell how the rails made Winnipeg the "hub of commercial activity in the northwest" or "the Chicago of the North" (Goldsborough, n.d.). Winnipeg being nearby to the States and uniting Western Canada with Eastern Canada, with a port in Churchill, was a strategic location for locating rail yards and lines. The Canadian Pacific Railway (CPR) decided to build its transnational route through Winnipeg in 1881 (Butterfield, 1987). Rail lines owned by Canadian Pacific Railway (CPR) in Winnipeg and Brandon transported mainly cereal grains from the prairies to Vancouver or Lake Superior (Butterfield, 1987). In 1902, the Canadian Northern Railway (CNR) successfully finalized the construction of the rail line extending from Winnipeg to Port Arthur in Thunder Bay, Canada and then to Vancouver's ports in Vancouver (see **Figure 1**).

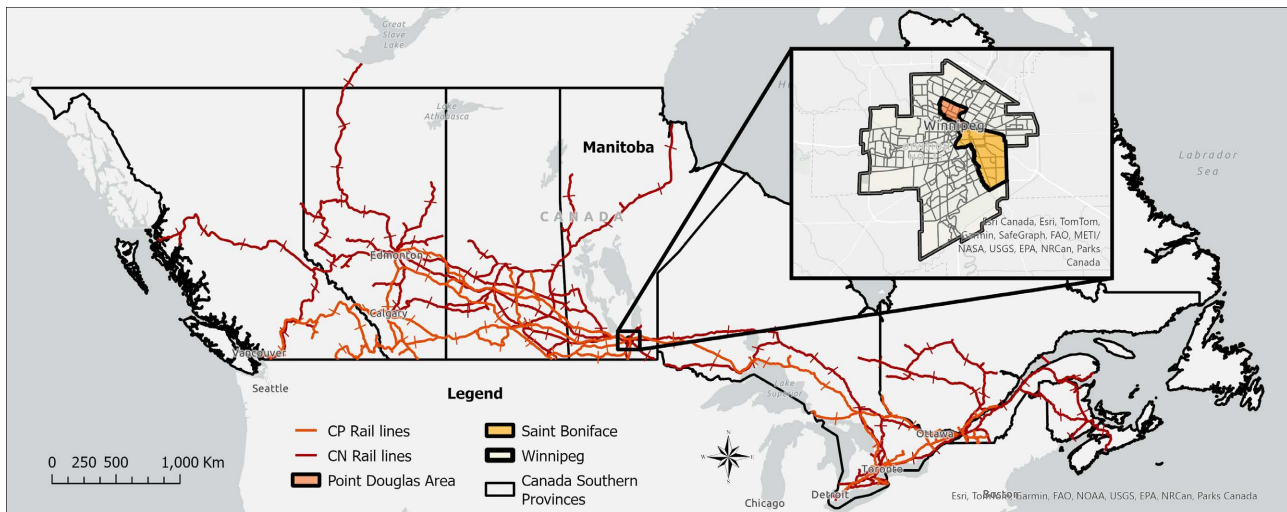


Figure 1. Map of Canada showing Canadian Pacific Rail (CPR) and Canadian National Rail lines (Eze, 2024).

In modern times, train loads are different. With many shipments of oil, dangerous goods, wood and grain (The Canadian Press, 2013; RAC, 2024). Trains are longer and transport tonnes of dangerous goods daily (CBC News, 2014; Railway Association of Canada, 2022). Trains carrying dangerous goods are considered a blight to urban areas due to risks of train derailments, accidents, and spills.

Past Rail Relocation Projects in Canada

In 1886, The Forks became a major location in the early development of railroads on the prairies. The rail yards of the Northern Pacific and Manitoba Railway company, Canadian Northern, Grand Trunk Pacific, and Canadian National Railway shaped Winnipeg's downtown forming a confluence at the Assiniboine and Red Rivers (Bernhardt, 2018; The Forks, n.d.). By the 1960s, as trucking and buses dominated freight transportation, Canadian National Railway ceased using the east yard, which led to discussions of rail relocation starting in the 1970s and culminating in 2000 (Aremu et al., 1986; Grover & Thomas, n.d.). Today, the redeveloped CN rail yard, now known as the Forks, is a vibrant public space with attractions including historic sites and modern amenities, drawing over four million visitors annually (The Forks, n.d.).

Rail relocation projects have also been implemented in other Canadian cities. In Red Deer, between 1961 and 1980, former Canadian National Railway lines were transformed into residential areas, parks, commercial spaces, and recreational facilities, including the Red Deer recreation centre and fairgrounds (Forth Junction, 2022b; Dawe, n.d.). Additionally, the Canadian Pacific Railway's relocation project in Red Deer began in 1990, leading to the removal of downtown tracks and the 45th Street overpass by 1992 (Forth Junction, 2022a; Dawe, n.d.). The downtown rail station was repurposed as office space, and former rail corridors were converted into pedestrian and bicycle pathways as part of the Waskasoo Park trail system and Trans Canada trail (Forth Junction, 2022a).

Train Derailments

Train derailments pose a direct safety risk to neighbouring communities. A

derailment is when train cars leave the tracks. Derailments can cause significant damage to nearby structures and pose a threat to people in the vicinity. In 2023, Canada reported 55 main track derailments, with six of these incidents occurring in Manitoba ([Transportation Safety Board of Canada, 2024](#)). The derailments in Manitoba increased from five incidents in both 2021 and 2022 to six in 2023, which was below the ten-year average of seven ([Transportation Safety Board of Canada, 2024](#)). In 2023, Canada recorded 404 non-main track derailments nationwide, with 37 occurring in Manitoba. This represented a 35% decrease compared to the 57 non-main track derailments in Manitoba in 2022 ([Transportation Safety Board of Canada, 2024](#)). A notable incident was the McPhillips derailment that occurred on April 21st, 2023, along the Canadian Pacific Railway train overpass above McPhillips Street, a major commuter route in northwest Winnipeg ([Bernhardt, 2023](#)).

Manitoba experienced six main track derailments and 37 non-main track derailments in 2023 ([Transportation Safety Board of Canada, 2024](#)). The proximity of rail lines to land uses in Point Douglas and St. Boniface increases the risk of derailments, which could have devastating consequences for residents. The frequency of derailments in Manitoba highlights the need for relocating or closing some spur lines to protect Point Douglas and Saint Boniface communities.

Accidents

The rail lines proximity to roads in communities also increases the risk of automobile and human accidents at rail crossings. In 2023, 149 crossing accidents occurred in Canada, with 114 of these occurring at public crossings, accounting for 77% of all crossing accidents ([Transportation Safety Board of Canada, 2024](#)). In 2023, 21 rail crossing accidents in Manitoba occurred, representing a 38% increase from the 13 crossing accidents recorded in 2022 ([Transportation Safety Board of Canada, 2024](#)). This figure surpassed the 10-year average of 19 crossing accidents in the province. Nationally, Canada recorded 114 rail crossing accidents, resulting in 67 fatal injuries: 53 due to trespassing, 13 from crossing accidents, and one related to other occurrences ([Transportation Safety Board of Canada, 2024](#)). From 2020 to 2023, the number of fatalities in Canada increased by 12% for rail crossing accidents and 33% for trespassing. The 10-year average from 2013 to 2023 was 21 fatalities per year in Canada.

Some non-fatal and fatal accidents have occurred recently in Winnipeg. An incident involving a train and human occurred on April 29th, 2024, in south Winnipeg, Manitoba, when a 16-year-old boy was struck by a train at a train crossing ([CBC News, 2024a](#); [Chang, 2024](#)). Another incident occurred on July 1st, 2024, in Osborne village, Winnipeg, Manitoba, when a 38-year-old Winnipeg woman died after being accidentally hit by a freight train ([CBC News, 2024c](#)).

A rise in rail crossing accidents occurred in Manitoba from 2022 to 2023. Rail line accidents increased from 13 to 21. With 240 rail crossing in Winnipeg in 2023, these interfaces where people and rails cross are at risk ([Social Planning Council of Winnipeg, 2023](#)). Point Douglas and St. Boniface, have numerous rail crossings

in densely populated areas. This heightens accident risks between trains and commuters/pedestrians.

Hazardous Material Spills

Railways transport hazardous materials. A derailment involving hazardous materials can result in environmental contamination, health risks, and fires, as seen in the Lac-Mégantic disaster (Government of Canada, Transportation Safety Board of Canada, 2017; Valiante, 2019). The costs of such accidents are substantial, with the Lac-Mégantic recovery totaling over \$400 million, including \$35 million for town revitalization and \$126 million for cleanup and reconstruction (CED, 2022; Woods, 2014).

Rail accidents continue after Lac Megantic. Over the decade from 2013 to 2023, the average number of accidents with dangerous goods was 129 per year. In 2023, 87 rail accidents involving dangerous goods occurred in Canada, six of which resulted in the release of dangerous goods (Transportation Safety Board of Canada, 2024). In Canada, accidents involving dangerous goods saw a five percent increase from 2020 to 2021 and a 28% increase from 2021 to 2022, followed by a 21% decrease from 2022 to 2023. Between 2020 and 2023, a 50% increase in rail accidents resulted in the release of dangerous goods. Rail incidents involving the release of dangerous goods rose from two in 2022 to six in 2023, surpassing the 10-year average of five (Transportation Safety Board of Canada, 2024).

Rail accidents involving the release of dangerous goods pose a significant risk of fires with potentially catastrophic consequences. This risk is particularly concerning in densely populated areas like Point Douglas and St. Boniface. Community members, during rail relocation group meetings, have voiced concerns about the dangers of transporting hazardous materials through urban areas, citing the Lac-Mégantic disaster as a stark example of the potential risks.

Traffic Disruptions

Rail crossings and intersections with roads lead to traffic disruptions and potential safety hazards, especially in densely populated areas (Morgan et al., 2007) like the Point Douglas and South St. Boniface communities. Over the past decade, railways have increasingly adopted longer and heavier trains to enhance cargo capacity (Stagl, 2018; Railway Association of Canada, 2022). In 2021, the average number of cars per freight train rose by 0.6%/year from 2020 and by 6.1% /year compared to the 2016-2020 average while over the last ten years, the average length of trains, has risen by 27.4%/year (Railway Association of Canada, 2022). These longer trains take more time to pass through grade crossings, causing increased delays and safety risks. Train derailments also cause traffic disruptions. On August 5th, 2024, a CP train derailed temporarily obstructing eastbound and westbound traffic on two main roads in southern Winnipeg (CBC News, 2024b).

Trains Start Fires

Trains can generate sparks that ignite dry grass, leading to fires, particularly during braking or due to brake component wear (Transportation Safety Board of Canada, 2021; Davis, 2024). The Transportation Safety Board of Canada (TSB)

lists several causes for train-related fires, including exhaust stack malfunctions and overheating traction motors. The spontaneous ignition of flammable cargo like sulphur can result in a boiling liquid expanding vapor explosion (BLEVE) (Transportation Safety Board of Canada, 2021). These BLEVEs are caused by external fires near storage vessels, such as rail tankers, and can lead to severe consequences, including vessel fragmentation, pressure waves, and secondary fireballs, especially when flammable liquids are involved (Ibarreta et al., 2016). Several fires have been started by trains in Canada. On April 22nd, 2024, a Canadian Pacific Kansas City Limited train fire in downtown London, Ontario was caused by sparks from the locomotive's exhaust system. A 2020 CN freight train fire ignited nine wildfires outside Prince George, Vancouver, BC (Luymes, 2023; Donnini, 2024).

Environmental Impacts of Rail Lines Proximity

Rail operations cause air pollution. Hoekstra (2014) identified a direct correlation between proximity to rail lines and elevated air pollution levels. Residents near rail lines are exposed to higher concentrations of harmful particles from diesel emissions, increasing their risk of respiratory and cardiovascular diseases (Kampa & Castanas, 2008; Mabahwi et al., 2014). In contrast, areas farther from rail operations exhibited better air quality (Hoekstra, 2014).

Rail operations also generate significant noise and vibrations, impacting the well-being of nearby residents (Syahputri & Damianto, 2021; Kumar et al., 2024). These disturbances can disrupt sleep, increase stress, and lead to both mental and physical health issues (EducationalWave, 2023; Morgan et al., 2007). Passing trains, along with rail yard activities such as shunting, loading, and unloading, generate noise pollution, with densely populated areas experiencing heightened levels of disruption (Federation of Canadian Municipalities & Railway Association of Canada, 2013; Milewicz et al., 2023). The prolonged exposure to such noise has been linked to adverse health effects (EducationalWave, 2023; Kumar et al., 2024). Additionally, vibrations from rail operations can affect the structural integrity of nearby buildings, posing risks to safety and comfort of residents (Wrótny & Bohatkiewicz, 2020; Bukala et al., 2021).

Rail operations also release heavy metals, which can contaminate the soil absorbed into the soil. Contaminated soil poses a potential risk to human health through direct contact or inhaling pollutants that have volatilized from the soil (Gangadhar, 2014). Stojic et al. (2017) study showed that the most polluted soil areas were within a 1 km radius of railroads and railway stations.

Property values near rail lines also tend to decrease due to noise, pollution, and safety concerns (Diaz, 1999; EducationalWave, 2023). Diaz (1999) found that in Atlanta, property values decreased by \$965 for every 100 feet closer to a rail line. Similarly, research by Bowes and Ihlanfeldt (2001) demonstrated that properties located within a quarter mile of a rail station sold for 19% less compared to those situated more than three miles (5 km) away. Despite the benefits of access to industrial sites, disturbances from rail operations remain a significant factor in

property devaluation (Diaz, 1999).

2. Methods

We first identified all the rail lines and railyards in Winnipeg. Geospatial and statistical analysis of rail lines and industrial sites within the Point Douglas area and St. Boniface community were undertaken. We explored using spatial techniques and statistical analysis, rail lines intersection with industrial sites, vulnerable land uses and the vulnerable population in Point Douglas and South St. Boniface.

The potential safety risks associated with the proximity of rail lines and industrial facilities to vulnerable land uses were identified through mapping. This examination provides valuable information for urban planning, risk mitigation strategies, emergency response services and community safety initiatives.

Spatial Analysis

The spatial analysis utilized Microsoft Excel, ArcGIS Pro version 3.1.2, and ArcGIS Online to develop and analyze various spatial layers. Shapefiles for Winnipeg and Canada rail lines were imported into ArcGIS Pro from ArcGIS Online, and data from the rail line attribute table was extracted to differentiate ownership between two rail companies. Buffer zones of 800 m, one km, and two km were generated around rail lines and industrial sites using the ArcGIS Pro buffer analysis tool, a commonly applied method for addressing proximity issues in GIS. This analysis also identified vulnerable land uses at risk from fires originating at industrial sites or trains transporting hazardous materials within these communities.

Vulnerable land uses in Point Douglas and Saint Boniface were sourced from official websites. School data was obtained from the Winnipeg and Louis Riel School Divisions (Louis Riel School Division, 2024; Winnipeg School Division, 2024). While Google search was used to identify early childhood education centers and hospitals. Information on senior living facilities was obtained from the Long Term and Continuing Care Association of Manitoba (LTCAM), Winnipeg Regional Health Authority (Winnipeg Regional Health Authority, 2024; LTCAM, n.d.), and Google. The coordinate data for the identified vulnerable land uses were imported into ArcGIS Pro and used to create a location map, displaying vulnerable land uses (N = 123) and industrial sites (N = 9). Additionally, an optimized hotspot analysis was conducted to visualize areas in Point Douglas and Saint Boniface with the highest concentrations of vulnerable land uses, highlighting spatial patterns and clusters near rail lines and industrial sites.

Determination of Vulnerable Land Uses

The study identified vulnerable land uses designated as evacuation-sensitive facilities, including early childhood centers, schools, hospitals, and senior living facilities. These facilities serve populations requiring assistance during emergencies due to age, mobility or health conditions. As classified by Manitoba Health (2012), these populations are a second priority for evacuation during incidents.

To assess the safety risks posed by rail lines and industrial sites, the study focused on vulnerable facilities within Point Douglas and South St. Boniface,

extending the study area to include the CPR Winnipeg rail yard and a 2 km buffer around it. The analysis covered designated neighborhoods in Point Douglas area (North and South Point Douglas, Lord Selkirk Park, William Whyte, Dufferin, Dufferin Industrial, Mynarski, Burrows Central, Robertson, Inkster-Faraday, St. John's, St. John's Park, Luxton), Downtown (Centennial, West Alexander, and Logan), Inkster and St. Boniface. Vulnerable facilities in the Inkster community and the specified Downtown neighborhoods were grouped with Point Douglas area for this study. This approach ensured all relevant vulnerable land uses were included in evaluating the risks associated with rail lines and industrial sites.

3. Regulatory Guidelines for Evacuation and Proximity of Rail Lines to Land Uses

Different organizations have different recommendations regarding the safety distance between residences, rail lines and yards. According to the Federation of Canadian Municipalities (FCM) and Railway Association of Canada (RAC), the recommended distance for residential buildings from freight rail yards should be 300 meters. In comparison, the principal and secondary main lines should be 30 meters from residential buildings, with branch and spur lines 15 meters away (Federation of Canadian Municipalities & Railway Association of Canada, 2013). In contrast, Transport Canada's Guide 128 recommends a minimum isolation and evacuation area of 800 meters (1/2 mile) in all directions in the event of a rail car carrying large quantities of dangerous goods being involved in a fire (Canada, 2021). This is a difference of 500 metres, with Transport Canada's guide being almost three times the distance of FCM and RAC.

Considering Transport Canada's guide of minimum isolation area, an 800-meter buffer was employed as the baseline buffer for the study. Also, a one km buffer was selected based on reports that initially cited a one km blast radius in the Lac-Mégantic incident. In addition, a two km buffer was utilized based on community feedback, particularly from Point Douglas and South St. Boniface residents. These communities have experienced fire incidents that resulted in evacuations for two km buffer. These buffers consider both regulatory guidelines and real-world experiences of affected residents.

To calculate the percentage of the vulnerable population in Point Douglas community:

$$\text{Percentage (\%)} = [(0 - 19 \text{ Years} + \geq 65 \text{ Years}) / \text{Total Population}] * 100;$$

$$\text{Percentage (\%)} \text{ Point Douglas} = [(11,415 + 4820) / 41,275] * 100 \approx 39\%;$$

$$\text{Percentage (\%)} \text{ St. Boniface} = [(14,645 + 10,035) / 62,150] * 100 \approx 40\%.$$

Point Douglas area estimated population $P(t)$:

Given:

- Initial population (P_0) = 16,235 (2021: 0 - 19 Years + 65 Years+);
- Growth rate (r) = 0.000862;
- Time period (t) = 5 years;
- Euler's number (e) \approx 2.71828.

$$\text{Formula: } P(t) = P_0 * e^{(rt)};$$

$$\text{Exponent } rt = 0.000862 * 5 = 0.00431;$$

$$e^{0.00431} \approx 1.0043193;$$

$$P(t) = 16,235 * 1.0043193 \approx 16,305.$$

The estimated vulnerable population in the Point Douglas area for the year 2026 is approximately 16,305, representing a potential 0.43% increase from the 2021 population.

St. Boniface estimated population $P(t)$:

Given:

- Initial population (P_0) = 24,680 (2021: 0 - 19 Years + 65 Years+);
- Growth rate (r) = 0.0215;
- Time period (t) = 5 years;
- Euler's number (e) \approx 2.71828.

$$\text{Formula: } P(t) = P_0 * e^{(rt)};$$

$$\text{Exponent } rt = 0.0215 * 5 = 0.1075;$$

$$e^{0.1075} \approx 1.1135;$$

$$P(t) = 24,680 * 1.1135 \approx 27,475.$$

The estimated vulnerable population in Saint Boniface for the year 2026 is approximately 27,475, representing a potential 11% increase from the 2021 population.

Statistical Analysis

The number of vulnerable land uses within the 800 m, one km and two km buffer zones for rail operations in the Point Douglas and St. Boniface communities were calculated. The distribution and concentration of vulnerable land uses in the three buffer zones were compared.

The vulnerable populations in the Point Douglas and St. Boniface communities were estimated from census data for 0 - 19 and 65+ years (City of Winnipeg & Statistics Canada, 2021; City of Winnipeg & Statistics Canada, 2021a) for 2006 to 2021. The exponential growth formula $P(t) = P_0 * e^{(rt)}$ (Testbook, 2023) was applied to estimate the potential vulnerable population in the Point Douglas area and the St. Boniface community that may be at risk from industrial and rail activities by 2026. These estimates are the potential impact an industrial or rail line incident would have on vulnerable populations in Point Douglas and Saint Boniface.

4. Results

In 2024, Winnipeg had 22 main rail lines connecting the city from different geographical locations, 240 rail grade crossings and five (5) rail yards within city limits (Werner & Institute of Urban Studies, 2011; Social Planning Council of Winnipeg, 2023). **Figure 2** visually represents rail lines and yards within Winnipeg's city limits. The map illustrates that CPR and CN are the major rail line operators in Winnipeg, each with discrete lines. These rail lines extend through the city limits, connecting to different provinces in Canada and serving as transportation routes for various industrial goods, including hazardous materials.

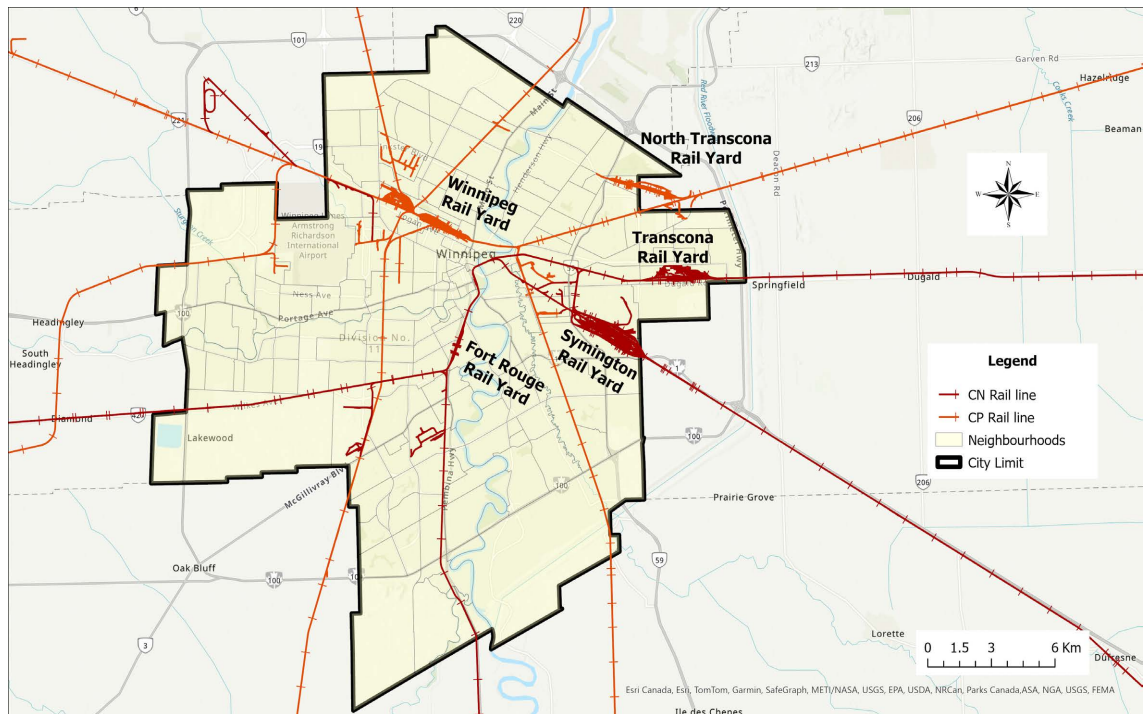


Figure 2. Map of Winnipeg rail line map showing CPR and CN rail lines and rail yards (Eze, 2024).

4.1. Rail Lines and Rail Yards in Winnipeg, Manitoba

In Winnipeg, there are two main rail owners. CPR owns 11 of the 22 main rail lines encompassing 739.1 Acres (equivalent to 2.991 km²). The coverage of CN is slightly smaller with CPR having 49% more land than CN lines in Winnipeg, Manitoba. CN owns 10 of the main lines and occupies a combined land area of 496.1 Acres (2.008 km²). A total of 1235.2 acres (4.999 km²) of land in Winnipeg are occupied by rail lines, demonstrating the significant land area occupied by rail lines within the city.

Five rail yards are within Winnipeg city limits (see **Figure 2**). Three rail yards are owned by CN and two by CPR. These five rail yards cover a land area of 2206.7 Acres (8.93 km²) as shown in **Table 1**. CPR possesses 802.2 Acres (3.246 km²) out of the 2206.7 Acres (8.93 km²) occupied by rail yards in Winnipeg, Manitoba, whereas CN owns 1404.5 Acres (5.684 km²) which is approximately 75% more land area than CPR. The two largest rail yards, Symington and Transcona, located south and northeast of the St. Boniface Industrial Park, are owned by CN. Winnipeg’s third largest rail yard (Winnipeg rail yard) is in the Point Douglas area.

Table 1. Total land area of CPR and CN lines in Winnipeg, Manitoba.

CPR Yards	Acres	km ²	CN Yards	Acres	km ²
Winnipeg	466.3	1.9	Symington	792.6	3.2
North Transcona	335.9	1.4	Transcona	564.6	2.3
			Fort Rouge	47.3	0.2
Total	802.2	3.246	Total	1404.5	5.684

4.2. Rail Lines in Point Douglas and South St. Boniface

Point Douglas and South St. Boniface have main and spur lines traversing the communities. The Kenora rail line is the eighth largest main line in Winnipeg; the line divides Point Douglas community into north and south, with the north referred to as the “other side of the tracks”. The Kenora rail line cuts across Point Douglas to connect with the Winnipeg rail yard (466.3 Acres equivalent to 1.9 km²). The Winnipeg rail yard, owned by CPR and located in the Point Douglas area, has been a barrier for over a century, separating north Winnipeg from the rest of the metropolitan area (Huband, 2017). The division has contributed to the stigmatization and marginalization of residents on the north side of the tracks, who are often perceived as being on the “wrong side of the tracks” and less privileged compared to those on the other side (Winnipeg Regional Real Estate News, 2015; Huband, 2017). **Figure 3** illustrates the rail line network in Point Douglas and South St. Boniface communities.

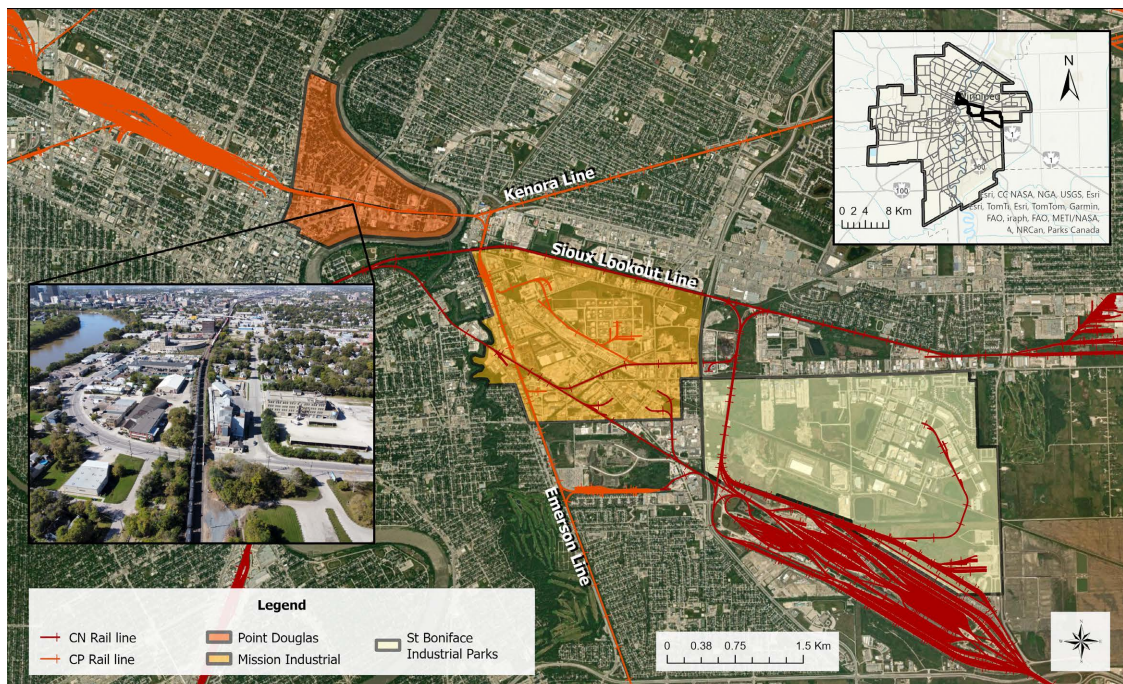


Figure 3. Map of rail lines in Point Douglas and South St. Boniface (Eze, 2024).

Main and spur rail lines traverse South St. Boniface industrial zones of Mission Industrial and South St. Boniface Industrial Park. The Mission Industrial area is crossed by several lines, such as the Emerson main line, owned by CPR, which covers 120.4 acres/ 0.49 km², making it the second-largest in Winnipeg. This line intersects the area’s western border before connecting with the Kenora line. The CN Sioux Lookout rail line (5.7 acres/0.02 km²) runs through the northern border, extending to the Transcona yards, the second-largest yard at 564.6 acres /2.3 km². Additionally, a CN spur line connects the southwest of South St. Boniface to the Fort Rouge yards, the smallest at 47.3 acres/0.2 km². The South St. Boniface

Industrial Park also hosts Winnipeg's largest rail yard, Symington, spanning 792.6 acres/3.2 km² along its southern border.

5. Safety Implications of Rail Lines and Industrial Sites on the Point Douglas and South St. Boniface Communities

The Point Douglas and South St. Boniface communities are surrounded by main lines, spur lines, and rail yards, all situated within proximity to various land uses.

5.1. Industrial Sites in Point Douglas and South St. Boniface Communities

Point Douglas and South St. Boniface are home to several scrap metal industries, most of which are in the South St. Boniface Mission Industrial area. Three industrial sites were identified in Point Douglas and six in the Mission Industrial area (see **Figure 4**). These industries are in proximity to rail lines and various other land uses, including residential houses and vulnerable land uses such as daycares, educational institutions, hospitals, and senior living facilities.



Figure 4. Map of Point Douglas and South St. Boniface showing Industrial sites (Eze, 2024).

Industrial activities and trains despoil neighbourhoods. Gary Tessier, a resident of South St. Boniface, described the area as once paradise but now polluted due to industrial activities and transportation of hazardous materials by train (**Eco-Health Learning Circle, 2023**). The St. Boniface community has experienced multiple fire incidents linked to industrial sites, notably the Speedway International fire on October 1st, 2012. This event involved explosions and a massive fireball,

with nearby rail cars carrying highly flammable fuels, exacerbating the safety risks and leading to the evacuation of approximately 100 homes in the surrounding area. (ChrisD.Ca, 2012; Nickel, 2015; Eco-Health Learning Circle, 2023).

Fires in Point Douglas have occurred with regularity. A fire at the Vulcan Iron Works industrial complex in North Point Douglas on July 4th, 2023, involved highly flammable materials, including vehicles, tire storage, and propane canisters. The large fire prompted the evacuation of a three-block area, including a nearby school, due to the significant safety risks (Hoye, 2023). During a community field visit on December 14th, 2023, Catherine Flynn, President of the Point Douglas Residents Association, reported feeling the intensity of the fire and smoke from her residence, several blocks away.

5.2. Vulnerable Land Uses in Point Douglas and South St. Boniface Communities

In a fire, isolation or evacuation, vulnerable people are at more risk due to age, mobility or other issues. Evacuation decisions should be part of a comprehensive strategy that addresses both the general population and subpopulations with specific vulnerabilities, such as those with respiratory or cardiovascular conditions, infants, children, the elderly, and individuals requiring continuous care (Manitoba Health, 2012; Stares, 2014). Fires can cause infrastructural damage and environmental impacts, including smoke, that pose significant health risks to these vulnerable groups. Prioritization in evacuations must account for both health vulnerabilities and the needs of those requiring continuous medical or personal care during emergencies (Manitoba Health, 2012; Stares, 2014). **Table 2** shows the Identified vulnerable land uses in Point Douglas and St. Boniface communities.

Table 2. Identified vulnerable land uses in Point Douglas and St. Boniface communities.

Vulnerable Land Uses	Location	Number
Early Childhood Educational Center	Point Douglas	25
	St. Boniface	22
School	Point Douglas	36
	St. Boniface	20
Hospital	Point Douglas	2
	St. Boniface	1
Senior Living Facility	Point Douglas	7
	St. Boniface	10
Total		123

The map of Point Douglas and St. Boniface (**Figure 5**) provides a detailed view of industrial sites and vulnerable land uses within these communities. **Figure 5** identifies a total of 70 vulnerable land uses in Point Douglas, Inkster, and Downtown, and 53 in St. Boniface. Industrial sites are concentrated in Point Douglas and the Mission Industrial area of St. Boniface. Early childhood centers (Aged 0 - 5 years) are notably

clustered in Point Douglas and Downtown, while hospitals are centrally located for accessible healthcare. Senior living facilities (Aged 65 and older) are densely situated in Point Douglas and Central St. Boniface, and schools (Age 5 - 19 years) are spread across the communities with significant clusters in Point Douglas and Central St. Boniface.

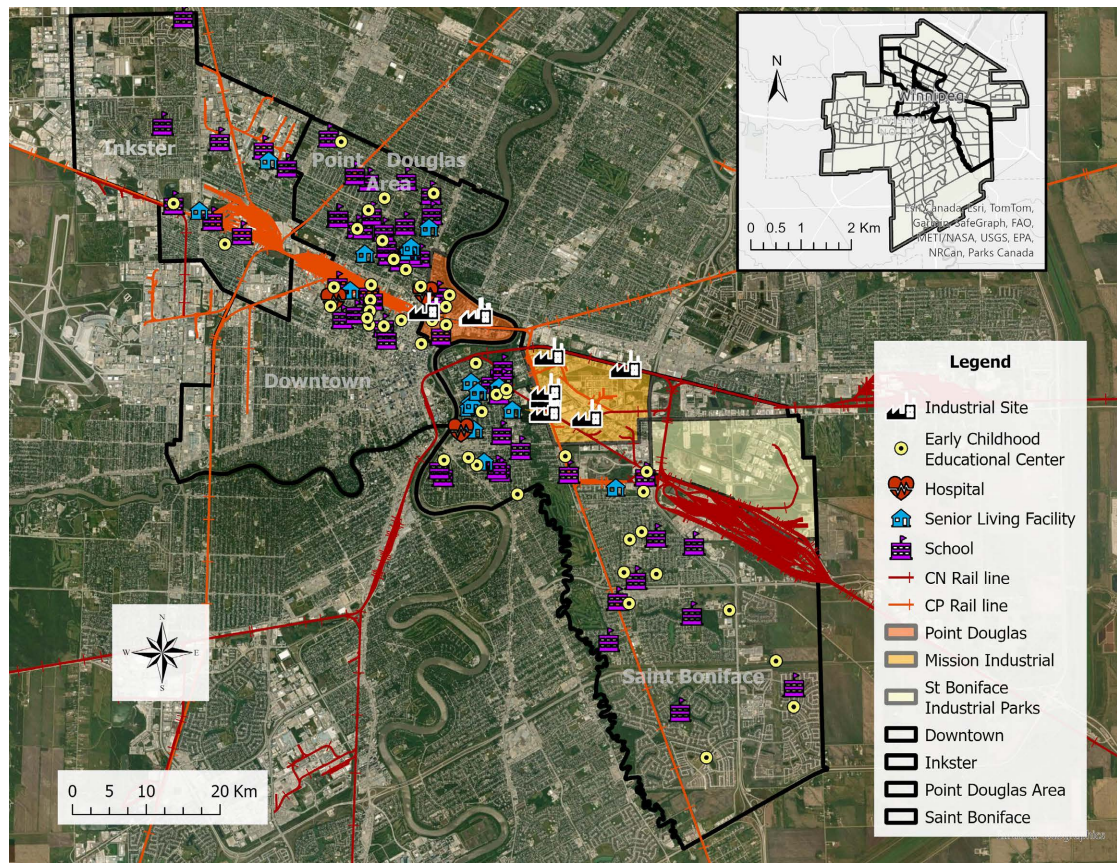


Figure 5. Point Douglas and St. Boniface's vulnerable land uses and industrial sites (Eze, 2024).

5.3. Safety Risk Assessment of Rail Lines and Industrial Sites Impacting Vulnerable Land Uses in Point Douglas and St. Boniface

The buffer analysis evaluated the safety risks from rail lines and industrial sites on vulnerable land uses. The different buffers indicate zones at risk of impact by rail lines and industrial sites. The minimum buffer of 800 meters, a medium buffer of one km and a maximum buffer of two km around rail lines and industrial sites include many vulnerable land uses. These distances reflect possible evacuation or isolation zones in case of a fire or spill of hazardous materials.

The buffer maps (refer to **Figures 6-8**) of 800 m, one km, and two km buffer maps of industrial sites in Point Douglas and South St. Boniface showing vulnerable land uses showed the land uses within the distinct industrial buffer zones and aided in the identification of potential safety risks to these land uses in the event of a fire requiring evacuation.

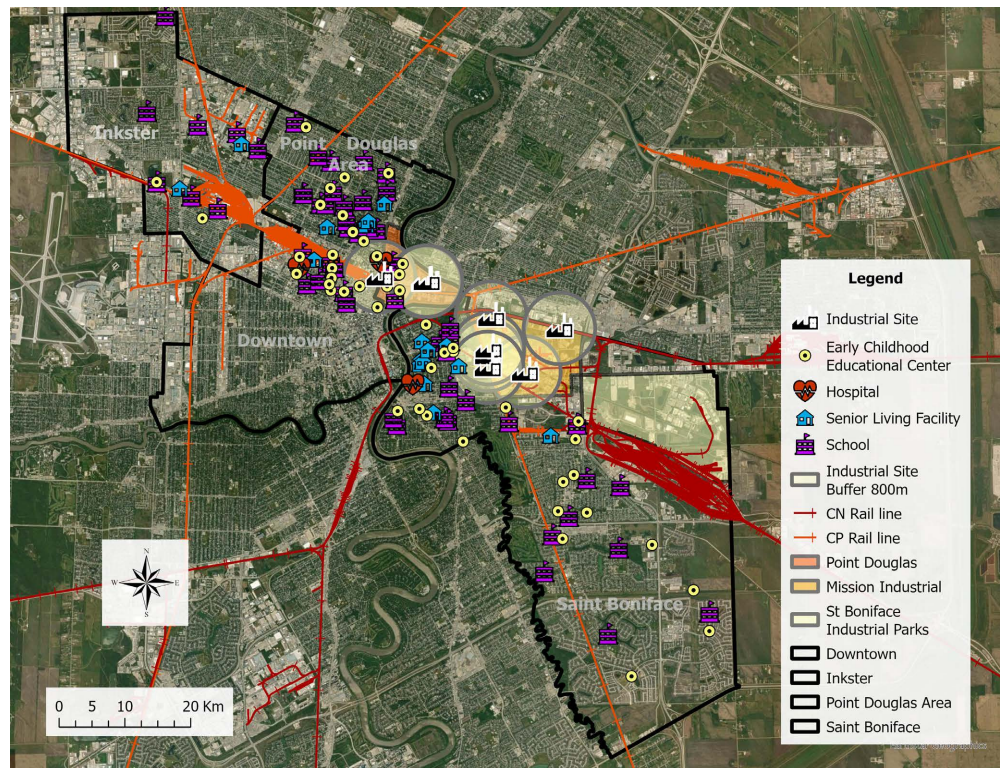


Figure 6. The 800 m buffer map of industrial sites in Point Douglas and St. Boniface showing vulnerable land use (Eze, 2024).

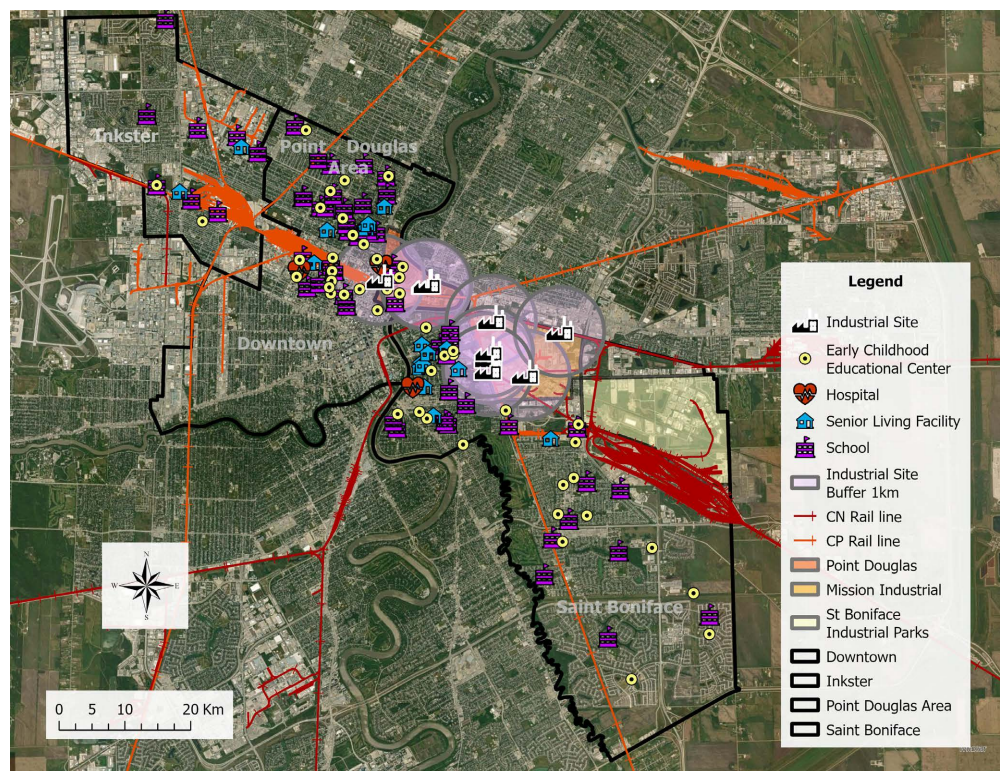


Figure 7. The one km buffer map of industrial sites in Point Douglas and St. Boniface showing vulnerable land use (Eze, 2024).

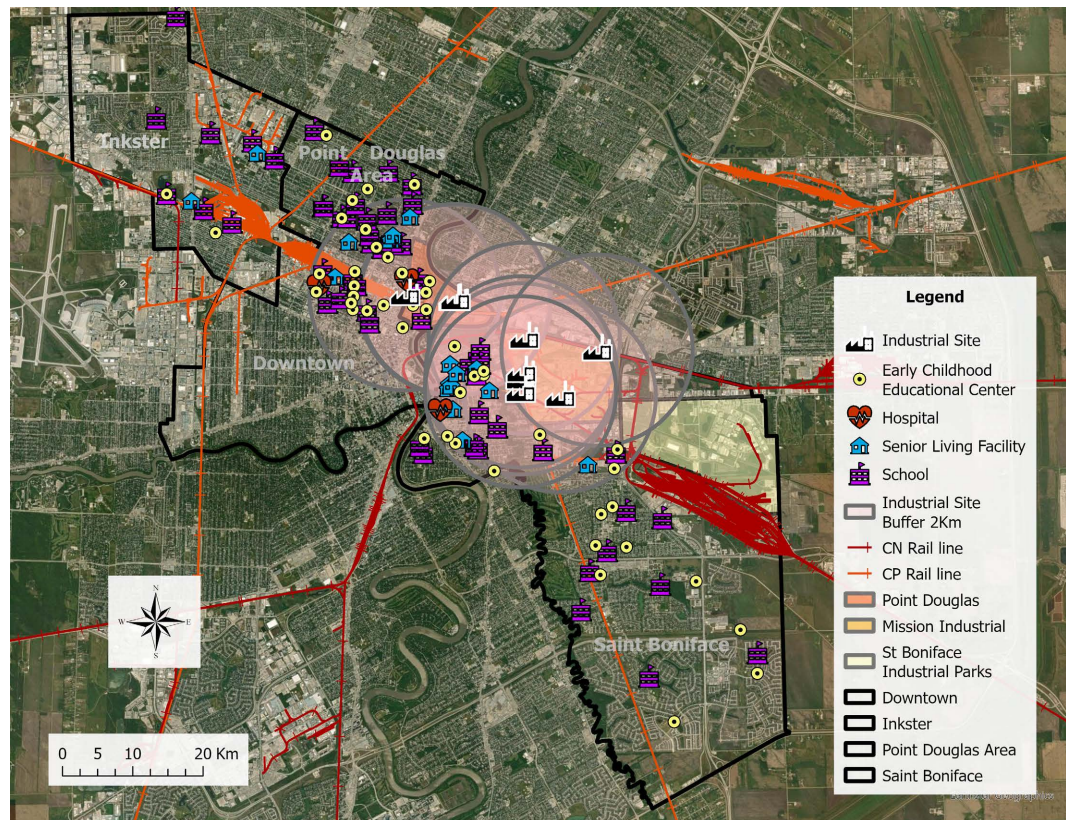


Figure 8. The two km buffer map of industrial sites in Point Douglas and St. Boniface showing vulnerable land use (Eze, 2024).

As the buffer distance expands so do vulnerable land uses. Out of 70 vulnerable land uses in Point Douglas area, 11 were within the 800 m buffer, growing to 19 and 45 for the one km and two km buffers. St. Boniface, has a total of 53 vulnerable land uses with three located within an 800 m zone, growing to 12 and 33 within one km and two km buffer zones, respectively. The rail line buffer maps for Point Douglas and St. Boniface (Figures 9-11) illustrate the vulnerable land uses affected by varying buffer zones. In Point Douglas area, 41 out of 70 identified vulnerable land uses were located within the 800 m buffer zone, increasing to 45 in the one km buffer and 64 within the two km buffer zone. In comparison, St. Boniface had approximately half (26) of 53 vulnerable land uses in the 800 m zone, 33 in the one km zone, and 48 in the two km zone. This indicates that over half of these vulnerable land uses could be impacted by an industrial fire or rail derailment, necessitating evacuation or isolation plans that extend up to two km.

Point Douglas and St. Boniface both had many early childhood centers and schools situated within the rail line and industrial buffer zones. Thus, many school-aged children would need evacuation in the event of a train derailment involving hazardous materials during school hours.

Hospitals house those vulnerable due to medical needs, providing essential care and treatment, and offering an environment for recovery and rehabilitation (Saint Boniface Hospital, Health Sciences center and Point Douglas community clinic).

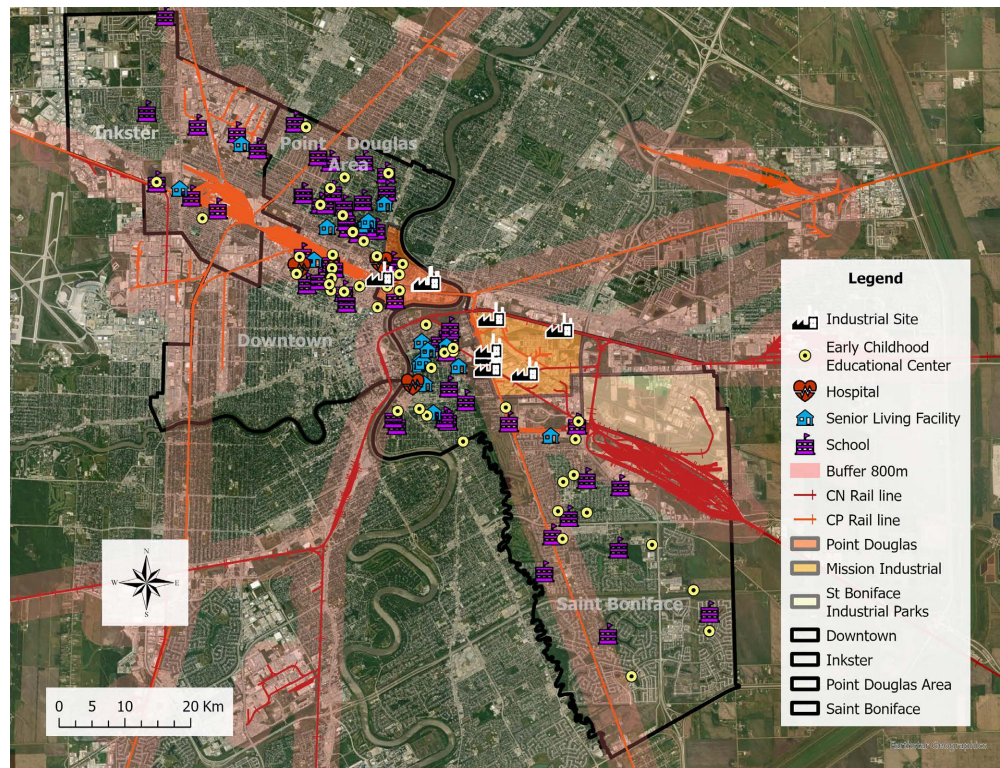


Figure 9. The 800 m buffer map of rail lines in Point Douglas and St. Boniface showing vulnerable land use (Eze, 2024).

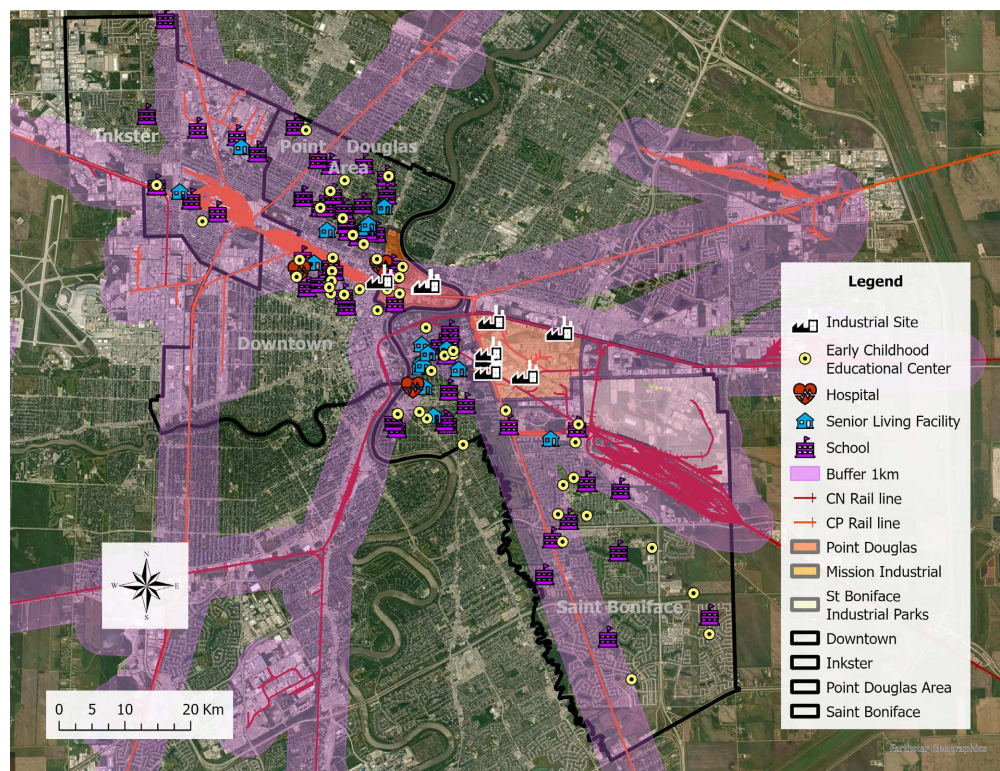


Figure 10. The one km buffer map of rail lines in Point Douglas and St. Boniface showing vulnerable land use (Eze, 2024).

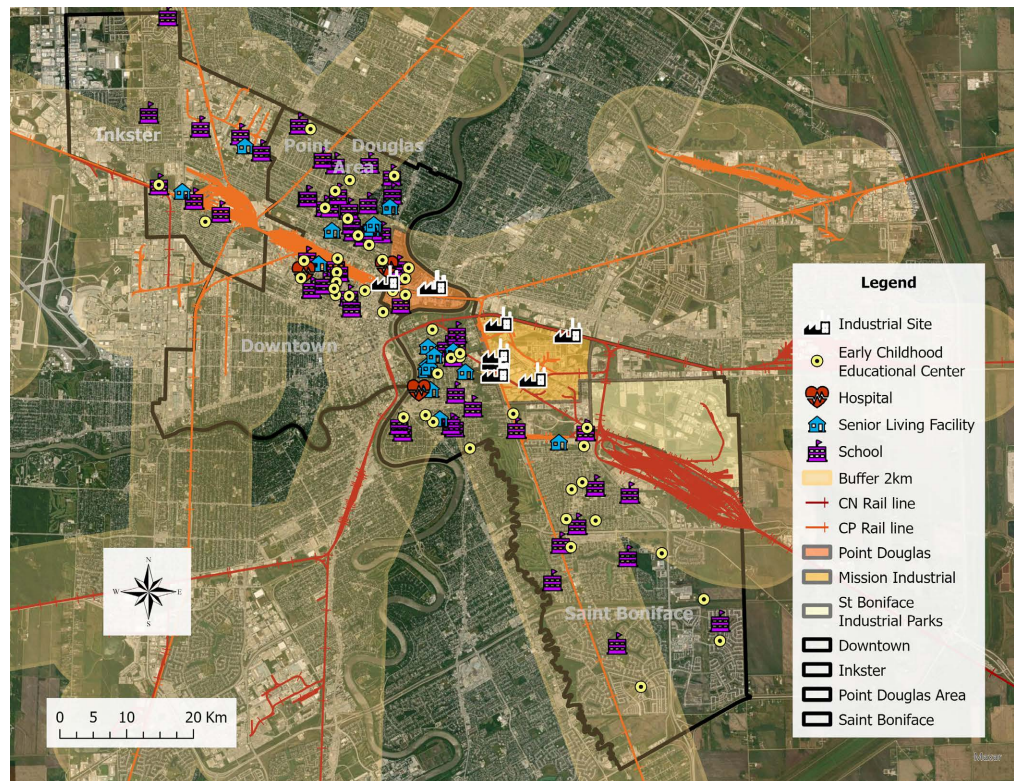


Figure 11. The two km buffer map of rail lines in Point Douglas and St. Boniface showing vulnerable land use (Eze, 2024).

Hospitals in Point Douglas area and St. Boniface fell within the buffer zones, posing safety risks to populations with medical needs. A train derailment or industrial fire involving hazardous materials presents a significant threat due to the vital medical services these facilities provide. Disruptions during emergencies could critically impact patient care.

Senior facilities near rails increase safety risks for elderly residents in the event of a train derailment or industrial incident. While the Point Douglas area had few senior living facilities within the buffer zones, St. Boniface had a higher concentration. Elderly individuals may have limited mobility and require additional assistance to evacuate safely.

6. Vulnerability Analysis and Optimized Hot Spot Analysis of Vulnerable Population in Point Douglas and South St. Boniface

Vulnerable populations are potentially at elevated risk in a fire incident due to factors such as limited mobility, age and proximity to hazardous areas.

6.1. Vulnerability Analysis

Table 3 summarizes the vulnerable population data for the Point Douglas area and St. Boniface community. The age groups are at high risk from fires, due to their age and limited mobility.

Table 3. Summation of vulnerable population in Point Douglas and South St. Boniface communities.

Community	Total Population (City of Winnipeg & Statistics Canada, 2021)	0 - 19 Years	65 Years and Over	Total
Point Douglas	41,275	11,415	4820	16,235
St. Boniface	62,150	14,645	10,035	24,680

The vulnerable population in Point Douglas is 39% and St. Boniface at 40% of total 2021 population. The estimated vulnerable population in Point Douglas and St. Boniface for 2026 is approximately 16,305 and 27,475 respectively, representing a potential 0.43% and 11% increase from the 2021 population. Considering the growing vulnerable populations in Point Douglas and St. Boniface. It is essential to assess environmental and safety risks. Relocation or closure of certain spur lines in Point Douglas and Saint Boniface could address these risks for the growing vulnerable population.

6.2. Optimized Hotspot Analysis

Optimized hotspot analysis was performed to examine the concentration of vulnerable land uses in Point Douglas and St. Boniface (refer to **Figure 12:** Optimized hotspot analysis map of Point Douglas and St. Boniface).

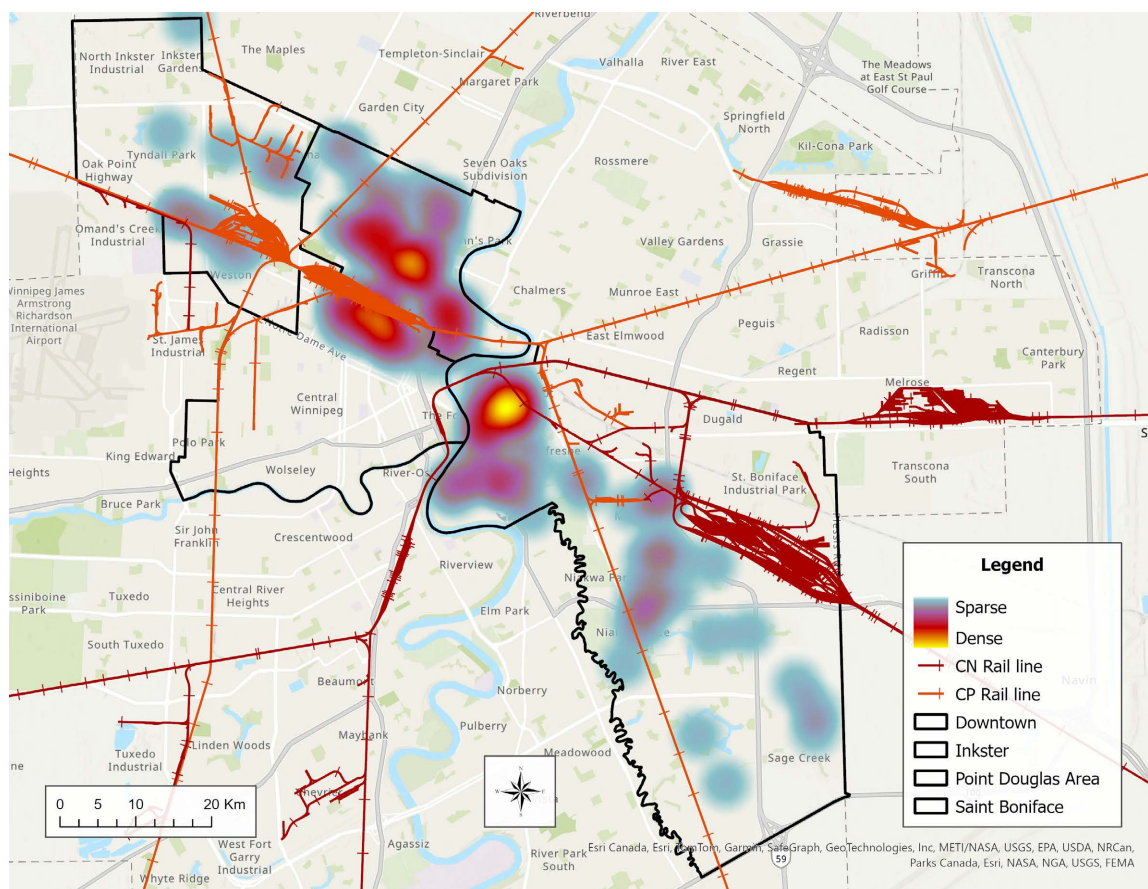


Figure 12. Optimized hotspot analysis of vulnerable populations in Point Douglas and St. Boniface intersection with rail lines.

The input features for the analysis were the vulnerable land uses, and the output was an optimized hotspot analysis of these vulnerable land uses. The analysis field focused on the absolute population, weighing 123 sites of vulnerable land uses. Evaluation of the analysis field values revealed a minimum value of 0, a maximum of 5350, a mean of 215, and a standard deviation of 524. The optimal distance for the analysis was determined to be 872 meters, based on the average distance to the six nearest neighbors. Furthermore, 40% of features had fewer than eight neighbors within the optimal distance band of 872 meters.

The optimized hotspot analysis map (**Figure 12**) showed areas of varying density of vulnerable land uses. Red and yellow areas on the map indicate hotspots with high concentrations of vulnerable populations, primarily around the Kenora main line and the Winnipeg rail yard in Point Douglas. In St. Boniface, areas around the Emerson main line and the Sioux Lookout line, particularly where the lines connected to the Fort Rouge yard, were hotspots. In contrast, blue areas represent cold spots with lower concentrations of vulnerable populations, which are more dispersed and less prominent compared to the hotspots.

The concentration of vulnerable land uses around major rail lines in Point Douglas and St. Boniface highlights the potential environmental and safety risks associated with the communities. A derailment leading to the release of hazardous materials on any of the main lines or spur lines could result in fires or explosions, with significant consequences for urban areas (Taylor & Sandler, 1986; Dou et al., 2019; Hou et al., 2021). Consequently, accidents involving dangerous goods pose a severe threat to public safety and property along the transportation route and can result in irreversible environmental pollution (Zhang et al., 2022). Clustering of vulnerable land uses in Point Douglas and St. Boniface indicates that a significant portion of the population could be affected in the event of a rail line incident.

7. Limitation

The limitations included the limited academic literature on rail line relocation and spatial analysis of rail line proximity to land uses. Most academic studies on rail lines primarily address environmental pollution and its impacts on human health (Marques & Lima, 2011; Jaffe et al., 2014; Syahputri & Damianto, 2021; Kumar et al., 2024). However, a noticeable gap in research is the risks posed by rail lines to vulnerable populations. Additionally, secondary data sources were used to collect information on vulnerable populations; however, these may not accurately reflect the 2024 population.

8. Discussion

Vulnerable people are schooled, housed and hospitalized near industrial and rail lines in Point Douglas and St. Boniface. Many early childhood centers and schools are within an 800 m and two km buffer, putting young children at risk from industrial incidents. The proximity of hospitals and senior living facilities within the two km zone of industrial sites highlights the need for tailored emergency

response and evacuation plans for healthcare services and elderly populations. The closeness of vulnerable people to industrial sites presents considerable environmental, health, and safety risks, particularly in the event of fire accidents involving hazardous materials (Benson, 2024). A fire incident necessitating a two km evacuation in Point Douglas would impact 16 vulnerable sites in St. Boniface, including early childhood education centers, schools, and senior living facilities (see Figure 7).

Point Douglas and St. Boniface rail yards and lines attract industrial sites to their proximity. Industrial activities in a community can impact surrounding communities as in the Seveso industrial accident. The 1976 Seveso industrial accident caused severe environmental pollution, the deaths of over 2000 animals, and the evacuation of 5000 people, impacting approximately 35,000 residents across seven neighboring communities (Bertazzi et al., 1998; Pesatori et al., 2003; Fekete & Neuner, 2023). Industrial and rail accidents, spills and fires pose health risks such as burns and toxic exposure, as well as long-term environmental hazards that affect air, soil, water, and food supplies (Pesatori et al., 2003; Brender et al., 2011; Eskenazi et al., 2018; Fekete & Neuner, 2023; Chan et al., 2015). These findings underscore the importance of integrated, proactive measures, including urban planning, regulatory policy adherence, monitoring, and risk management strategies, to protect vulnerable populations from industrial hazards (Benson, 2024).

The rail line buffer analysis in the neighbourhoods of Point Douglas and St. Boniface revealed that over 90% of vulnerable land uses are within the two km buffer zone. This concentration raises safety concerns, particularly for children and the elderly, who are more susceptible to health complications during emergencies. The presence of hospitals serving large vulnerable populations further underscores the need for comprehensive mitigation strategies to address safety risks from nearby rail lines (Burgess, 1999).

In Point Douglas, most vulnerable land uses are clustered around the CP Kenora main line and CP Winnipeg rail lines. In St. Boniface, they are concentrated in Central St. Boniface, near industrial sites and surrounded by the CP Emerson main line, with connections to the CN Fort Rouge yard via the CN Sioux Lookout line. The presence of these rail infrastructures heightens the safety risks for vulnerable populations in these areas. Railway operations can cause injury or death and have significant environmental impacts, including noise, air, and soil pollution, which adversely affect nearby residents (Brtnický et al., 2022; BCF Group, n.d.).

Railway noise is a significant environmental concern, contributing to both auditory and non-auditory health issues for nearby residents (Raj et al., 2020). Ranking second in transport noise pollution after road traffic (Tao et al., 2019), reducing railway noise exposure could improve learning environments, sleep quality, cardiovascular health, and hospital outcomes (Raj et al., 2020). Safety risk mitigation strategies, such as closing certain rail lines, proper land use planning, and

tailored emergency responses, are essential for protecting vulnerable populations and enhancing safety in Point Douglas and St. Boniface.

The vulnerability analysis of Point Douglas and St. Boniface revealed a significant portion of the population consists of vulnerable groups. Projected population growth in Point Douglas and St. Boniface indicates an increase in the number of vulnerable individuals. As a result, the number of people at risk from rail line and industrial operations is expected to rise in the coming years.

The hotspot analysis underscored the critical areas of vulnerable population proximate to rail lines in Point Douglas and St. Boniface. Community members in Point Douglas and St. Boniface have expressed concerns about the frequent transportation of dangerous goods through their neighborhoods, particularly considering the rising number of Canada's rail accidents.

Mitigation strategies could reduce the environmental and safety risks posed by rail lines in Point Douglas and St. Boniface. Complete or partial removal and relocation of the CP Winnipeg rail yard in Point Douglas to CentrePort is an option with the allocated 665-acre Rail Park and Foreign Trade Zone (Aimee, 2023). Initial or partial removal efforts could focus on the 466-acre Winnipeg rail yard in the Point Douglas area (Werner & Institute of Urban Studies, 2011), which poses risks to nearby vulnerable land uses. Relocating rail operations or consolidating urban rail routes into a grade-separated corridor outside the urban area could also reduce these impacts (Morgan et al., 2007).

Some associated benefits of rail relocation include a reduced potential for derailments, decreased grade crossing delays and accidents, and lowered community vulnerability to hazardous materials transported through urban areas (Taylor & Sandler, 1986). Furthermore, during group meetings, the Rail relocation group and community members of Point Douglas and St. Boniface discussed the potential to repurpose the brownfields into residential and commercial buildings. They also proposed creating an urban park with green spaces and active transportation infrastructure.

9. Conclusion

The spatial analysis and mapping of land uses revealed environmental, health, and safety concerns for residents in both the Point Douglas area and St. Boniface community. These concerns are attributed to the presence of rail lines and industrial sites. Proximity of various vulnerable land uses to rail lines and industrial sites in Point Douglas and St. Boniface increases the risks for evacuation-sensitive facilities. The study highlighted the potential vulnerability of these evacuation-sensitive facilities to hazards such as industrial fires and train derailments involving dangerous goods. The situation necessitates the need for proactive mitigation strategies, such as the relocation or closure of some rail lines in Point Douglas and St. Boniface.

Statistical analysis of vulnerable populations in the Point Douglas area and St. Boniface further emphasized the importance of proactive measures. These

measures are essential to ensure the safety and well-being of residents due to the environmental and safety risks posed by rail lines and industrial sites.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- Aimee (2023, January 20). *Government of Manitoba Announces Development Partner for the CentrePort Canada Rail Park*. CentrePort Canada.
<https://centreportcanada.ca/media-release-government-of-manitoba-announces-development-partner-for-the-centreport-canada-rail-park/>
- AlQuhtani, S., & Anjomani, A. (2021). Do Rail Transit Stations Affect the Population Density Changes around Them? The Case of Dallas-Fort Worth Metropolitan Area. *Sustainability*, 13, Article No. 3355. <https://doi.org/10.3390/su13063355>
- Aremu, S., Brundrige, R., Lowe, J., & Ziotas, I. (1986). *C.N.R. East Yards Redevelopment '84: A Showcase of Winnipeg's Past and Future*. The Institute of Urban Studies, University of Winnipeg.
- BCF Group (n.d.). *Health and Safety Issues Regarding Trains and Railway Lines*.
<https://www.thebcfgroup.co.uk/health-and-safety-pages/health-and-safety-trains-railway-lines.php>
- Benson, O. (2024, April 18). *Negative Effects of Situating a Residential Building in Industrial Areas*.
<https://diamondfm.net/blog/negative-effects-of-situating-a-residential-building-in-industrial-areas/>
- Bernhardt, D. (2018, September 7). *CN Forges New Partnership Extends Long History with Renaming of Stage, Park at the Forks*. CBC.
<https://www.cbc.ca/news/canada/manitoba/cn-stage-field-forks-naming-partner-1.4814325>
- Bernhardt, D. (2023, April 21). *Train Derailment at Winnipeg Overpass Could Close McPhillips Street for Several Days*. CBC.
<https://www.cbc.ca/news/canada/manitoba/train-derail-ment-winnipeg-overpass-1.6817839>
- Bertazzi, P. A., Bernucci, I., Brambilla, G., Consonni, D., & Pesatori, A. C. (1998). The Seveso Studies on Early and Long-Term Effects of Dioxin Exposure: A Review. *Environmental Health Perspectives*, 106, 625-633. <https://doi.org/10.1289/ehp.98106625>
- Bowes, D. R., & Ihlanfeldt, K. R. (2001). Identifying the Impacts of Rail Transit Stations on Residential Property Values. *Journal of Urban Economics*, 50, 1-25.
<https://doi.org/10.1006/juec.2001.2214>
- Brender, J. D., Maantay, J. A., & Chakraborty, J. (2011). Residential Proximity to Environmental Hazards and Adverse Health Outcomes. *American Journal of Public Health*, 101, S37-S52. <https://doi.org/10.2105/ajph.2011.300183>
- Brtnický, M., Pecina, V., Juříčka, D., Kowal, P., Vašínová Galiová, M., Baltazár, T. et al. (2022). Can Rail Transport-Related Contamination Affect Railway Vegetation? A Case Study of a Busy Railway Corridor in Poland. *Chemosphere*, 293, Article ID: 133521.
<https://doi.org/10.1016/j.chemosphere.2022.133521>
- Bukała, M., Chmielewski, R., Chyla, A., Kruszka, L., Januszewski, B., Ostatek, P. et al. (2021). Analysis of Rail Traffic Vibrations' Impact on a Residential Building. a Case Study. *Engineering Expert*, No. 1, 35-49. <https://doi.org/10.37105/enex.2021.1.05>

- Burgess, J. L. (1999). Hospital Evacuations Due to Hazardous Materials Incidents. *The American Journal of Emergency Medicine*, 17, 50-52.
[https://doi.org/10.1016/s0735-6757\(99\)90016-5](https://doi.org/10.1016/s0735-6757(99)90016-5)
- Butterfield, D. (1987). *Railway Stations of Manitoba: An Architectural History Theme*.
https://www.gov.mb.ca/chc/hrb/internal_reports/pdfs/railway_stations_intro.pdf
- Canada (2021, August 23). *Understanding the Emergency Response Guidebook*. Transport Canada.
<https://tc.canada.ca/en/dangerous-goods/canutec/understanding-emergency-response-guidebook>
- Caporale, A., & Fast, H. (2023, January). *The Burden of Concern: The Healthy Environment, Healthy Neighbourhood Project*. Manitoba Eco-Network.
<https://mbeconetwork.org/wp-content/uploads/2023/03/HEHN-v6.pdf>
- CBC News (2014, October 17). *City Keeps "Secret" on Dangerous Rail Cars, Says Winnipeg Councillor*. CBC News.
<https://www.cbc.ca/news/canada/manitoba/city-keeps-secret-on-dangerous-rail-cars-says-winnipeg-councillor-1.2802447>
- CBC News (2024a). *Boy, 16, Hit by Train in Winnipeg Suffered "Life-Altering In-juries," Police Say*.
<https://www.cbc.ca/news/canada/manitoba/teen-hit-train-winnipeg-university-manitoba-1.7188333>
- CBC News (2024b). *Train Derailment Briefly Blocks Traffic in South Winnipeg*.
<https://www.cbc.ca/news/canada/manitoba/train-derailment-grant-taylor-blocked-1.7285676>
- CBC News (2024c). *38-Year-Old Woman Died after Being Hit by Train in Osborne Village Early Monday: Winnipeg Police*.
<https://www.cbc.ca/news/canada/manitoba/woman-train-accident-death-winnipeg-osborne-1.7252089>
- CED (2022, June 16). *Evaluation of the Lac-Mégantic Economic Recovery Initiative*.
<https://ced.canada.ca/en/departamental-publications/evaluation-of-the-lac-megantic-economic-recovery-initiative/>
- Chan, E. Y. Y., Wang, Z., Mark, C. K. M., & Da Liu, S. (2015). Industrial Accidents in China: Risk Reduction and Response. *The Lancet*, 386, 1421-1422.
[https://doi.org/10.1016/s0140-6736\(15\)00424-9](https://doi.org/10.1016/s0140-6736(15)00424-9)
- Chang, A. (2024, April 29). *At Least One Person Struck by Train near University of Manitoba*. CBC.
<https://www.cbc.ca/news/canada/manitoba/train-person-struck-by-train-near-university-of-manitoba-1.7187712>
- ChrisD.ca (2012, October 2). *St. Boniface Blaze One of the "Largest Fires" City Has Ever Faced*. ChrisD.ca Winnipeg News.
<https://www.chrisd.ca/2012/10/02/speedway-internationalfire-st-boniface-winnipeg/>
- City of Winnipeg & Statistics Canada (2021). *2021 Census Data—St. Boniface Community Area* (pp. 1-17). City of Winnipeg and Statistics Canada.
<https://legacy.winnipeg.ca/Census/2021/Community%20Area/St.%20Boniface%20Community20Area.pdf>
- City of Winnipeg & Statistics Canada (2021a). *2021 Census Data—Point Douglas Community Area* (pp. 1-17). City of Winnipeg and Statistics Canada.
<https://legacy.winnipeg.ca/Census/2021/Community%20Area/Point%20Douglas%20Community%20Area.pdf>

- Davis, J. (2024, April 11). *Cottage Q&A: How Do Trains Cause Wildfires?* Cottage Life. <https://cottagelife.com/outdoors/cottage-qa-how-do-trains-cause-wildfires/>
- Dawe, M. (n.d.). *Rail Relocation Project a First in Western Canada*. Forth Junction Heritage Society. <https://forthjunction.ca/dawe-cnr-relocation.htm>
- Diaz, R. B. (1999). *Impacts of Rail Transit on Property Values*. Transportation Research Board. <https://trid.trb.org/view/504776>
- Donnini, A. (2024, May 9). *Exhaust Sparks Likely Caused CPKC Train to Ignite before Rolling through Downtown London, Ont.: TSB*. CBC News. <https://www.cbc.ca/news/canada/london/london-fire-flame-train-sparks-cause-investigation-1.7197853>
- Dou, Z., Mebarki, A., Cheng, Y., Zheng, X., Jiang, J., Wang, Y. et al. (2019). Review on the Emergency Evacuation in Chemicals-Concentrated Areas. *Journal of Loss Prevention in the Process Industries*, 60, 35-45. <https://doi.org/10.1016/j.jlp.2019.03.008>
- Eco-Health Learning Circle (2023, March 21). *Polluting Paradise: Mission Industrial Impacts on Residents of South St. Boniface, Winnipeg [Video]*. YouTube. <https://www.youtube.com/watch?v=D24ASG-oQA>
- EducationalWave (2023, August 6). *Pros and Cons of Living near Train Tracks*. <https://www.educationalwave.com/pros-and-cons-of-living-near-train-tracks/>
- Eskenazi, B., Warner, M., Brambilla, P., Signorini, S., Ames, J., & Mocarrelli, P. (2018). The Seveso Accident: A Look at 40 Years of Health Research and beyond. *Environment International*, 121, 71-84. <https://doi.org/10.1016/j.envint.2018.08.051>
- Federation of Canadian Municipalities, & Railway Association of Canada (2013, May). *Guidelines for New Development in Proximity to Railway Operations*. https://www.proximityissues.ca/wp-content/uploads/2017/09/2013_05_29_Guidelines_NewDevelopment_E.pdf
- Fekete, A., & Neuner, S. (2023). Spatial Industrial Accident Exposure and Social Vulnerability Assessment of Hazardous Material Sites, Chemical Parks, and Nuclear Power Plants in Germany. *International Journal of Disaster Risk Science*, 14, 223-236. <https://doi.org/10.1007/s13753-023-00486-x>
- Forth Junction (2022a). *The Calgary and Edmonton Railway at Red Deer—CPR Red Deer—Historical Perspective*. Forth Junction Heritage Society. <http://forthjunction.ca/ce-railwayreddeer.htm#:~:text=In%201985%2C%20the%20provincial%20government,years%20between%201989%20and%201991>
- Forth Junction (2022b). *Canadian National Red Deer Downtown Station 1920-1960—CNR Brazeau—Historical Perspective*. Forth Junction Heritage Society. <https://forthjunction.ca/cnr-reddeer.htm>
- Gangadhar, Z. S. (2014). Environmental Impact Assessment on Soil Pollution Issue about Human Health. *International Research Journal of Environment Sciences*, 3, 78-81. <http://www.isca.in/IJENS/Archive/v3/i11/14.ISCA-IRJEvS-2014-203.pdf>
- Généreux, M., Petit, G., Maltais, D., Roy, M., Simard, R., Boivin, S. et al. (2014). The Public Health Response during and after the Lac-Mégantic Train Derailment Tragedy: A Case Study. *Disaster Health*, 2, 113-120. <https://doi.org/10.1080/21665044.2014.1103123>
- Goldsborough, G. (n.d.). *MHS Centennial Business: Canadian Pacific Railway Company/CPKC*. Manitoba Historical Society. <https://www.mhs.mb.ca/docs/business/cpr.shtml>
- Government of Canada, Transportation Safety Board of Canada (2017, August 21). *Railway Investigation Report R13D0054*. Transportation Safety Board of Canada. <https://www.tsb.gc.ca/eng/rapports-reports/rail/2013/r13d0054/r13d0054.html>

- Grover, S., & Thomas, G. (n.d.). *The Forks: A Meeting Place Transformed*. Winnipeg Architecture Foundation. <https://winnipegarchitecture.ca/digital-tours/the-forks/>
- Hoekstra, G. (2014, March 24). *Homes near Rail Lines Face Exposure to Harmful Emissions: Study*. Vancouver Sun. <https://vancouver Sun.com/news/metro/homes-near-rail-lines-face-exposure-to-harmful-emissions-study>
- Hou, J., Gai, W., Cheng, W., & Deng, Y. (2021). Hazardous Chemical Leakage Accidents and Emergency Evacuation Response from 2009 to 2018 in China: A Review. *Safety Science*, 135, Article ID: 105101. <https://doi.org/10.1016/j.ssci.2020.105101>
- Hoye, B. (2023, July 5). *Large Industrial Fire Triggers Evacuation of 3-Block Area in Point Douglas*. CBC News. <https://www.cbc.ca/news/canada/manitoba/point-douglas-fire-1.6896251>
- Huband, C. (2017, July 13). *Let's Get Started on Rail Relocation*. Winnipeg Free Press. <https://www.winnipegfreepress.com/opinion/analysis/2017/07/13/lets-get-started-on-rail-relocation>
- Ibarreta, A., Biteau, H., & Sutula, J. (2016). BLEVES and Fireballs. In M. J. Hurley, et al. (Eds.), *SFPE Handbook of Fire Protection Engineering* (pp. 2792-2816). Springer. https://doi.org/10.1007/978-1-4939-2565-0_71
- Jaffe, D. A., Hof, G., Malashanka, S., Putz, J., Thayer, J., Fry, J. L. et al. (2014). Diesel Particulate Matter Emission Factors and Air Quality Implications from In-Service Rail in Washington State, Usa. *Atmospheric Pollution Research*, 5, 344-351. <https://doi.org/10.5094/apr.2014.040>
- Kampa, M., & Castanas, E. (2008). Human Health Effects of Air Pollution. *Environmental Pollution*, 151, 362-367. <https://doi.org/10.1016/j.envpol.2007.06.012>
- Kumar, K., Bhartia, A., Mishra, R. K., Jadon, R. P. S., & Kumar, J. (2024). Diurnal Rail Noise Measurement, Analysis, and Evaluation of Associated Health Impacts on Residents Living in the Proximity of Rail Track Area. *Environmental Monitoring and Assessment*, 196, Article No. 543. <https://doi.org/10.1007/s10661-024-12681-4>
- Long Term and Continuing Care Association of Manitoba, Manitoba, Canada. (n.d.). LTCAM. <https://www.ltcam.mb.ca/>
- Louis Riel School Division (2024). <https://www.lrsd.net/>
- Luymes, G. (2023, April 27). *CN Fined after Sparking Nine Wildfires near Prince George in 2020*. Vancouver Sun. <https://vancouver Sun.com/news/cn-fined-after-sparking-nine-wildfires-nearprince-george-in-2020>
- Mabahwi, N. A. B., Leh, O. L. H., & Omar, D. (2014). Human Health and Wellbeing: Human Health Effect of Air Pollution. *Procedia—Social and Behavioral Sciences*, 153, 221-229. <https://doi.org/10.1016/j.sbspro.2014.10.056>
- Manitoba Health (2012). *Smoke Exposure from Wildland Fires*. <https://www.gov.mb.ca/health/publichealth/environmentalhealth/docs/wildland-firesmokeexposure.pdf>
- Marques, S., & Lima, M. L. (2011). Living in Grey Areas: Industrial Activity and Psychological Health. *Journal of Environmental Psychology*, 31, 314-322. <https://doi.org/10.1016/j.jenvp.2010.12.002>
- Milewicz, J., Mokrzan, D., & Szymański, G. M. (2023). Environmental Impact Evaluation as a Key Element in Ensuring Sustainable Development of Rail Transport. *Sustainability*, 15, Article 13754. <https://doi.org/10.3390/su151813754>
- Morgan, C. A., Warner, J. E., Roco, C. E., Anderson, G. C., Olson, L. E., Roop, S. S., & Texas

- Transportation Institute (2007). *Rail Relocation Projects in the U.S.: Case Studies and Lessons for Texas Rail Planning*. Texas Transportation Institute.
<https://static.tti.tamu.edu/tti.tamu.edu/documents/0-5322-1.pdf>
- Nickel, L. (2015, January 26). *Speedway Owner Must Pay \$30,000 in Penalties for St. Boniface Fire*. Global News.
<https://globalnews.ca/news/1792810/st-boniface-speedway-explosion-courtcase-opens-monday/#:~:text=The%20Oct.,just%20over%20%2431%2C000%20to%20fight>
- Northern Lights, K. (2019). *Remediation of Contaminated Soil Following the Train Derailment at Lac-Megantic*. Website [Canadian Brownfields Case Study].
<https://www.brownfieldsresearchlab.com/wp-content/uploads/2019/06/FINAL-Lac-Megantic-Final-Final.pdf>
- Pesatori, A. C., Consonni, D., Bachetti, S., Zocchetti, C., Bonzini, M., Baccarelli, A. et al. (2003). Short- and Long-Term Morbidity and Mortality in the Population Exposed to Dioxin after the “Seveso Accident”. *Industrial Health*, 41, 127-138.
<https://doi.org/10.2486/indhealth.41.127>
- RAC (2024, January 5). *Delivering Canada’s Amazing Products to the World*. Railway Association of Canada.
<https://www.railcan.ca/101/delivering-canadas-amazing-products-to-the-world/#:~:text=The%20Goods%20We%20Move&text=Intermodal%20trafic%E2%80%94the%20transportation%20of,%2C%20electronics%2C%20and%20much%20more>
- Railway Association of Canada (2022). *Railway Association of Canada—Rail Trends 2022*. Railway Association of Canada.
<https://www.railcan.ca/wp-content/uploads/2022/12/RAC-Rail-Trends-2022-EN.pdf>
- Raj, U., Sahu, P., Galhotra, A., & Ranjan, R. (2020). A Study of Self-Reported Health Problems of the People Living near Railway Tracks in Raipur City. *Journal of Family Medicine and Primary Care*, 9, 740-744. https://doi.org/10.4103/jfmpc.jfmpc_1029_19
- Rutgers, J. (2023, June 9). “A Toxic Soup”: *Why a Winnipeg Neighbourhood Is Fighting for Its Right to a Healthy Environment*. The Narwhal.
<https://thenarwhal.ca/winnipeg-point-douglas-contamination/>
- Social Planning Council of Winnipeg (2023, December 11). *Rail Yard Relocation and the Arlington Bridge: Crisis or Opportunity?* <https://spcw.mb.ca/>
- Solademi, F., & Thompson, S. (2020). Spatial Analysis of Heavy Metal Emissions in Residential, Commercial and Industrial Areas Adjacent to a Scrap Metal Shredder in Winnipeg, Canada. *Journal of Geoscience and Environment Protection*, 8, 359-386.
<https://doi.org/10.4236/gep.2020.85023>
- Solademi, F., & Thompson, S. (2023). Spatial Analysis of Fine Particulate Matter (PM_{2.5}) in South St. Boniface and Mission Industrial Area, Winnipeg, Manitoba, Canada. *Journal of Geoscience and Environment Protection*, 11, 176-196.
<https://doi.org/10.4236/gep.2023.118011>
- Spencer-Hwang, R., Montgomery, S., Dougherty, M., Valladares, J., Rangel, S., Gleason, P., & Soret, S. (2014, September 1). *Experiences of a Rail Yard Community: Life Is Hard*. PubMed Central (PMC). <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4486117/>
- Stagl, J. (2018, July). *Class I Railroads Continue the Longer-Train Trend*. Progressive Railroading.
https://www.progressiverailroading.com/bnsf_railway/article/Class-I-railroads-continue-the-longer-train-trend--55035
- Stares, J. (2014). *Evidence Review: Use of Evacuation to Protect Public Health during Wild-*

fire Smoke Events.

http://www.bccdc.ca/resource-gallery/Documents/Guide-lines%20and%20Forms/Guidelines%20and%20Manuals/Health-Environment/WFSG_EvidenceReview_Evacuation_FINAL_V3_edstrs.pdf

- Stojic, N., Pucarevic, M., & Stojic, G. (2017). Railway Transportation as a Source of Soil Pollution. *Transportation Research Part D: Transport and Environment*, 57, 124-129. <https://doi.org/10.1016/j.trd.2017.09.024>
- Syahputri, R. A., & Damianto, B. (2021). Effects of Railway Noise on Residents' in a Residential Area. *Applied Research on Civil Engineering and Environment (ARCEE)*, 3, 17-28. <https://doi.org/10.32722/arcee.v3i01.3687>
- Tao, Z., Wang, Y., Sanayei, M., Moore, J. A., & Zou, C. (2019). Experimental Study of Train-Induced Vibration in Over-Track Buildings in a Metro Depot. *Engineering Structures*, 198, Article ID: 109473. <https://doi.org/10.1016/j.engstruct.2019.109473>
- Taylor, S., & Sandler, D. (1986). Benefit-Cost Analysis of a Proposed Rail Line Relocation: A Case Study. *Transportation Research Record*, 1074, 2.
- Testbook (2023, August 30). *Exponential Growth Formula—Definition, Explanation and Examples*. Testbook. [https://testbook.com/maths-formulas/exponential-growth-formula#:~:text=The%20exponential%20growth%20formula%20is%20P\(t\)%20%3D%20P%20e,rate%2C%20e%20is%20Euler%27s%20number](https://testbook.com/maths-formulas/exponential-growth-formula#:~:text=The%20exponential%20growth%20formula%20is%20P(t)%20%3D%20P%20e,rate%2C%20e%20is%20Euler%27s%20number)
- The Canadian Press (2013, July 29). *Rail Safety Advocates Urge New Rules for High-Risk Cargo*. CBC News. <https://www.cbc.ca/news/politics/rail-safety-advocates-urge-new-rules-for-high-risk-cargo-1.1312525>
- The Forks (n.d.). *History*. The Forks. <https://www.theforks.com/about/history>
- The Impact Project (2012). *Tracking Harm: Health and Environmental Impacts of Rail Yards*. The Impact Project—Policy Brief Series. <https://envhealthcenters.usc.edu/wp-content/uploads/2016/11/Tracking-Harm.pdf>
- Transportation Safety Board of Canada (2021, July 15). *Common Causes of Fire in Canada's Rail Transportation Sector*. Transportation Safety Board of Canada. <https://www.tsb.gc.ca/eng/medias-media/fiches-facts/r21v0143/r21v0143-20210715.html>
- Transportation Safety Board of Canada (2024). *Statistical Summary: Rail Transportation Occurrences in 2023*. Transportation Safety Board of Canada [Report]. <https://www.tsb.gc.ca>
- United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), Steiner, A., Türk, V., & Andersen, I. (2022). *What Is the Right to a Healthy Environment?* Information Note. <https://www.undp.org/sites/g/files/zskgke326/files/2023-01/UNDP-UNEP-UNHCHR-What-is-the-Right-to-a-Healthy-Environment.pdf>
- Valiante, G. (2019, January 18). *Lac-Mégantic Rail Disaster*. The Canadian Encyclopedia. <https://www.thecanadianencyclopedia.ca/en/article/lac-megantic-rail-disaster>
- Werner, A., & Institute of Urban Studies (2011). *2011 Winnipeg Railway Areas and Land Use [Map; Digital]*. https://www.uwinnipeg.ca/ius/docs/Map-Month/2011_railway_areas_winnipeg.pdf
- Winnipeg Regional Health Authority (2024). *WRHA—Winnipeg Regional Health Authority*. <https://wrha.mb.ca/>

- Winnipeg Regional Real Estate News (2015, November 20). *Relocation of Rail Lines*. <https://www.winnipegregionalrealestatenews.com/publications/real-estate-news/2590>
- Winnipeg School Division (2024). <https://www.winnipegssd.ca/>
- Woods, A. (2014, June 16). Quebec Submits \$400 Million Claim for Lac-Mégantic Train Disaster. *Toronto Star*. https://www.thestar.com/news/canada/quebec-submits-400-million-claim-for-lac-megantic-train-disaster/article_823bffa6-7ec9-5485-ac41-8a747cabb83f.html#:~:text=MONTREAL-The%20Quebec%20government%20has,be%20more%20than%20%24400%20million
- Wrótny, M., & Bohatkiewicz, J. (2020). Impact of Railway Noise on People Based on Strategic Acoustic Maps. *Sustainability*, *12*, Article No. 5637. <https://doi.org/10.3390/su12145637>
- Zhang, W., Cheng, W., & Gai, W. (2022). Hazardous Chemicals Road Transportation Accidents and the Corresponding Evacuation Events from 2012 to 2020 in China: A Review. *International Journal of Environmental Research and Public Health*, *19*, Article No. 15182. <https://doi.org/10.3390/ijerph192215182>