An Investigation of Designated Pedestrian Grade Crossings and Flangeway Fillers

by

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ABSTRACT

There have been fatalities in Canada due to wheelchairs becoming immobilized in the "flangeway gap", the gap between the road and the railway tracks that allows the train wheel to pass unimpeded. The Transportation Safety Board has identified the potential of flangeway fillers to eliminate the gap, but research on product suitability is needed, including deployment criteria. Crossings can be designated by road authorities for persons using assistive devices and Transport Canada's Grade Crossing Standards outline the geometric requirements. Designated crossings may be candidates for flangeway fillers, however, the road authority designation process is not well understood at a national level.

The following presents an inventory of practices for crossing designation among select road authorities across Canada. An analysis of designated crossings was conducted, and observations were generated. Finally, an economic evaluation of these products was conducted, and a discussion of potential next steps in this field is provided.

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List of Symbols, Nomenclature or Abbreviations

AADT- Average Annual Daily Traffic
BC- British Columbia
BCA- Benefit-Cost Analysis
BCR- Benefit Cost Ratio
CN- Canadian National Railway
CP- Canadian Pacific Railway
SK- Saskatchewan
TC- Transport Canada
TRB- Transportation Research Board
TSB- Transportation Safety Board
UNB- University of New Brunswick
MS Excel- Microsoft Excel
MS Forms- Microsoft Forms
MS Teams- Microsoft Teams
NB- New Brunswick
NPV- Net Present Value
NRC- National Research Council
NBC- National Building Code of Canada
ON- Ontario
VSL- Value of Statistical Life

Chapter 1- Introduction

Canada has an extensive railway network comprised of 43,065 kilometers of rail and 25,155 grade crossings (14,000 public crossings) (Transport Canada, 2020). Figure 1 displays an image of the National Railway Network. Grade crossings are defined as level locations where rail lines intersect highways or roads. Transport Canada is the governing body for ensuring rail safety at grade crossings, and periodically updates the Grade Crossing Standards and Grade Crossing Regulations. These documents outline specifications and attributes that rail crossings must maintain to ensure safety for pedestrians and vehicles.

Figure 1: Canadian Railway Network (Transport Canada, 2020).

At the location of a grade crossing, a flangeway exists. The flangeway or flangeway gap is positioned parallel to the tracks to allow for flanged train wheels to pass freely. Figure 2 displays an image of this gap for clarification.

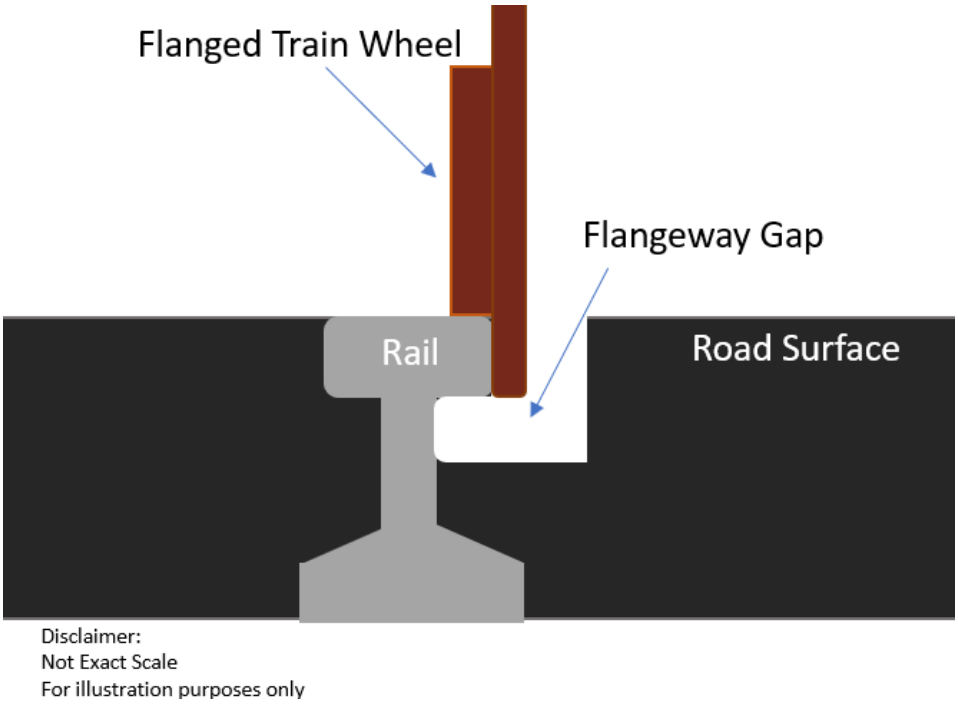

Figure 2: Flangeway Illustration

Transport Canada has specifications for the dimensions of the flangeway gap in the Grade Crossing Handbook. “A flangeway must be provided between the gauge side of the rail and the road surface and must be between 65 mm and 120 mm wide” (75 mm at designated pedestrian crossings) “…and between 50 mm and 75 mm deep” (Transport Canada, 2016).

It should be noted there is a specific provision for crossings designated for persons with a disability. The purpose of this provision is to provide a smoother path for those who require assistive devices (wheelchairs, walkers, etc.). This imposes the restriction of a

maximum 75 mm deep and wide gap, when a crossing is designated by the road authority for pedestrians with a disability. A review of crossing data provided by Transport Canada show that only 1% of all grade crossings in Canada have received this designation. Transport Canada has stated "Because the requirement to designate crossings for use with assistive devices is new, it is not yet known how many crossings will be designated" (TSB, 2016).

Although the flangeway is a necessary component of a railroad crossing, it introduces risk to pedestrians using assistive devices, as well as to cyclists. Transport Canada notes in the Grade Crossing Handbook "A smooth and continuous surface helps to ensure the safe and comfortable crossing by cyclists and pedestrians" (Transport Canada, 2016). It should be noted that the current flangeway gap specifications at designated crossings exceeds the maximum acceptable dimensions for a barrier-free path outlined in Section 3.8 of the National Building Code of Canada (NBC). Although this is not specifically intended to govern outdoor grade crossings, it indicates that flangeway gaps create a significant barrier for those who use assistive devices, even when the designation is given to a crossing, and the gap is limited accordingly.

Fatalities have occurred when the wheels of devices became entrapped within the flangeway, trapping a person at the grade crossing. Flangeway filler products fill the gap between the rail and the roadway and are typically compressible material (engineered foam or rubber) and would prevent wheel entrapment at crossings and potential fatalities. Figure 3 displays an image from a Transport Canada investigation report outlining one of these events. These accidents have a low probability, but high severity (typically result in fatalities or serious injury).

Figure 3: Wheel Entrapment at Rail Crossing (Transportation Safety Board of Canada, 2018)

In 2022, the University of New Brunswick began a project with the National Research Council (NRC) to identify and test several flangeway filler products at their Ottawa test facility. The purpose of this project was to develop a testing plan to assess several products for use in the Canadian environment. Several existing products were identified and tested, with the eventual future goal of identifying a product or products for use in Canada. Currently, many of the products that are on the market are not tested or assessed under Canadian climate conditions. The products that are used in Canada currently are only for light rail or low-speed industrial scenarios. Little is understood surrounding

how these products will perform under prevailing weather conditions and Canadian rail operations. Furthermore, how these products would deteriorate in the Canadian climate, in a heavy rail application, is unknown.

Once the feasibility of flangeway filler products is assured from the testing conducted by the NRC, several questions will remain. Recall that Transport Canada has set an upper limit for the dimensions of a flangeway gap at an at-grade designated crossing (maximum 75 mm wide and deep). Designated pedestrian crossings are a significant component of the active transportation network, however, there does not appear to be a methodology or guidelines for assessing crossings to determine if they should be deemed as designated.

1.1 Problem Statement

Currently there is a limited understanding of existing agency practices at a national level for designating crossings for persons using assistive devices, as well as whether there are common factors among these crossings, such as traffic volume and number of lanes. In addition, there are unknowns surrounding how flangeway fillers would be deployed on a network level, and what long-term maintenance and replacement resources would be required.

First, there is a need to determine a clear methodology or guidelines for assessing grade crossings to determine which should be designated for pedestrians who require assisted devices. It is likely that the inventory of designated grade crossings will grow over time, as this designation is new and only represents a small proportion of all grade crossings. Moreover, there may be additional treatments to improve crossing safety.

Currently in Canada, the road authority is responsible for assigning this designation though the criteria for selection is unclear. It is hypothesized that the process is reactive, based on public requests or in response to an accident, though a better understanding of the road authority selection process is needed.

Second, it may be possible to ascertain the land use, traffic and other factors that may be common among designated crossings through an application of statistical analysis to Transport Canada crossing data and related geographic attribute data. This analysis may be useful in being able to extrapolate results to identify other candidate crossings for upgrading as “designated crossings". With only 1% of grade crossings designated for persons with a disability, it is likely that more analysis is required to determine when this designation is appropriate.

Third, it is likely flangeway fillers will become a feasible solution to wheel entrapment in Canada at some point, and in that case would be installed at designated crossings. Such products will deteriorate and will require periodic replacement. An asset management plan would aid in implementing and managing flangeway filler products at designated grade crossings. With the cost of a single rubber flangeway filler system installation estimated at $30,000 (Baldock, 2018), and approximately 250 designated crossings currently in Canada, the economic impact of installing and maintaining these products over time must be determined. The degradation of flangeway fillers will likely be a function of train traffic, winter weather, road volume, etc. With this information documented, it would be possible to determine an order of magnitude cost of this infrastructure addition over a set period (the next 30 years) and help develop a plan.

1.2 Significance of the Study

The benefits of understanding and documenting how different road agencies are designating crossings for persons who use assistive devices is a significant first step in determining if a set of guidelines should be created. Recall that this process is new as of 2016, with many municipalities with active railways having yet to assign this designation. An analysis of the current inventory of crossings and the corresponding surrounding infrastructure, traffic volumes, and demographics would aid in determining what correlations or trends appear to be relevant to assigning this designation. The correlations could be used in future work to establish a set of guidelines for assigning this designation.

The true cost of maintaining these products at crossings designated for pedestrians who use assistive devices would be of interest to both rail companies and road agencies. Depending on the cost structure, each of these parties would likely contribute a significant amount of money to have these products installed and maintained.

1.3 Research Goals and Objectives

The goal of the research was to understand how grade crossings are currently assessed and examine the infrastructure, traffic, and demographic related data at designated pedestrian grade crossings. This information could be helpful in establishing some guidelines for when this designation would be appropriate. In addition, an asset management plan was produced to determine the true cost of this infrastructure addition at designated crossings. The research goal was achieved through the completion of the three objectives below:

1. Document the existing road authority process for designating rail crossings for persons who use assistive devices.

2. Quantify the contribution of geographic, traffic and related factors to the determination of a designated crossing through statistical analysis.

3. Create a preliminary asset replacement plan for the deployment of flangeway gap fillers at designated crossings.

1.4 Scope

The research was limited to understanding the practices of road agencies with active railways subject to Transport Canada's Grade Crossing Standards and crossings within Transport Canada's national inventory of crossings. Light Rail systems and crossings were outside the scope of this research.

1.5 Thesis Layout and Organization

This thesis is separated into six (6) chapters. Chapter 2 examines the current use of flangeway fillers in various nations and a review of past research efforts. Chapter 3 provides the methodology outlining the procedures used in this study. This includes the process of administering the survey to produce an inventory of grade crossing practices and flangeway filler use, the statistical analysis component of this work, and the process of producing a replacement schedule and preliminary asset management plan. Chapter 4 presents the inventory of practices used and flangeway filler use in Canada, evaluates, and analyzes grade crossing characteristics that appear to be correlated to designating grade crossings for persons who use assistive devices, and presents the preliminary asset management plan. A detailed discussion of the results is outlined in Chapter 5. Conclusions, recommendations, and limitations of the study are provided in Chapter 6.

Chapter 2- Literature Review

A detailed literature review was conducted to determine the current state of research surrounding flangeway filler products. In addition, literature surrounding pedestrian safety and how government bodies/railway organizations are determining when to implement these products has been explored. Canada appears to be interested in this research; however, no major Canadian publications have been created surrounding the testing of these products or warrants for implementation. It should be noted no similar research was found in countries which have similar climate conditions to Canada.

2.1 Background

There are more than 14,000 grade crossings within the National Rail Network that are federally regulated and open for public crossing (25,000 crossings in total). A total of 324 of these crossings have received the designation for users who require assistive devices (DATA- Grade Crossings, Transport Canada, 2022). The overall number of crossings that have received this designation remains low, despite the prevalence of mobility disabilities increasing in recent years.

In 2012, Statistics Canada administered the Canadian Survey on Disability. From the results of this survey, it was determined that approximately 14% of Canadians (15 years or older) reported living with a disability. Of this 14%, roughly half were identified as having a mobility disability that limited daily activity (7.2% of adult Canadians). Other relevant findings from this survey were that the use of wheelchairs, mobility scooters, walkers and electric/motorized wheelchairs is increasing in Canada. More specifically, it was found that the use of motorized wheelchairs is increasing 3-5% a year, while the use

of manual wheelchairs is increasing by 2-3% annually (TSB, 2016). Figure 4 displays the prevalence of mobility disability by age group.

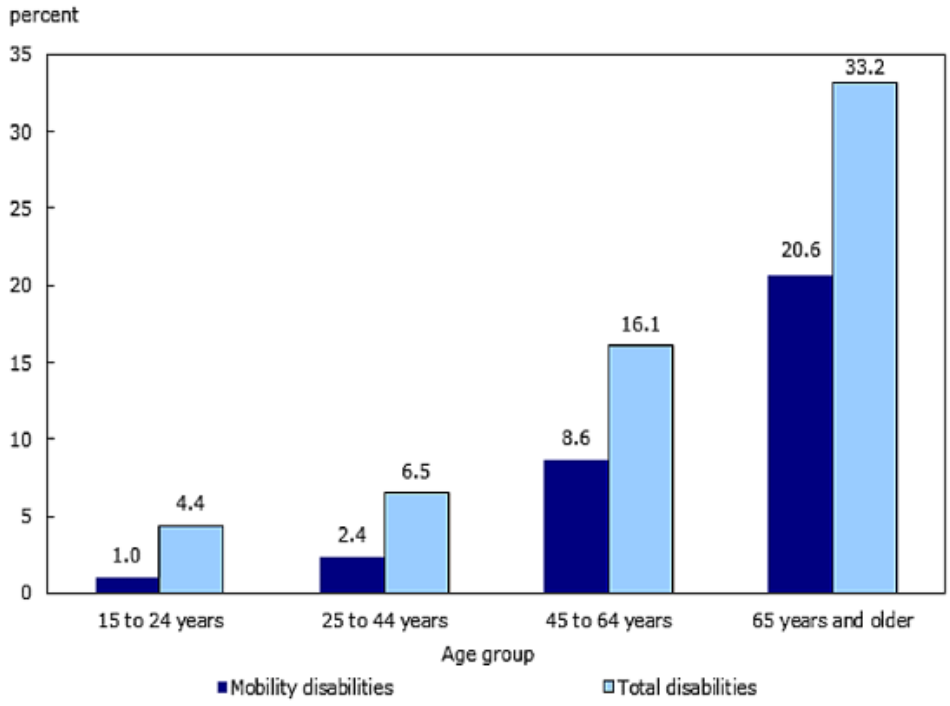

Figure 4: Mobility Disabilities by Age (C. Bizier, G. Fawcett and S. Gilbert, 2016)

With the prevalence of both mobility disabilities and the use of assistive devices increasing, an examination of the inventory of grade crossings should be conducted.

2.2 Canadian Flangeway Filler Research Efforts

The safety issues surrounding flangeway gaps have been well documented in several Transportation Safety Board (TSB) investigations. The TSB released Railway Investigation Report R99S0071, in April of 2001. This report outlined a crossing accident that occurred in 1999, involving two pedestrians using assisted devices and a VIA Rail train. Flangeway filler products were mentioned several times throughout the report as a potential solution and means of eliminating pedestrian- train collisions. *"Plastic materials*

have been used as flangeway fillers in low-speed (5 mph trains) industrial sidings. However, there is no equivalent system to provide a completely smooth surface to users of a level crossing which would permit a higher speed train to pass without the risk of a derailment." (TSB, 2001). The report also mentions that following the incident *"The Association of American Railroads has requested the U.S. Transportation Research Board to test and develop a flangeway filler which will accommodate higher train speeds."* (TSB, 2001). It is worth noting that no product or testing of products appears to have been developed to date.

Later, on July 27, 2016, in Moncton New Brunswick, a Canadian National Railway Company (CN) freight train struck and killed a pedestrian using a wheelchair at a public crossing. At the time of the collision, the crossing was not designated for persons with a disability. It is worth noting that the crossing was outfitted with flashing lights, alarms, and gates. The TSB issued report R16M0026 on February 15th, 2018. This report outlined the investigation that took place along with the details of the collision. The report concluded that "the wheelchair's right caster wheel dropped into the void in the sidewalk, the wheelchair became stuck in the ballast, immobilizing the pedestrian." (TSB, 2018). The document acknowledges the use of flangeway filler products as a potential solution.

The TSB Report R16M0026, includes Recommendation R18-01, which states "*The Department of Transport work with stakeholders to identify engineering options for the improvement of crossings designated for persons using assistive devices, conduct an assessment of their effectiveness, and update its regulatory provisions as appropriate*." (TSB, 2018).

On May 26th, 2018, another CN train struck and fatally injured a pedestrian using a motorized wheelchair, this time in the City of Chilliwack, British Columbia. In addition, a bystander who attempted to aid the pedestrian sustained serious injuries. The TSB released investigation report R18V0127 on July 23rd, 2019. At the time of the accident the crossing was not designated as a pedestrian crossing and the width of the flangeway gaps at various locations exceeded the maximum flangeway gap specified in the GCS for designated crossings. The report states *"In this occurrence, the rear caster wheels of the motorized wheelchair were 50 mm (1.96 inches) wide. At the location where the rear caster wheels fell into the flangeway, the gap was 103 mm (4.05 inches) wide"* (TSB, 2019). The report suggests the use of *"displaceable flangeway gap fillers"* as a potential solution and acknowledges that when crossings are not designated by road authorities as necessary, the changes required by the GCR will not be implemented (lower threshold for acceptable gap).

In February of 2019, Transport Canada made the following response to Recommendation R18-01: *"…The department has reviewed available literature and studies describing engineering options, in addition to those already contained in the Grade Crossings Regulations, to improve the safety of crossings designated for persons using assistive devices. The findings from this work will be included in the updated copy of the Grade Crossing – Handbook… This update to the handbook is expected to be published by June 2019."*

The updated Grade Crossing Handbook published in 2019 includes *Appendix M-supplemental engineering guidance for vulnerable road users at grade crossings.* The Handbook states *"…flangeway gap fillers are designed to reduce the risk of small wheels or objects getting stuck in the flangeway gap and provide a smooth and continuous crossing surface. However, at the time of publication, the Canadian freight rail sector has limited experience with flangeway gap fillers; therefore, additional research may be warranted."* (Grade Crossing Handbook, 2019).

On June 31st, 2021, UNB researchers met with representatives from Transport Canada and subject matter experts to determine the current state of flangeway filler products. In summary, Australia appears to have conducted more comprehensive research and testing compared to Canada or the United States. It was discovered that a proposal has been submitted to the TRB, however, the results of the study are unknown. Other than the single proposal, no notable studies were mentioned from the United States. It was also noted that if there is current research being conducted in the United States, it may be not applicable due to differences in climate.

A representative of Transport Canada recalled the use of Omni Rail flangeway filler products in Quebec, Alberta, and Ontario. The representative could not recall any significant maintenance issues. Omni Rail products are a kit-based product and can be applicable for heavy and light rail, however, they do not remove the flangeway gap. No members involved in the meeting knew of any scenarios where flangeway fillers were implemented in Atlantic Canada.

The durability of these products and testing was a key theme within the meeting. Concerns were raised surrounding durability and the potential of failure due to weather conditions. It was noted that a failed product may become a potential hazard/liability for both pedestrians and locomotives. In addition, the accumulation of snow, ice and other debris could have the potential to cause derailment. Therefore, testing of these products should include an environmental element.

It was recommended that walkers and additional mobility devices are included in the testing of these products at the NRC. It was noted that input and consultation with pedestrians who use assisted devices is crucial. Following the meeting, it was communicated to the UNB research group that a representative of the FRA has confirmed that there was no additional research conducted or planned for flangeway filler products in the United States.

2.3 American Literature and Research Efforts

Requirements for flangeway gap dimensions exist in the United States at a federal level. Both the United States Access Board and the Americans with Disabilities Act have set requirements for flangeway dimensions at pedestrian crossings. The U.S Access Board has stated that the flangeway at pedestrian at-grade crossings must be no greater than 2.5 inches (64 mm) wide for non-freight tracks and 3 inches wide (75 mm) for tracks facilitating freight. The Americans with Disabilities Act published in 2006 prescribes a maximum width of 2.5 inches (64 mm) and a maximum depth of 1.5 inches (38 mm) for the flangeway gap.

Acknowledgments have been made to address the fact that the current design guidelines for flangeway gaps do not eliminate safety risks to those who use assisted devices. The Public Rights-of-Way Accessibility Guidelines published in 2013 states *"Flangeway gaps are necessary to allow the passage of train wheel flanges. Flangeway gaps pose a potential hazard to pedestrians who use wheelchairs because the gaps can entrap the wheelchair casters."* (U.S Access Board, 2013).

Two Research Need Statements have been published to the Transportation Research Board (TRB) involving flangeway filler research, with the goal of improving accessibility and pedestrian safety. Issues surrounding flangeway gaps have been documented in DOT reports since the 1980s, however, it appears little to no research has been completed in the United States.

In 1984, graduate research author Eric Paltell and the Virginia Highway & Transportation Research Council published a document titled *An Investigation of Safety Problems at Skewed Rail-Highway Grade Crossings.* The document outlined the safety issues imposed on cyclists and pedestrians at skewed rail crossings and concluded that *"engineering feasibility studies be conducted on the use of a rubber crossing surface with filler strips in the flangeways"* (Paltell, 1984). The document acknowledged that rubber flangeway filler products existed, however, stated *"If filler strips are used at crossings where train speeds exceed 10 mph (16.1 kph), they deteriorate rapidly and require frequent replacement"* (Paltell, 1984). The document concluded that more research was required to determine the usefulness of these products. The document also stressed that an economic evaluation should occur when determining if a filler product should be implemented at a crossing. *"The ultimate decision must weigh the benefits to be gained in cyclist safety*

against the cost for installing the crossing and the possible replacement of deteriorated filler strips" (Paltell, 1984). It should be recognized that this report was published 40 years ago and there may be significant improvements to materials used today.

Recent research surrounding flangeway filler products at a federal level in the United States appears to be at a standstill. The Transportation Research Board, US Army Corps of Engineers, as well as the Federal Railroad Administration have published documents and discussed flangeway filler products. There are limited articles or research published within the United States involving the use of flangeway fillers for improving pedestrian safety.

In 2000, the US Army Corps of Engineers published a document titled *Railroad Design and Rehabilitation.* This document briefly mentions the use of rubber flangeway filler products, but for the purpose of shielding tracks from ice and other debris. The document states *"Rubber flangeway fillers are especially useful where: (1) crossing geometry and low relative elevation naturally direct rainwater to the crossing flangeways, (2) where crossing drainage is naturally difficult, or (3) where crossing heave from freeze-thaw cycles is a common problem from rainwater or snowmelt entering unsealed flangeways."* (Beranek, 2020). There is no mention or focus of improving pedestrian safety.

Later in 2008, the Transportation Research Board AHB60 Committee developed and endorsed a Research Needs Statement involving Highway-Rail Grade Crossings. The purpose of this statement was to outline that there is an absence of effective and tested flangeway filler products for improving pedestrian safety. In this document it also noted that there has been no recent research surrounding this topic. This statement describes the

need for a product that would meet the Americans with Disabilities Act Accessibility Guidelines, by providing a crossing surface with a gap less than 0.5 inches, while not introducing risk to train operations.

The 2019 Highway Rail Grade Crossing Handbook published by the US DOT's Federal Railroad and Highway Administrations briefly mentioned flangeway filler products and passive devices for pedestrian crossings. This document acknowledges that these products exist, but does not describe these products in depth, recommend their usage or offer any substantial information. The Handbook makes note of the US DOT's 2016 report entitled *Engineering Design for Pedestrian Safety at Highway-Rail Grade Crossings.* In this report, it states there are currently no compliant Manual on Uniform Traffic Control Devices (MUTCD) flangeway filler products.

"Currently there are no design strategies that can completely eliminate the flange way gap for high speed passenger and freight rail systems. The gap could be eliminated in the future with further research to develop a system similar to what is currently available for low speed, light rail trains" (U.S. DOT & FRA, 2016).

There does not appear to be any successful or recent research published from the United States that would involve testing products or an analysis of flangeway fillers. It is worth noting that no relevant published standards involving testing accessibility or assisted devices at grade crossings were found throughout the literature review. Table 1 displays the databases and search terms that were explored.

Table 1: Exploring Relevant Standards

Database	Search Term	Results
ASTM International	Rail	587
ASTM International	Flange	245
ASTM International	Grade Crossing	103
ASTM International	Railway	102
ASTM International	Crossing	52
ASTM International	Rail Crossing	32
ASTM International	Rail Accessibility	18
ASTM International	Gap filler	11
ASTM International	Wheelchair	7
ASTM International	Rail Human Engineering	2
ASTM International	Wheelchair crossing	0
ASTM International	Flangeway	0
ASTM International	Flangeway Filler	0
ASTM International	Flangeway gap	0
ANSI	Crossing	2093
ANSI	Flange	1532
ANSI	Rail Accessibility	735
ANSI	Rail	734
ANSI	Railway	417
ANSI	Grade Crossing	238
ANSI	Wheelchair	113
ANSI	Rail Crossing	51
ANSI	Rail Human Engineering	13
ANSI	Gap filler	7
ANSI	Wheelchair crossing	0
ANSI	Flangeway	0
ANSI	Flangeway filler	0
ANSI	Flangeway gap	0

2.4 European Research Efforts

Since 2014, the European Union Commission Regulations has required a maximum of 75 mm and 50 mm, for the width and depth of a gap at a pedestrian crossing, respectively. There are documented uses of flangeway filler systems in many European countries. The

VeloSTRAIL system has been tested in both field and laboratory settings in Austria. An image of this product is shown in Figure 5. In 2005, the product was installed on the Salzburger Lokalbahn Railway. The crossing facilitated high truck traffic (roughly 6000 trucks per day) and rail speeds of up to 80 km/hr. It was determined that the product had been in contact with 1.4 million train axles in a field setting, resulting in 10mm of vertical wear (Roseman, 2008). Later in a laboratory, the deflection of both new and worn fillers were tested under a simulated wheelchair load. It was found that when 75 kg of force was applied, the new product deflected vertically 9mm, compared to 11mm for a product with 1.4 million axle cycles (Roseman, 2008). It was concluded in a report published discussing the results of this study that *"A used wearing part has approximately 80% load capacity of a new wearing part at the maximum deflection value of 20mm; however the load capacity is 47% (350N) above the required load value of 750N, therefore providing a very good factor of safety in worn conditions."* (Roseman, 2008).

Figure 5: VeloSTRAIL Flangeway Filler (STRAIL, 2024)

Research has been conducted in Europe involving train station accessibility. In this research it was found that the most challenging issue for users of wheelchairs and assisted devices was entry/exit of light rail and transit systems. It was determined that wheelchairs users have a difficult time traversing horizontal gaps greater than 100 mm (COST, 1999). In addition, The European Union published Commission Regulation No 1300 (2014) which stated that "*A level access is an access from a platform to the doorway of a rolling stock for which it can be demonstrated that:*

-The gap between the door sill of that doorway (or of the extended bridging plate of that doorway) and the platform does not exceed 75 mm measured horizontally and 50 mm measured vertically and

-The rolling stock has no internal step between the door sill and the vestibule." (European Union, 2014).

Although these publications are not directly related to pedestrian crossings, it provides some insight for gap dimensions that are potentially problematic.

No European publications were found related to decision making or location selection for use of implementing these products.

2.5 Australian and New Zealand Literature and Research Efforts

In 1999, it was estimated that the total cost of level crossing collisions in Australia was $32 million dollars (BTRE, 2002). Furthermore, collisions at level crossings account for greater than 40 precent of rail-related fatalities in Australia (Cairney, 2003). Although the cost associated with injury or death due to cyclist falls or entrapment in the flangeway

likely represent a small proportion of this number, it suggests a need for rail crossing safety improvements.

Design requirements for flangeway dimensions at pedestrian crossings are outlined in Australian Standards AS 1742.7. In addition, Railcorp, the Queensland manual of uniform traffic control devices and the John Holland engineering manual have published standards. Table 2 displays a summary of these dimensions.

Table 2: Summary of Australian and New Zealand Regulations/ Standards (Baldock et al, 2018)

Publication	Width of Gap **(mm)**	Max. Depth of Gap **(mm)**	Additional Commentary
Australian Standards AS 1742.7 (2016)	65-75	50	• Maximum of 5 mm vert. difference between track and crossing surface • Min crossing width of 1800 mm (1200mm at specific locations). • Alignment greater than or equal to 70 degrees between track and crossing surface (90 degrees ideal).
Queensland MUTCD (2014)	60 +5/-0	50 +0/- 5	N/A
Railcorp (2010)	60 +5/-0	50 +0/-5	• Min. crossing width of 3000 mm
John Holland Engineering Manual (2012)	60 +5/-0	50+0/-5	• Min. crossing width of 1200 mm

Flangeway filler and rubber compressible rail products have been in use in New Zealand for the past two decades. KiwiRail, a stated-owned New Zealand rail enterprise has utilized rubber crossing systems since 2004 (Baldock, 2018). In addition, Strail crossing products including both VeloSTRAIL and PedeSTRAIL have been implemented

in New Zealand and are expected to become quickly more popular due to developments in the active transportation network. It has been reported that Rosehill Rail products have been less effective "…it was found that for heavy or high-speed road traffic, the bolted connections (which allow panels to be removed individually and in any order) tended to work loose and tear the rubber block inserts." (Baldock, 2018). Other products used by KiwiRail includes EPFLEX rail seal and Edilon Serdra ERS (Baldock, 2018). KiwiRail has reported that products with the ability to use concrete edge systems or members have greater durability and negative impact on the contacting/neighboring asphalt (Baldock, 2018).

In 2018, the Australasian Centre for Rail Innovation (ACRI) published a research report titled LC15 Identification of Solutions to Rail Flange Gap Issues at Pedestrian Level Crossings. The report outlined the results of the first part of a two-stage project which aimed to minimize risk to pedestrians with flangeway filler products. The goal of report LC15 was to identify available flangeway filler products, identify the features necessary to test in Stage 2 from both the user and engineering perspective, and deliver a final report outlining solutions and an approach for the second stage. Stage 2 would involve testing and examination of the identified products. Report LC15 communicated that the current state of research surrounding flangeway filler products is limited. "Flange-gap fillers are a way to further reduce or eliminate the risk of trip and entrapment. Although a number of products are available, flange-gap fillers are not covered in standards relevant to pedestrian level crossings. While material testing and compliance with relevant product standards are published by some manufacturers, testing and evaluation of their effectiveness are lacking, making it difficult to determine whether flange-gap fillers are effective at reducing the risks

posed to pedestrians, and are fit for purpose for installation in Australian rail networks." (Baldock, 2018). The report developed a short list of products to be tested in Stage two (LC15B) and suggested that "*The greatest need for further research is regarding compressible fillers which eliminate the gap*." (Baldock, 2018). The list of products that were to be tested included: Sylomer Rail Groove Filler, Enclosed Flangeway Filler, Railseal with closed flangeway and VeloSTRAIL. The report also noted that there are many manufacturers which produce flange filler products that appear to be suitable for New Zealand and Australian climate conditions.

Currently, the research proposal for project LC15B (Stage 2), which includes field trials, and an economic/ life cycle cost assessment of these products is under review. For this work, it was stated that *"The programme should test and evaluate, in order of priority: 1. Implications for rail safety of adopting compressible fillers; 2. Implications for user safety of adopting compressible fillers; 3. Whole of life cost comparison of products including implications for track maintenance operations*" (Baldock, 2018).

2.6 Summary of Literature

In Canada, specific grade crossings are designated for pedestrians who require assistive devices. When this designation is assigned to a specific grade crossing, the flangeway gap is limited in size (maximum 75 mm deep and wide). Although this may have some benefit, literature suggests this alone does not prevent wheel entrapment and may not decrease the likelihood of a train pedestrian collisions. Flangeway fillers are used in Europe, as well as New Zealand and Australia. There are limited documented instances where they have been used in North America and several publications have suggested that more research is

needed to determine their feasibility under cold climate conditions. Furthermore, the true cost of this infrastructure addition to Canada's rail network is unknown, as the degradation of these products is not documented for North American climate conditions. Designated grade crossings will be most likely to receive flangeway fillers once a product is identified, however, this designation is new and arbitrary. More analysis is required to determine what locations should receive flangeway fillers and when the designation is appropriate.

Chapter 3- Methodology

This chapter outlines the thesis methodology used to accomplish the research goal and objectives. Three phases were undertaken to complete this work:

1. Create an inventory of grade crossing practices and flangeway filler use in Canada.
2. Statistical analysis of designated grade crossing attributes and characteristics.
3. Development of a flangeway filler replacement schedule at designated grade crossings and preliminary asset management plan.

3.1 Necessity of Research Ethics Board Application

Before conducting a survey, which would be used to create an inventory of the practices and process road agencies are using to designate grade crossings, it was necessary to determine if a Research Ethics Board application was required. Through communication with UNB's Ethics Department, it was determined that for this work a Research Ethics Board application was not required as public representatives would be participating in the survey by providing information on behalf of their road authority.

The survey was structured in a manner that would not allow respondents to provide personal/expert advice, but rather state the practices and policies of their organization.

3.1.2 Producing a Survey to Create an Inventory

The survey was structured into three (3) sections as detailed in Appendix A. The first section (Part A) gathered information about the organization and representative. For instance, respondents name, position, road authority type (municipal/provincial), type of

railways active within the road network, and the number of designated crossings within the jurisdiction were all recorded. This categorical information was useful for compiling the results.

Part B of the survey was created to understand the designation process. Respondents were asked what process initiates the designation being assigned. For instance, is it typically initiated through internal analysis, in response to a citizen inquiry, in response to a request from a different level of government or railway company, etc. In addition, road agencies were asked if they use a formal or informal methodology and prompted to elaborate. Lastly, respondents were asked to provide the typical time interval between a crossing being designated for pedestrians who use assistive devices and the flangeway gap being reduced. This information allowed for a better understanding of the procedure road authorities are using across Canada to designate crossings.

From a review of the literature, it appeared that road agencies in Canada do not have technical guidance for a process to designate crossings for persons who use assistive devices. Recall that the road agency is responsible for providing this information (in writing) to railways so that the flangeway gap is limited accordingly. It was previously hypothesized from the literature that many of these agencies were relying on inquiries from citizens to report a problematic crossing.

Part C of the survey focused on past and present use of flangeway filler products at grade crossings. From a review of the literature, little information was published surrounding what products have been tested or used in North America. Respondents provided information to the following questions:

- Have flangeway filler products been installed on any grade crossings under the jurisdiction of your road authority? Specifically, products that eliminate or reduce the flangeway gap to provide a smoother crossing surface for wheelchairs and cyclists.
- If answered yes to the previous question, please provide specific product names and manufacturer information:
- Has your road agency received applications to include flangeway fillers from railway companies at grade crossings?
- Has there been communication or interest expressed by railways in installing these products at grade crossings within your agency's jurisdiction?
- Are there plans at your agency to work with railways to test or procure flangeway fillers?

3.1.3 Gathering Contact Information

An appropriate representative from each province with active railways was contacted via email and requested to provide a response to the survey. Once each province had responded to the inquiry, select municipalities were invited to provide responses. Contact information was primarily gathered through online sources (municipal and provincial websites). Survey questions were administered through MS Forms.

3.1.4 Administering Survey and Compiling Results

An online method of securing responses was necessary as the goal of the survey was to collect information across Canada and compile results into an inventory of practices.

Before the survey was released, a pilot version was sent to a representative working in rail within a provincial transportation department who provided feedback on the structure. Once the survey was completed the results were summarized by jurisdiction.

3.2 Statistical Analysis of Transport Canada's Grade Crossing Data

The following describes the methodology employed for the statistical analysis component of this work. The objective of this study was to identify any characteristics or infrastructure attributes that may be associated with the assignment of the designation "for pedestrians who use assistive devices" to grade crossings.

The Transport Canada Grade Crossing Inventory was utilized to obtain data pertaining to each crossing, including details such as speed limits, train speeds, number of trains and vehicles, number of tracks, and location type (rural or urban). By retrieving this information from the inventory, it was possible to ascertain which factors were associated with the assignment of the designation.

Determining the road characteristics that contribute to this designation would be valuable for establishing a set of guidelines or a warrant system for designating crossings accordingly.

3.2.1 Sources of Information and Approach

Before conducting any sort of statistical analysis, the Transport Canada Grade Crossing Inventory needed to be organized and restructured. For instance, crossings with missing data (speed limits, number of tracks, train volumes, etc.) needed to be removed from the database. These crossings would have impacted the accuracy of any models created, as missing data would be interpreted by software packages as zeros.

For the statistical analysis portion of the work 25,155 grade crossings were used with 293 being designated for pedestrians who use assistive devices. It should be noted that 31 designated crossings could not be located within the database or were removed due to missing or incomplete/incorrect information.

3.2.2 Box Plots

As a preliminary experiment, box plots were created to visualize the grade crossings data. The goal of this initial test was to determine if any patterns could be observed between the traffic volumes and posted speeds, with respect to the crossings that are designated for pedestrians who use assistive devices, and those that are not designated. Traffic volumes and vehicle/train speed limits were gathered from the Transport Canada Grade Crossing Inventory.

First, the vehicle and train volumes were compared between designated and non-designated crossings. To start, the daily vehicle and train traffic was collected for the sample of crossings that are designated for pedestrians who use assistive devices from the inventory. In total 293 designated grade crossings from the inventory were plotted for this experiment. The daily vehicle traffic was plotted on the X-axis, with train traffic plotted on the Y-axis. After this scatter plot was created, the procedure was completed again, but with a random sample of 293 non-designated crossings. This was repeated for an additional four (4) times with non-designated crossings (creating five (5) non- designated plots in total). The average daily vehicle and train traffic was then plotted on each graph. Once traffic volumes were plotted, this procedure was then conducted again, but with vehicle speed.

It should be recognized that this initial test was used only as a visualization tool and an attempt to determine if traffic volumes or speed limits have any association with the designation and by what magnitude.

3.2.3 Contingency Tables

Before conducting any statistical analysis work with sophisticated software packages, contingency tables were created using the Transport Canada Grade Crossing Inventory. These tables demonstrated the association between different crossing attributes with respect to the designation for pedestrians who use assistive devices. Table 3 displays an example for clarification purposes.

Table 3: Example Contingency Table

	Binary Road Attribute/Characteristic X	Binary Road Attribute/Characteristic Y	
Designated for peds who use assistive devices	A= Number of Crossings in this category.	B= Number of Crossings in this category.	Total
Not Designated	C= Number of Crossings in this category.	D= Number of Crossings in this category.	Total
Total	Total	Total	
Odds Ratio	OR= Odds Ratio		

From these contingency tables relationships can be observed by calculating OR (odds ratios). The OR identifies the number of times that an event has occurred relative to the number of times it has not. For instance, what is the probability or likelihood of a crossing being designated for pedestrians who use assistive devices based on a speed limit over 50 km/hr, rural vs urban, more than 1 track at the crossing, vehicle traffic over 10,000, etc. Equation 1 displays the formula for OR.

$$OR = \frac{\frac{A}{B}}{\frac{C}{D}} = \frac{A*D}{B*C} \quad \text{(Equation 1)}$$

Where, A= Number of times observed (column 1, row 1)

B= Number of times observed (column 2, row 1)

C= Number of times observed (column 1, row 2)

D= Number of times observed (column 2, row 2)

3.2.4 SPSS Analysis

SPSS was used to generate several useful charts and statistics. Histograms, bar graphs, correlation studies and logistic regression were all explored using this tool.

3.2.5 Logistic Regression

Binary logistic regression can be used as a statistical tool for predicting the probability of a binary outcome variable based on one or more independent variables. This statistical tool is commonly deployed when the outcome variable is categorical with only two potential outcomes (yes/no, true/false, is/is not, etc.). In this study, the designation *for pedestrians who use assistive devices* was assigned to the outcome variable and the independent variables represented the road attributes (speed, traffic counts, rural vs urban, number of lanes and tracks, etc.). The goal of this was to determine the relationship between the individual independent variables (or the combination of them) and the probability of the crossing being assigned the designation. It should be noted that when conducting logistic regression, independent variables can be continuous, categorical or a combination of both.

This statistical tool uses the logistic function/sigmoid function (Equation 2) to demonstrate the relationship between each of the grade crossing attributes and the

dependent variable. Crossings that were designated for pedestrians were assigned a dependent variable of 1, with the rest assigned zero. The logistic or sigmoid function transforms the linear combination of independent variables into a value between 0 and 1 (which constitutes the probability of the outcome).

$$P(Y=1) = 1/(1+ e^{(-z)}) \quad \text{(Equation 2)}$$

Where P(Y=1) is the probability of the outcome being in category 1 (designated for pedestrians who use assistive devices).

e= the base of the natural logarithm

z= the linear combination of the independent variables and corresponding coefficients

In Equation 3, β0 represents the intercept value and β1, β2, Bn represent the coefficients corresponding to the independent variables (X1, X2, Xn). The β values are calculated based on maximum likelihood estimation which maximizes the likelihood of observing the two outcomes (designated or not designated for pedestrians who use assistive devices). Once these coefficients are determined they are used to predict the probability of the outcome variable based on the independent variables. When the predicted probability is above a specific threshold (typically 0.5), the outcome is assigned a value of 1 (which means the grade crossing would be predicted to be designated for pedestrians who use assistive devices based on speed, train traffic, number of lanes, etc.).

$$z= \beta0 + \beta1X1 + \beta2X2+ \ldots+ \betanXn \quad \text{(Equation 3)}$$

3.3 Producing a Flangeway Filler Replacement Schedule and Cost Estimate

Estimating the approximate cost of adding flangeway fillers at designated crossings included gathering sources of information, determining the rate these products deteriorate

with use, and creating a model with reasonable assumptions, and addressing uncertainty. It should be noted that the figures presented in Chapter 4 are only meant to act as an approximate estimate and some variation may exist.

3.3.1 Sources of Degradation and Cost Information

First, it was necessary to gather information surrounding how these products would degrade with time/use and the corresponding cost of these products. Several manufacturers were contacted, and some shared their confidential test reports under the condition that they be used for order of magnitude estimates for an approximate service life of their products based on axle cycles. It should be noted that the material cost of these products was already known as several products were previously purchased by UNB for the testing that occurred at the National Research Council of Canada. Manufacturer invoices were used to approximate the cost of the full crossing systems and the cost associated with the replacement of the rubber inserts which contact the flanged train wheel and require periodic replacement.

The Transport Canada Grade Crossing Inventory provided information related to each crossing's daily train traffic, and the number of tracks and travel lanes located at each crossing. The number of vehicle travel lanes and tracks were required to estimate the amount of material required at each crossing as the products are purchased according to crossing size (length of roadway, number of tracks, etc.).

3.3.2 Replacement/Cost Estimation Model Assumptions

Manufacturers were contacted and asked to provide deterioration information related to their products. One manufacturer provided a confidential test report and stated it the results

of the report could be used for this research but has asked to remain anonymous. From this report it was determined that approximately 3 million axle crossings would generate 14 mm of vertical deterioration. It should be recognized that this value was determined with light rail operating at a maximum speed of 80 kilometers per hour. In addition, the testing outlined in this report was conducted in a climate which is not subject to the same environmental/weather conditions. Manufacturer information suggested that once the product had deteriorated 20 mm vertically, it must be replaced to provide a smooth crossing. To be conservative and partially due to lack of information/testing in Canada, 3 million axle cycles was used as the trigger point for replacing the flangeway filler rubber inserts.

Recall that the Transport Canada Grade Crossing Inventory did not include information related to the number or type of railcars or axle cycles a crossing would experience daily but rather daily train traffic. It should be recognized that the number and type of railcars positioned within a train would likely vary daily. However, Transport Canada restricts trains to a maximum of 10,000 feet in length. To be conservative, it was estimated in the model that all trains would be 10,000 feet in length, which corresponds to 667 axle cycles per train. With the number of axle cycles per train estimated, the cut-off point for replacing the rubber inserts (3 million cycles), and the daily train traffic provided in the Transport Canada database, it was possible to generate a replacement plan.

The time period that was selected to examine the total cost was a 30-year period. It should be noted that the cost estimate only focused on the cost of materials, as generally, railway companies establish agreements with road agencies to install products themselves. Recall that the goal of this model was to approximate costs which could potentially be

covered through a federal funding program, such as the Rail Safety Improvement Program (RSIP).

3.3.3 Sensitivity Analysis and Discount Rates

The Transport Canada Grade Crossing Inventory did not display which crossings were designated for pedestrians who use assistive devices. However, a separate confidential database provided from Transport Canada was used to match the designation to the crossings in the inventory. It should be noted that Transport Canada approved the use of this information for the purpose of this research. Due to errors in the Grade Crossing Inventory (incorrect latitude/longitude, street names, etc.), 31 out of 324 crossings were excluded from the replacement plan and cost estimation models initially. To account for the missing crossings, average train traffic values, a single track and two lanes were assumed for the remainder of the crossings and applied to the cost estimation.

Discount rates were used for sensitivity analysis. The purpose of this technique was to provide pessimistic and optimistic estimations of the potential total cost in terms of Present Value (today's dollars). Typically, net present value would be used to assess an infrastructure addition, however, the benefits have not yet been quantified. The Treasury Board of Canada Secretariat has required the use of a social discount rate of 10% since 1976 when conducting Benefit-Cost Analysis. However, recent guidelines from the Board (2007) suggest the use of a discount rate of 8%, with sensitivity rates of 3% and 10%. These rates were applied to the cumulative cost each year. It should be noted that a complete Benefit-Cost Analysis was not conducted.

Chapter 4- Analysis of Results

4.1 Survey Results

Public officials within provincial and municipal road authorities with active railways were contacted via email to participate in a survey to assemble an inventory of practices and procedures. The goal was to determine the current practices and rationale road agencies were using to designate crossings for persons with a disability and determine the past/present use of flangeway fillers in their jurisdiction. Emails were sent with a link to participate in a MS Forms survey directed to municipal and provincial engineering/rail safety related email addresses. In some cases, MS Teams meetings were held to inform respondents on the purpose of the research and answer questions before respondents submitted answers to the survey questions. In total there were 12 responses collected from 30 invitations.

In total, there were 17 questions separated into three (3) sections. Part A asked for the official title of the respondent, their organization and to identify the railways active within their jurisdiction. Part B was designed to understand the methodology or reasoning road agencies were using to designate crossings for persons with a disability. Part C gathered information on any past or present flangeway filler use. The public officials were advised that their participation would be acknowledged in published work. Appendix B displays the instructions provided to road authorities.

The results are summarized below by jurisdiction. It should be noted that the information presented was collected in the summer of 2023. While reviewing the results, recall that in the Grade Crossing Regulations it states, "*road agencies are responsible for*

assigning this designation to crossings and notifying the railways" (with regards to designating a crossing for a person who use assistive devices) (Grade Crossing Regulations, 2014). However, each road authority may have different agreements with railways with regards to the delegation of roles and responsibilities.

4.1.1 Responses from Municipal Road Agencies

The following summarizes survey responses received from municipalities. Generally, the municipality assigned and selected the appropriate person to provide a response after initial contact with rail or transport related city email addresses.

Moncton, New Brunswick

The City of Moncton is in southeastern New Brunswick with a population of approximately 80,000 (Census of Population, Statistics Canada, 2021). A Class 1 railway is active within the City of Moncton. The rail network is displayed in Figure 6.

Figure 6: Moncton Rail Network (Google Maps, 2023)

In 2018, nine (9) grade crossings were designated for pedestrians who use assistive devices. There are currently no plans to continue to designate additional crossings. Designations were based on downtown area which would have higher pedestrian traffic. One location was also prioritized due to a fatal collision. Moncton does not use a methodology for assigning this designation to a crossing. In Moncton, the typical time interval between a crossing receiving this designation and the crossing surface being modified (flangeway gap reduced) is greater than 12 months. Moncton has used flangeway filler products in the past, but the exact product information is not known. The products that were used in Moncton were described as “concrete panels with rubber flangeways”. It is unknown by the current staff at the city if Moncton has received applications to include flangeway fillers from railway companies at grade crossings. In addition, there has not been communication or interest expressed by railways to Moncton in installing these products and there are currently no plans to test or procure these products. (R. Rifaat, Personal Correspondence, July 18, 2023).

Bathurst, New Brunswick

Bathurst is a city in the northern part of New Brunswick, with a population of approximately 12,000 (Census of Population, Statistics Canada, 2021). Figure 7 displays an image of the railway network in Bathurst.

Figure 7: Bathurst Rail Network (Google Maps, 2023)

Class 1 railways are active within the municipality (CN Rail). The Director of Engineering from the City of Bathurst, New Brunswick, was contacted via email with a request to participate in the survey and provided a written response by email. They indicated that rail crossings in Bathurst are managed and maintained by CN Rail, and they plan any work in the railway right-of-way with CN. The road authority has not assumed a role to assign this designation and notify the railway. (A. MacLaggan, Personal Correspondence, June 26, 2023).

Miramichi, New Brunswick

Miramichi has a population of roughly 17,000 people (Census of Population, Statistics Canada, 2021). The municipality is in the northeastern part of New Brunswick. A Class 1 railway is active within the municipality. Figure 8 displays the rail network.

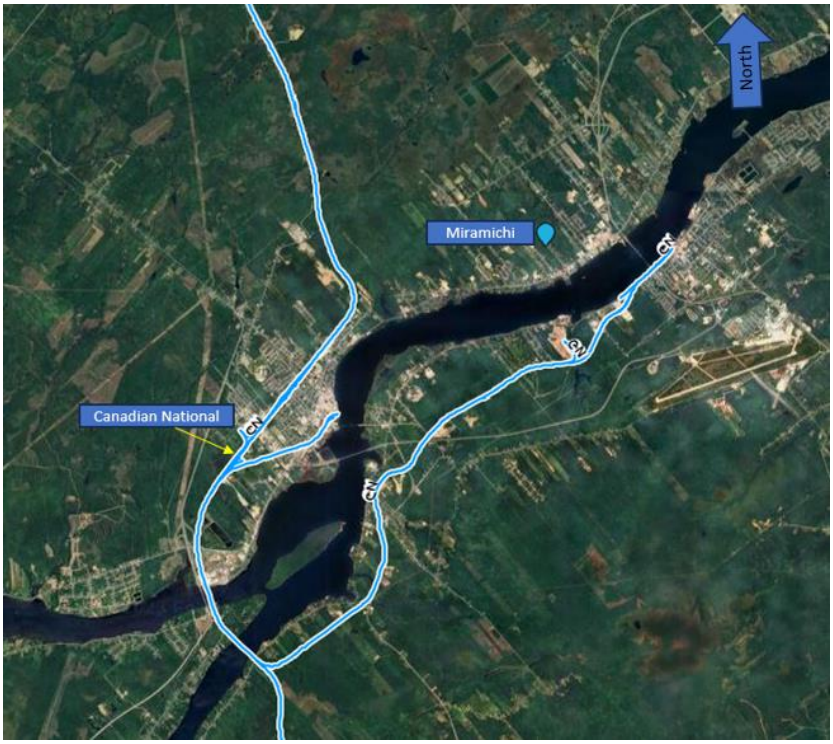

Figure 8: Miramichi Rail Network (Google Map, 2023)

In Miramichi, there are no crossings currently designated for pedestrians who use assistive devices and there are no future plans to designate crossings. The city does not have a methodology for assigning this designation to a crossing. Flangeway filler products have not been used at crossings located within the jurisdiction of this road agency. In addition, Miramichi has not received applications to include flangeway filler products at grade crossings and railways have not expressed or communicated interest in these products. There are no plans for the City of Miramichi to test or procure flangeway fillers (D. Row, Personal Correspondence, June 30, 2023).

Edmundston, New Brunswick

Edmundston is a city of roughly 16,500 people in the northwestern part of New Brunswick (Census of Population, Statistics Canada, 2021). The railway network is displayed in Figure 9.

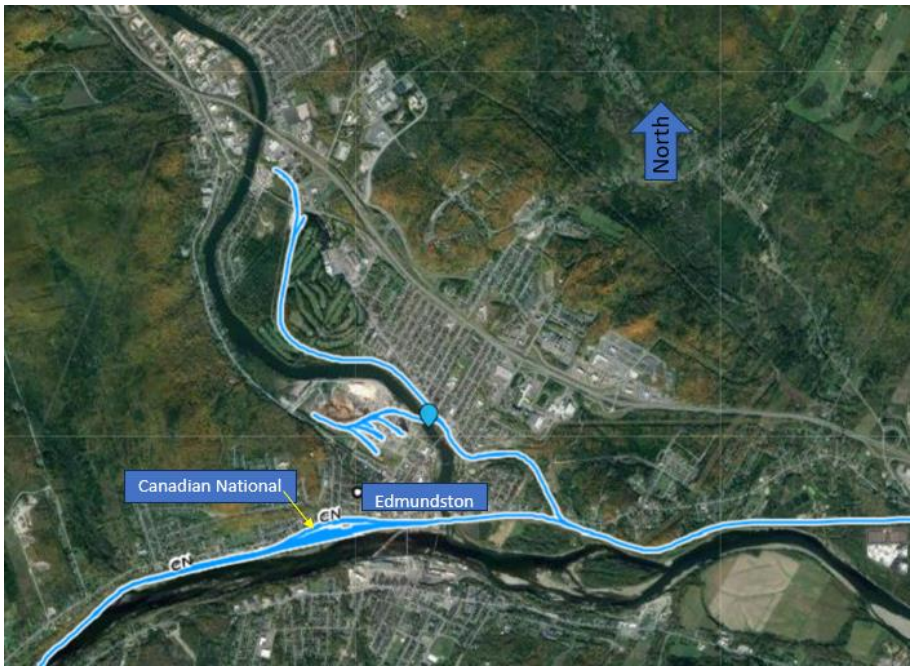

Figure 9: Edmundston Rail Network (Google Maps, 2023)

Class 1 rail services are active within this municipality. There are currently no designated rail crossings for pedestrians with a disability and no formal plans to introduce designated crossings. If a crossing were to be designated, the process to designate crossings would be initiated through internal analysis or in response to a citizen inquiry. There is currently no formal or informal methodology for determining which grade crossings should receive this designation. No flangeway filler products are known to be used, though it may be possible if a railway is doing its own modifications (G. Cyr, Personal Correspondence, July 13, 2023).

Toronto, Ontario

The city of Toronto is Canada's largest city, located in the province of Ontario. Toronto has a population of more than 3 million people (Census of Population, Statistics Canada, 2021). Toronto's rail network is comprised of Canadian National, Canadian Pacific, and Go Transit railways. The network is shown in Figure 10.

Figure 10: Toronto's Network (Google Maps, 2023)

A Senior Project Manager from the City of Toronto's Transportation Services team provided the following information:

- The city of Toronto is currently seeking clarification from Transport Canada regarding the designation of a sidewalk, path or trail for persons using assistive devices and are awaiting their response.

- Flangeway fillers are not used much in Toronto.

Winnipeg, Manitoba

Winnipeg is the capital city of Manitoba with a population of approximately 750,000 residents (Census of Population, Statistics Canada, 2021). Class 1 railways are active within this location (Canadian Pacific, Canadian National) and there is a Class 2 railway operating as well (Cando Rail). It should be noted that the Greater Winnipeg Water District Railway is also operating but is used and maintained by the city for industrial purposes. Figure 11 displays Winnipeg's network.

Figure 11: Winnipeg Rail Network (Google Maps, 2023)

A total of 20 out of 159 crossings in Winnipeg are designated for persons using assistive devices, with plans for additional designations, though in the past two years, no requests were received to initiate new designations. The timeframe for modifying a

crossing surface after receiving this designation is uncertain. Winnipeg lacks a formal or informal methodology for assigning such designations. The city has not installed flangeway fillers for smoother crossing surfaces at grade crossings, and there have been no applications or expressed interest from railways to include these products. Currently, there are no plans in Winnipeg to test or procure these products (G. Blatz, Personal Correspondence, August 11, 2023).

Vancouver, British Columbia

Vancouver is located on the west coast of Canada in the province of British Columbia. The city has a population of approximately 50,000 people and Class 1 railways are active (Census of Population, Statistics Canada, 2021). The city's rail network is shown in Figure 12. The network is comprised of Canadian National, Canadian Pacific and the Vancouver SkyTrain (commuter rail).

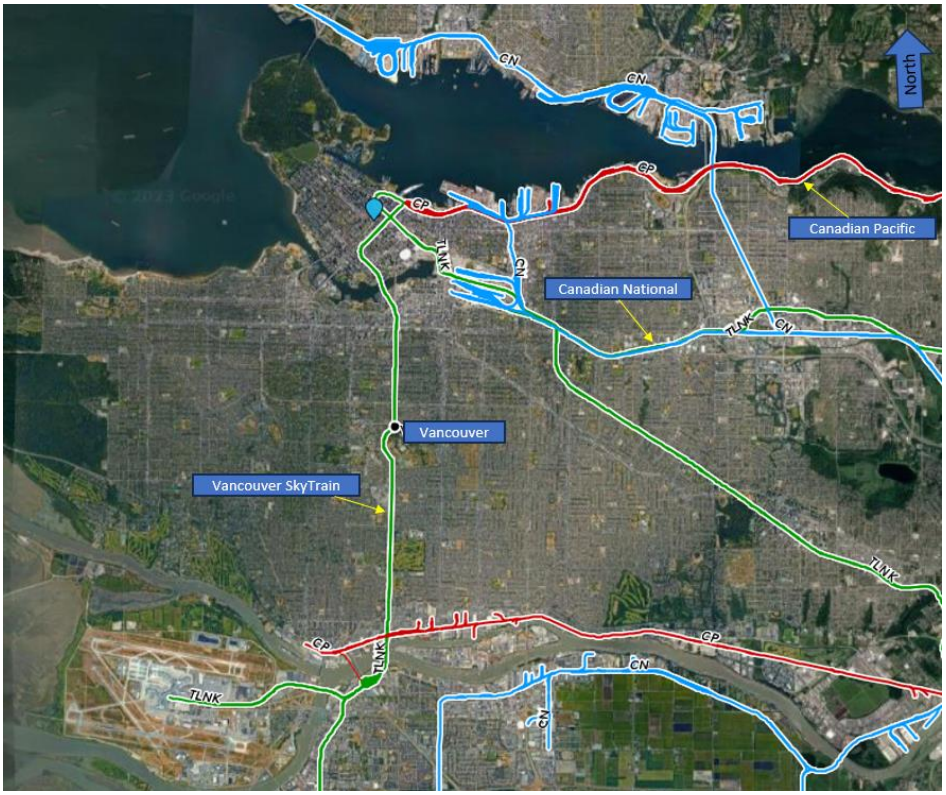

Figure 12: City of Vancouver Rail Network (Google Maps, 2023)

In Vancouver, no crossings have been designated for pedestrians who use assistive devices, however, there are future plans to designate crossings, including a project intended for users requiring assistive devices. This project has not been built yet but will be designed to meet City standards for users requiring assistive devices and the initiation of the designation would begin then (S. Leung, September 11, 2023). Vancouver does not use a methodology for assigning this designation. In the past, Vancouver has had products installed at grade crossings that were intended to provide a smoother crossing surface for wheelchairs and cyclists, however the specific product information is unknown as the railway companies generally would be responsible for installation. Vancouver has received applications to include flangeway fillers from railway companies at crossings and there has

been interest expressed by railways in installing these products. There are no future plans for Vancouver to work with railways to test or procure flangeway fillers (S. Leung, Personal Correspondence, September 11, 2023).

4.1.2 Summary of Results from Municipal Road Agencies

No municipality that provided a response to the survey stated that they use a methodology (informal or formal) or a set of guidelines for deciding when to designate grade crossings for pedestrians who use assistive devices. The largest city in Canada has requested guidance and clarification from Transport Canada for when this designation is appropriate.

In addition, smaller municipalities with less resources/technical staff appear to be unaware of the designation or its significance (as several have zero crossings currently designated for pedestrians who use assistive devices). There may be some ambiguity in terms of the perceived role of the road authority for initiating a grade crossing for a person who uses assistive devices. The current set of crossings that have been designated have been selected based on a response to a citizen inquiry, some sort of internal analysis, selected based on location or due to a fatality. The ambiguity of responsibilities and lack of technical guidance provided to municipalities have created an environment in which several cities do not have any of the grade crossings in their network designated for those with a disability. Recall that when this designation is assigned, the grade crossing surface is modified to provide a smoother crossing surface (flangeway gap is limited in depth and width).

Flangeway filler products do not have widespread adoption as a solution for removing or eliminating the flangeway gap among the municipalities that provided a

response. Many municipalities have not used these products or have any plans to test or procure them for their crossings. This could be due to a lack of awareness on how the flangeway gap limits mobility for wheelchair users, cities being unaware that these products exist, or a lack of research/publications demonstrating a safe and effective product being used in Canada. In addition, the few responding municipalities that have used these products are unaware of the exact products installed- as the railways have managed installation and maintenance. Table 4 is a summary of the information gathered from the municipalities that participated in the research.

Table 4: Current Municipal Procedures for Designating a Grade Crossing

Municipality	Number of Designated Crossings	Formal plans to designate a crossing?	Process to initiate	Installed flangeway fillers?
Bathurst, NB	Zero (0)	No	N/A	No
Edmundston, NB	Zero (0)	No	N/A	No
Miramichi, NB	Zero (0)	No	N/A	No
Moncton, NB	Nine (9)	No	Based on pedestrian traffic downtown & fatality that occurred.	Yes- exact product unknown.
Toronto, ON	Zero (0)	Unsure	Currently requesting guidance from Transport Canada	Unknown
Vancouver, BC	Zero (0)- 1 potentially pending	Yes	Based on project scope and addressing accessibility needs.	Yes- exact product unknown.
Winnipeg, MB	Twenty (20)	Yes	Unknown	No

4.1.3 Responses from Provincial Road Agencies

The following section summarizes the results received from provincial road authorities. Respondents were selected by their road authority to provide a response after initial contact with provincial rail or transport engineering office email addresses.

Nova Scotia

Nova Scotia is an east coast province with approximately 970,000 residents (Census of Population, Statistics Canada, 2021). Class 1 and Class 3 railways are active within this province (Canadian National, Cape Breton & Central Nova Scotia Railway, and Sydney Coal Railway). Figure 13 displays the rail network.

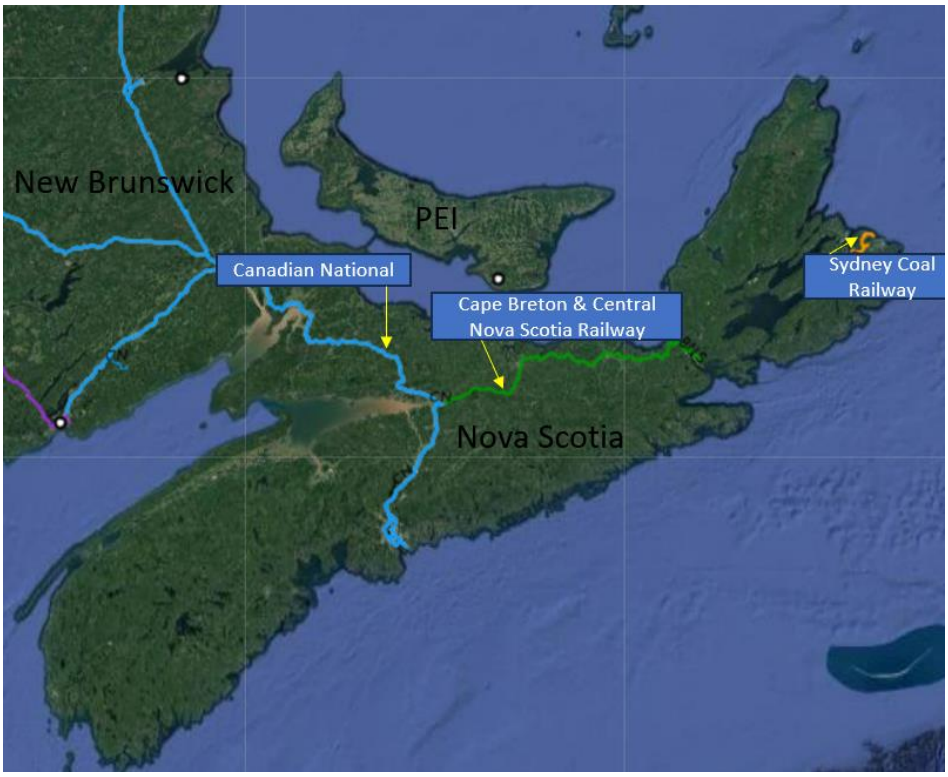

Figure 13: Nova Scotia Rail Network (Google Maps, 2023)

In Nova Scotia, zero (0) grade crossings have been designated by the province for persons who use assistive devices. The representative of the province stated that Class 1 railways are regulated under federal jurisdiction (Transport Canada) and that it would fall under their jurisdiction. Nova Scotia does not use a methodology for designating a grade crossing for a person who uses assistive devices and no flangeway fillers products that intend to reduce or eliminate the flangeway gap have been installed on grade crossings under their jurisdiction. There has not been interest expressed in these products from railway companies, and NS Department of Public Works has not received applications to include flangeway fillers. There are no future plans to procure or test these products at grade crossings under the jurisdiction of Novia Scotia (W. Crocker, Personal Correspondence, July 18, 2023).

New Brunswick

New Brunswick is located on the east coast of Canada with a population of approximately 775,000 (Census of Population, Statistics Canada, 2021). Class 1 and Class 3 railways are active within this province (Canadian National and New Brunswick Southern). The New Brunswick rail network is displayed in Figure 14.

Figure 14: New Brunswick Rail Network (Google Maps, 2023)

Two (2) crossings have been designated for pedestrians who use assistive devices under New Brunswick Department of Transportation and Infrastructure's (NBDTI) jurisdiction. There are no plans to designate additional crossings. The decision to designate crossings has been prompted by citizen inquiries or railway requests. New Brunswick does not use an informal or formal methodology for assigning this designation. The typical time interval between a crossing receiving this designation and the grade crossing surface being modified (flangeway gap reduced) is greater than 12 months. In New Brunswick, flangeway filler products have not been used to provide a smoother crossing surface for wheelchairs and cyclists. NBDTI has not received applications to install these products at

grade crossings, however, there are plans for the agency to work with railways to test and procure these products (R. Francis, Personal Correspondence, June 2, 2023).

Ontario

Ontario has the highest population of any Canadian province with approximately 11 million residents (Census of Population, Statistics Canada, 2021). Class 1 and Class 3 railways are active under Ontario's jurisdiction. The railways active within the province are Canadian National, Canadian Pacific, Ontario Northern Railway, Huron Central Railway, Agawa Canyon Railroad, and Nipissing Central Railway). An image of the rail network is displayed in Figure 15.

Figure 15: Ontario Rail Network (Google Maps, 2023)

The Ontario Ministry of Transportation (MTO) has designated zero (0) grade crossings for persons who use assistive devices and there are no plans to designate additional crossings. MTO's highways are predominantly in a rural setting and do not have sidewalks where they cross railway lines. Additionally, pedestrians and people using assistive devices have not typically been a design consideration. Flangeway fillers have not been installed on grade crossings under Ontario's jurisdiction and there has not been interest or communication from railways to use these products. Ontario has not received applications to include flangeway fillers at crossings from railway companies. There are no future plans to work with railways to test or procure flangeway filler products (Kenneth Shannon, Personal Correspondence, July 14, 2023).

Saskatchewan

Saskatchewan is a western province with approximately 1.1 million residents (Census of Population, Statistics Canada, 2021). Class 1 and Class 3 railways are active within the province. In total, thirteen (13) shortlines are active within the province with a cumulative 2131 kilometres of rail (Province of Saskatchewan, 2018). An image of Saskatchewan's rail network is available in Figure 16.

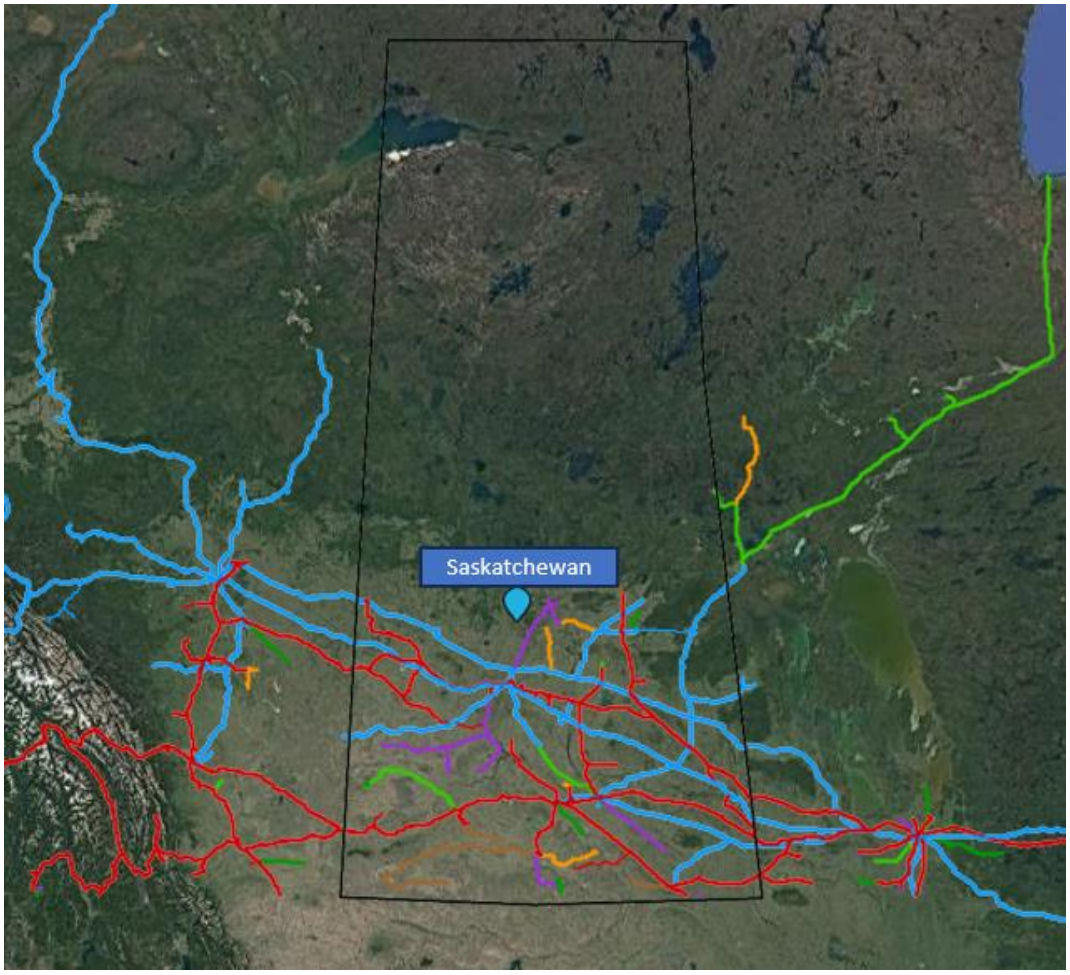

Figure 16: Saskatchewan Rail Network (Google Maps, 2023).

The Saskatchewan Ministry of Highways has designated zero (0) crossings for pedestrians who use assistive devices. In addition, Saskatchewan does not use any informal or formal methodology for assigning this designation and no flangeway filler products have ever been installed which eliminated or reduced the flangeway gap. There has not been communication or interest expressed by railways to install these products at grade crossings under Saskatchewan's jurisdiction and there are no future plans to test or procure flangeway fillers (C. Bezo, Personal Correspondence, July 4, 2023).

British Columbia

British Columbia is a western province in Canada with a population of approximately 5 million residents (Census of Population, Statistics Canada, 2021). Class 1 and Class 3 railways are active across the province (Canadian National and Canadian Pacific). An image of the BC rail network is available in Figure 17.

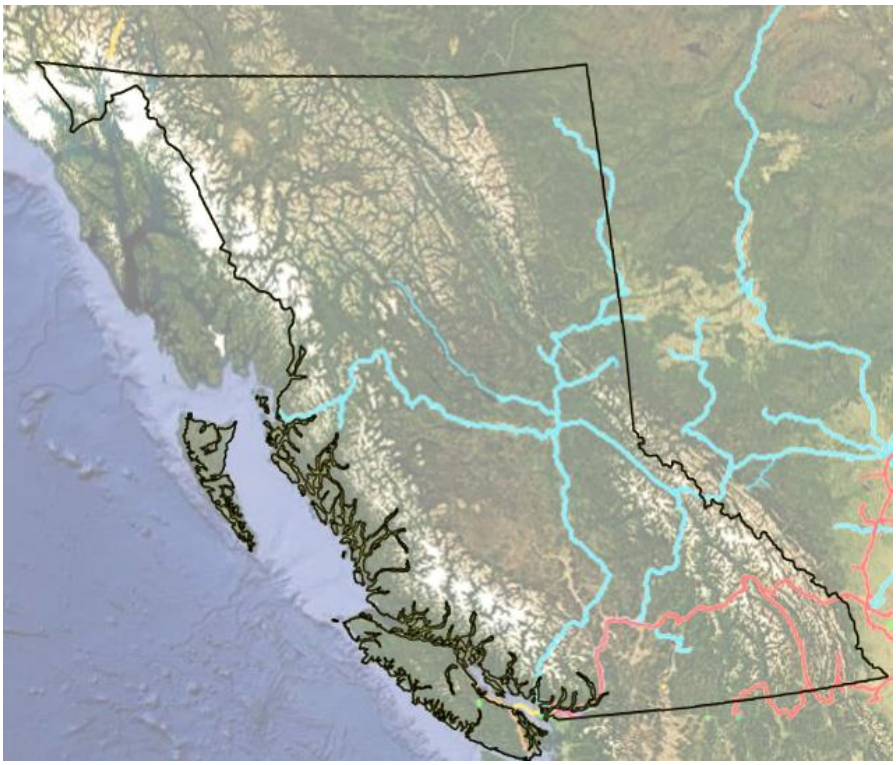

Figure 17: BC Rail Network (Google Maps, 2023).

The BC Ministry of Transportation has designated zero (0) crossings for persons who use assistive devices. The consideration of pedestrian traffic during the development of project scope for a highway improvement project involving rail could be a potential factor for assigning the designation to a crossing in the future. In urban settings, the province works with a municipality to ensure local pedestrian needs are addressed. The BC Ministry

of Transportation has had flangeway fillers installed on grade crossings in the past, but the product information is unknown. Any products that are installed have been provided and maintained on the grade crossing(s) by railway companies. BC Ministry of Transportation has received applications to include flangeway fillers at grade crossings and there has been interest communicated by railways to use these products. As of now, there are no immediate future plans to test or procure flangeway fillers that reduce or eliminate the flangeway gap (M. Henley, Personal Correspondence, June 28, 2023).

4.1.4 Summary of Results from Provincial Road Agencies

Provincial road authorities do not frequently designate grade crossings for persons who use assistive devices for a variety of reasons.

It was found that New Brunswick DTI was the only provincial road authority that participated in the survey that stated they had designated a crossing and reduced the flangeway gap in those locations. In New Brunswick, the decision to designate grade crossings has been based on a response from a citizen inquiry or railway request.

There is uncertainty surrounding the responsibilities of road authorities to make decisions at grade crossings. For instance, Nova Scotia believes it is the responsibility of Transport Canada to regulate and assign the designation to crossings.

In addition, crossings that would be typically selected to be designed for pedestrians who use assistive devices are typically located in urban areas with higher pedestrian traffic. These grade crossings typically fall under the authority of municipalities rather than provinces. For instance, crossings have not been designated on British Columbia highways as they consider pedestrian traffic during the development of project scope for highway

improvement projects involving rail. The amount of pedestrian traffic on provincial highways in BC is minimal. The lack of pedestrian traffic and rural locations of crossings is a factor in British Columbia for crossings to not to receive the designation by the provincial road authority.

Similarly, the Ontario MOT has not designated a crossing for pedestrians who use assistive devices for two reasons. First, Ontario's highways are predominantly in a rural setting and do not have sidewalks where they cross railway lines. Secondly, pedestrians and people using assistive devices have not typically been a design consideration.

It can be concluded that flangeway fillers that are intended to provide a smoother crossing surface for those who use assistive devices are not common. Every provincial road authority that participated in providing a response stated that they have not used these products before except British Columbia. British Columbia was unaware of how frequently they were used or the exact product information as the railways have been responsible for installation and maintenance. Table 5 is a summary of the information gathered from the provinces that participated in the research.

Table 5: Current Provincial Procedures for Designating a Grade Crossing

Province	Number of Designated Crossings	Formal plans to designate a crossing?	Process to initiate	Installed flangeway fillers?
Nova Scotia	Zero (0)	No	N/A	No
New Brunswick	Two (2)	No	Based on citizen inquiry or request from railway	No
Ontario	Zero (0)	No	N/A	No
Saskatchewan	Zero (0)	No	N/A	No
British Columbia	Zero (0)	No	N/A	Yes- exact product unknown.

4.2 Statistical Analysis of Designated Grade Crossing Attributes

The survey results indicate that the responding road authorities were not using a detailed methodology for deciding when a grade crossing should be designated for pedestrians who use assistive devices. A statistical analysis was conducted to determine if it was possible to see whether measured road characteristics correlated to the designation being assigned to a crossing, in absence of any formal criteria. If it could be determined which road attributes were significant, some guidelines could be created which can be used to determine what crossings could be eligible to be designated for pedestrians who use assistive devices. This is significant as once an acceptable flangeway filler product is identified it will be eligible for installation at crossings designated for pedestrians who use assistive devices.

4.2.1 Experiment 1- Box Plots

Before using SPSS or more advanced methods of analysis, some preliminary boxplots were created in Microsoft Excel. These were used to develop some preliminary observations related to the relationship between vehicle and train traffic at grade crossings and the designation. Figure 18 Vehicle Traffic at Grade Crossings displays the first set of boxplots created.

Recall that there were 293 grade crossings that could be identified in the Transport Canada database as designated for pedestrians who use assistive devices. Five (5) random sets of 293 non-designated crossings were plotted alongside the designated crossings. In this preliminary test it was observed that the designated grade crossings appeared to have higher vehicle traffic. Higher traffic volumes could be expected to be correlated with more pedestrian traffic, especially if in urban areas.

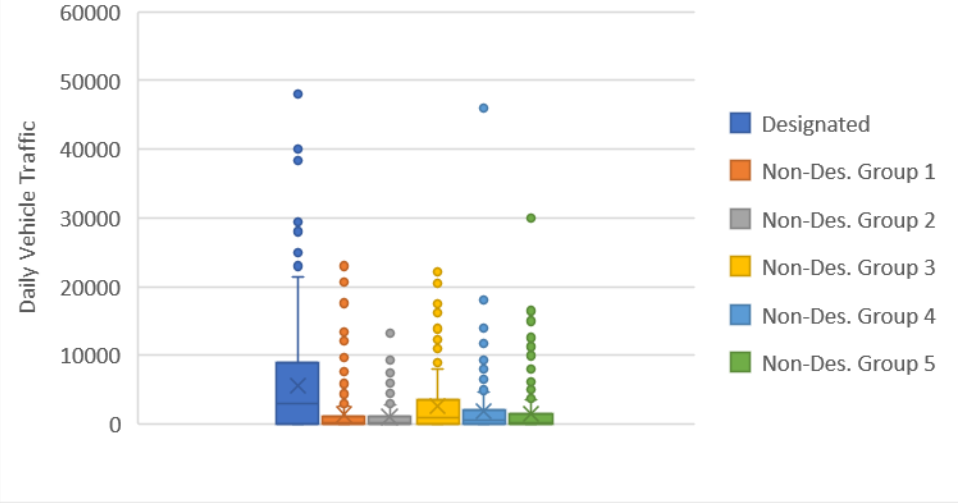

Figure 18: Vehicle Traffic at Grade Crossings

Figure 19: Train Traffic at Grade Crossings was created in a similar manner but with daily train traffic. Little observations can be made from Figure 19, however, the

relationship between train traffic and designation was examined further in Section 4.2.4 Experiment 3- SPSS Analysis. Further analysis was conducted as it was hypothesized that crossings that are more frequently used by trains have a higher risk of experiencing a conflict with a pedestrian.

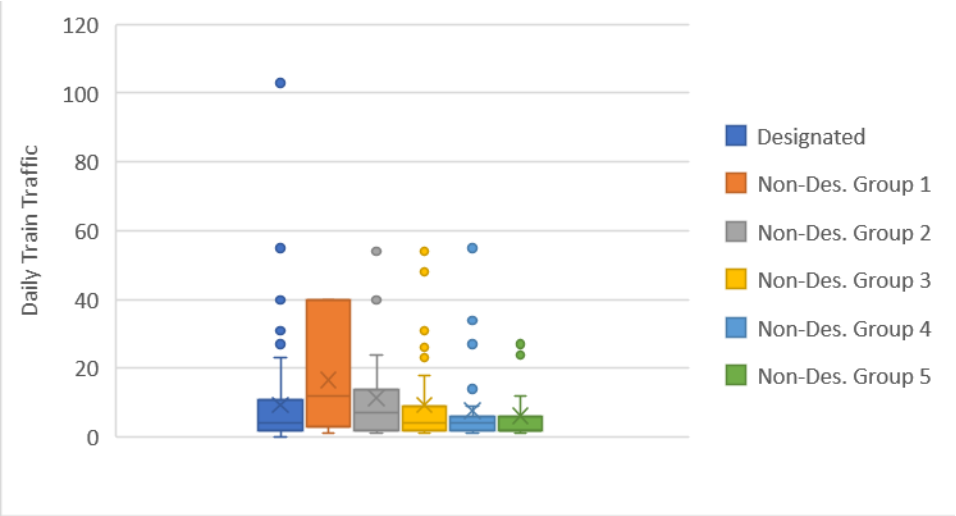

Figure 19: Train Traffic at Grade Crossings

Figure 20: Speed Limits at Grade Crossings displays a preliminary experiment with road speed limits. It can be observed that the group of designated grade crossings have lower posted speed limits than all five (5) groups of non-designated grade crossings. Grade crossings located around areas with high pedestrian traffic are likely located within city centers. These locations would generally have a lower posted speed limit (opposed to collectors, arterials, freeways). Many municipalities regulate a posted speed limit of 50 kilometres per hour or lower on municipal roads. From Figure 20, it can be observed that most of the designated grade crossings are in these areas.

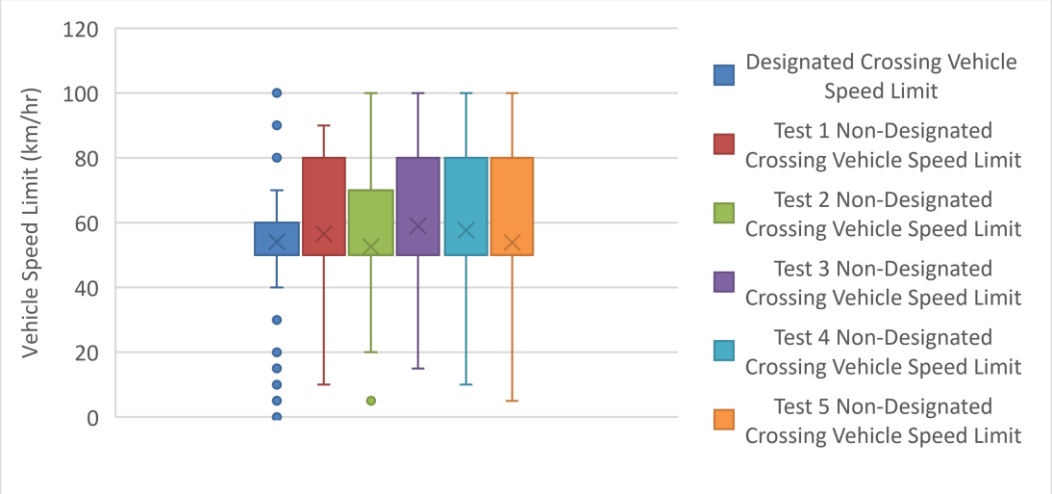

Figure 20: Speed Limits at Grade Crossings

A similar plot is located below in Figure 21. This figure shows the maximum train speed for the group of designated crossings and five (5) test groups. The maximum train speed is the maximum velocity a train can travel on a given section of track. This is a function of rail operations and track maintenance. It should be noted that regardless of the posted maximum track speed, some carriers may be restricted to travel slower based on the products they are carrying (dangerous goods, crude, etc.). Generally, the older and less maintained a section of track is the lower the speed trains can travel. When a section of track is not frequently maintained at a grade crossing several operational and accessibility related concerns can arise. For instance, the gauge of the track or the vertical tolerance between the asphalt surface and the rail may increase. Either of these situations may make it more difficult for a person in a wheelchair to cross a grade crossing. From the boxplots, it appears that the speeds at grade crossings designated for pedestrians who use assistive devices tend to trend lower than the other samples of crossings. More analysis related to this relationship is conducted in Section 4.2.4.

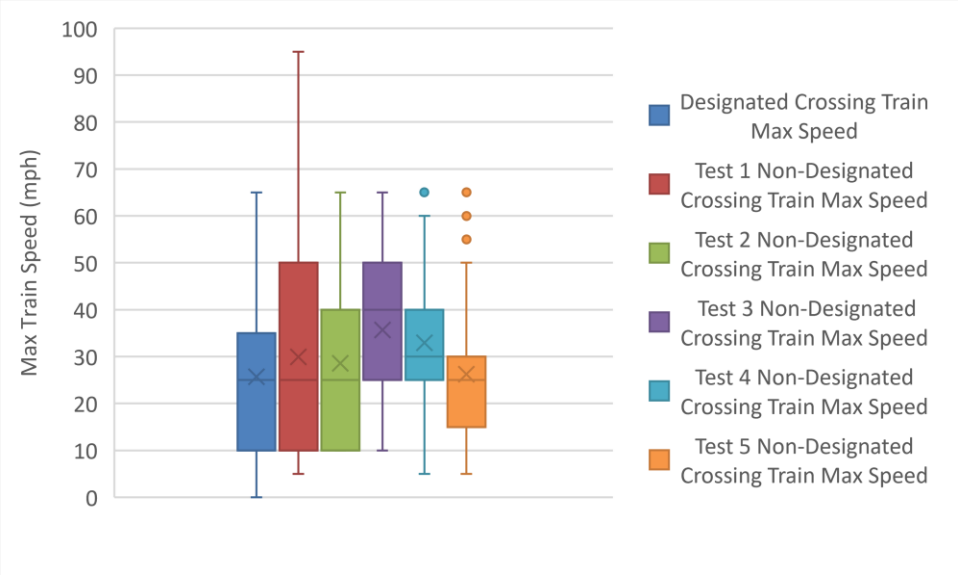

Figure 21: Max Train Speed at Grade Crossings

4.2.3 Experiment 2- Contingency Tables

Several contingency tables were created using the methodology outlined in Chapter 3. Table 6-12 demonstrate the association between location (urban/rural), speed limits, number of tracks, number of vehicle travel lanes, train and vehicle traffic, and the designation being assigned to grade crossings, respectively. It should be recognized that the Odds Ratio (OR) displays the association between each of these variables and the outcome.

Table 6 demonstrates the association between urban and rural grade crossings and the designation for pedestrians who use assistive devices. In this case the OR was calculated to be 13.4. This indicates that crossings in urban locations are 13.4 times more likely to have received the designation than those located in rural areas. Recall that from the survey conducted, many provincial road authorities overlook assigning this designation to a grade crossing due to low amounts of pedestrian traffic in rural areas.

Table 6: Urban Vs Rural Grade Crossings

	Urban	Rural	Total
Designated for pedestrians who use assistive devices	190	103	293
Non-Designated Crossing	3001	21861	24862
Total	3191	21964	25155
Odds Ratio			13.4

The association between the posted speed limit and the designation being assigned was also examined in this study. This is displayed in Table 7. According to the Geometric Design Guide for Canadian roads, roadways are classified as either Local, Collector, Arterial or Freeway. Local roads are generally restricted to a speed limit of 50 kilometres per hour. From Table 7, it can be observed that crossings that have a speed limit of 50 kilometres per hour or lower are 1.3 times more likely to have received the designation than those above this speed. This suggests that many of the crossings that have received this designation are in areas with lower posted speed limits (such as urban areas and city streets).

Table 7: Speed Limits and Grade Crossing Designation

	Speed limit 50 km/hr. or under	Speed limit over 50 km/hr.	Total
Designated for pedestrians who use assistive devices	204	89	293
Non-Designated Crossing	15867	8995	24862
Total	16071	9084	25155
Odds Ratio			1.3

Recall that Section 3.8 of the NBC suggests that even when a grade crossing receives the designation, and the gap is limited in size, the crossing still prevents a person from having a barrier-free path of travel. Although this building code is not intended to

govern grade crossings it provides insight into the barrier that grade crossings present. The greater the number of tracks at a location, the more obstacles in the path of travel for a person using an assistive device. In addition, the crossing distance essentially becomes one standard gauge larger (1435mm) per additional track. This increases the time it takes for a person in a wheelchair to traverse a crossing. From Table 8, it can be determined that crossings with two or more tracks are 2.7 times more likely to have received the designation than single track grade crossings. Crossings that have multiple tracks in urban areas with high pedestrian traffic should be prioritized for receiving the designation based on the reasons stated above.

Table 8: Number of Tracks and Grade Crossing Designation

	Two or more tracks	One Set of tracks	Total
Designated for pedestrians who use assistive devices	75	218	293
Non-Designated Crossing	2777	22085	24862
Total	2852	22303	25155
Odds Ratio			2.7

The number of travel lanes at a grade crossing refers to the number of vehicle lanes that are non-parallel to the train tracks at a grade crossing. The relationship was examined to determine if there is a correlation between larger road facilities and the designation being assigned (which is displayed in Table 9). The OR was calculated to be 12.8, indicating that crossings with more than two traffic lanes are 12.8 times more likely to have been designated for pedestrians who use assistive devices. This could be for a variety of reasons. One potential reason for these larger facilities receiving the designation more often could be that larger road facilities are located in larger urban areas with greater technical staff and resources. For instance, Vancouver, BC is more likely to have staff solely managing

their rail and traffic operations compared to a smaller city like Miramichi, NB. This would allow for the designation to be considered more frequently.

Another reason could be that there is likely a correlation between vehicle traffic (and therefore the number of lanes at a crossing) and pedestrian traffic (with the exception of provincial freeways). For instance, busy city streets with higher vehicle traffic are more likely to have several traffic lanes and more pedestrians.

Table 9: Number of Travel Lanes and Grade Crossing Designation

	More than two traffic lanes	Two or less traffic lanes	Total
Designated for pedestrians who use assistive devices	77	216	293
Non-Designated Crossing	672	24190	24862
Total	749	24406	25155
Odds Ratio			12.8

Table 10 shows a contingency table created for the number of trains daily and the designation being assigned. It was calculated that crossings that experienced 5 or more trains daily were 1.6 times more likely to have received the designation compared to crossings that did not. Train traffic should be considered when evaluating crossings and assigning the designation. The busier a grade crossing is the more potential there is for a conflict to occur. In addition, when an entrapment occurs there is on average less time available for the pedestrian to become mobile the greater the number of trains travelling along the section of track.

Table 10: Number of Trains and Grade Crossing Designation

	5 or more trains daily	Under 5 trains daily	Total
Designated for pedestrians who use assistive devices	126	167	293
Non-Designated Crossing	7997	16865	24862
Total	8123	17032	25155
Odds Ratio			1.6

Table 11 displays a contingency table for demonstrating the relationship between the grade crossings with 25,000 or more vehicles daily and the designation. The OR was calculated to be 7.1. This means that crossings with more than 25,000 vehicles per day are 7.1 times more likely to have received the designation compared to those with less traffic. Higher vehicle traffic appears to be a factor in whether the designation is assigned or not to a grade crossing. An exception to this observation would be provincial freeways where little pedestrian traffic is experienced.

Table 11: High Vehicle Traffic and Grade Crossing Designation

	25,000 or more vehicles per day	Less than 25,0000 vehicles per day	Total
Designated for pedestrians who use assistive devices	7	286	293
Non-Designated Crossing	85	24777	24862
Total	92	25063	25155
Odds Ratio			7.1

In Part C, Section 9 of the GCS Warning System Specification, the specifications for a public grade crossing in which a warning system with gates is outlined. A key component of this specification is that crossings with poor sightlines must have a forecasted cross-product of 50,000 or more to warrant a crossing system with gates. The cross-product refers to the number of vehicles multiplied by the number of trains daily. A contingency

table was created with this criterion and is displayed as Table 12. It was found that crossings with a cross product of 50,000 or more were found to be 9.3 times more likely to be designated for pedestrians who use assistive devices.

It is logical that crossings with a high cross product of vehicle and train traffic, and poor sightlines would be a concern for those using assistive devices. Sightlines play an important role in grade crossing safety and should be a factor in considering whether a specific grade crossing is designated for pedestrians with a disability (as those who use assistive devices may take longer to traverse a grade crossing).

Table 12: Cross Product and Grade Crossing Designation

	Cross Prod. greater than 50,000	Cross Prod. less than 50,000	Total
Designated for pedestrians who use assistive devices	63	230	293
Non-Designated Crossing	713	24149	24862
Total	776	24379	25155
Odds Ratio		9.3	

Table 13 displays a summary table of the odds ratios. From this table it can be determined what attributes have a stronger relationship associated with the designation being assigned to a grade crossing.

Table 13: Grade Crossing Attributes and Odds Ratios

Attribute or Characteristic	Odds Ratio	Description
Urban Vs Rural	13.4	Urban locations are 13.4 times more likely to have received the designation.
Speed limit 50 km/hr. or under	1.3	Crossings that have a speed limit of 50 kilometres per hour or lower are 1.3 times more likely to have received the designation.
Two or more tracks	2.7	Crossings with two or more tracks are 2.7 times more likely to have received the designation
More than two traffic lanes	12.8	Crossings with more than two traffic lanes are 12.8 times more likely to have received the designation.
5 or more trains daily	1.6	Crossings that experienced 5 or more trains daily were 1.6 times more likely to have received the designation.
25,000 or more vehicles per day	7.1	Crossings with more than 25,000 vehicles per day are 7.1 times more likely to have received the designation.
Cross Prod. greater than 50,000	9.3	Crossings with a cross product of 50,000 or more were found to be 9.3 times more likely to have received the designation.

4.2.4 Experiment 4- SPSS Software Analysis

In the statistical analysis component of this work, 293 designated grade crossings were examined and compared to the remaining crossings in Transport Canada Grade Crossing Inventory. Recall that Transport Canada has claimed that in total 324 have been designated. Thirty-one (31) of these crossings could not be identified in the Transport Canada Grade Crossing Inventory due to missing information or errors in Transport Canada's data.

SPSS was used as a statistical tool to analysis the data. The goal of this study was to examine how the surrounding infrastructure and road attributes correlate to the designation being assigned to a specific crossing. In this study, SPSS was used for creating boxplots, determining the correlation between variables (number of tracks, lanes, traffic, etc.) and the designation, and conducting an Independent Samples Hypothesis Test.

First, the relationship between the designation and the number of lanes, tracks, daily vehicle and train traffic, road speed limits, and maximum train speed was observed by generating boxplots. It should be noted that points and stars within these charts represent outliers. The mean value is represented by a dark thick line. In addition, the 25th and 75th percentile are located at the bottom and top of the boxes, respectively.

From observing Figure 22, it can be determined that on average, crossings that have received this designation have a greater number of lanes at the location of the crossing. It should be recognized that generally, the larger the number of traffic lanes located at a grade crossing, the larger the amount of vehicle traffic. In addition, grade crossings that have many travel lanes are more likely to be located in an urban or busy location and therefore would correspond to greater pedestrian traffic.

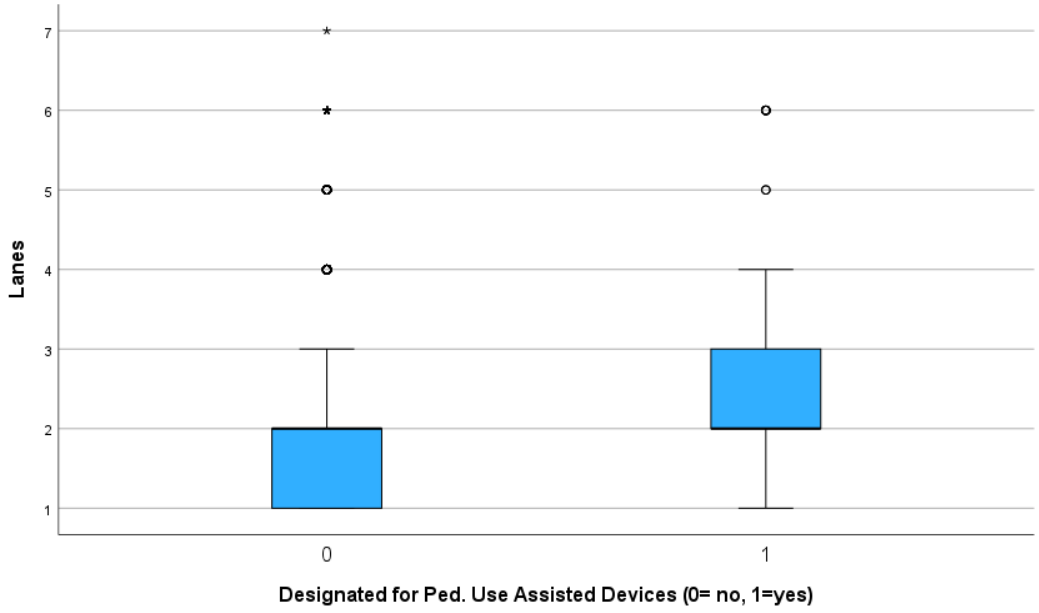

Figure 22: Number of Lanes

Figure 23 displays daily vehicle traffic. It should be recognized that because there is a high number of data points in the non-designated category (roughly 24,000 crossings), many outliers exist in the data. From observing the graphs, it can be determined that the mean daily vehicle traffic is higher for crossings that have been designated for persons who use assistive devices. This graph supports the previous statement, suggesting that the busier a grade crossing is the more likely it would be to receive the designation.

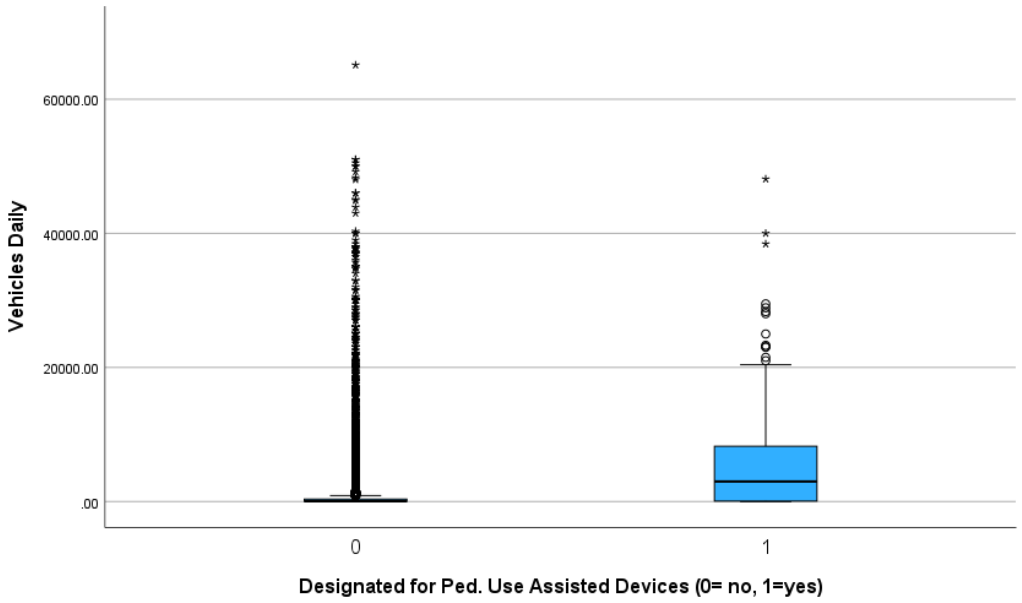

Figure 23: Vehicles Daily

Figure 24: Number of Tracks displays the difference between the number of tracks at designated and non-designated crossings. It can be observed that a greater proportion of the crossings that are designated have more than one set of train tracks. It should be recognized that multiple tracks would present a greater barrier for a person using a mobility

aid. Therefore, it is logical that this grade crossing attribute is considered when determining what crossings should receive this designation.

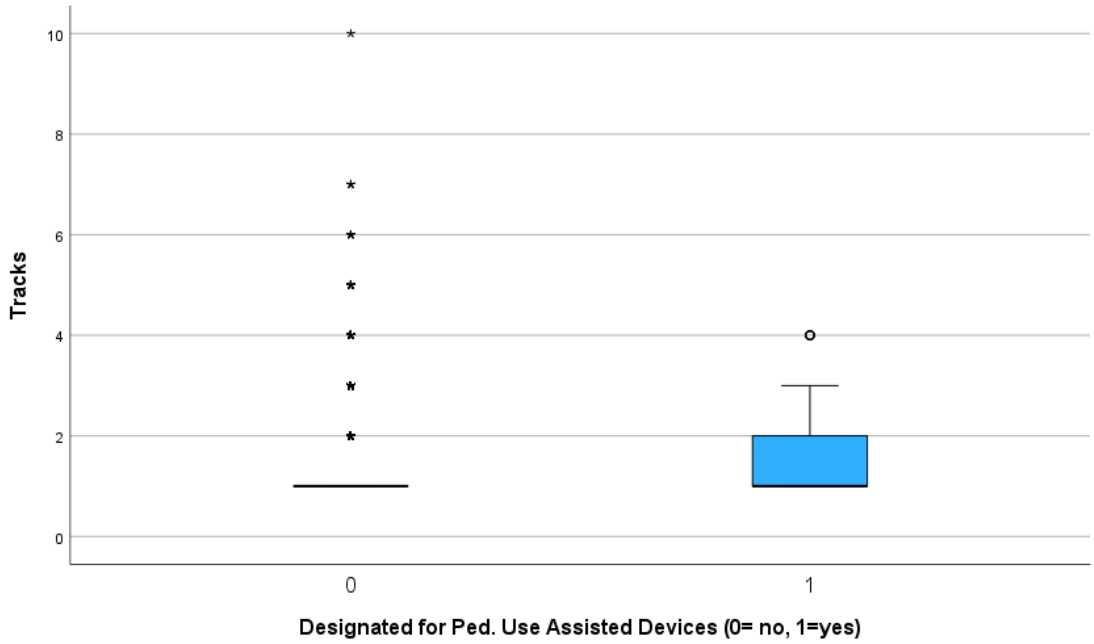

Figure 24: Number of Tracks

Figure 25 compares the posted speed limit and the two categories of grade crossings. The designated category of grade crossings has less variation in the posted speed. This is likely because municipal city streets are typically assigned the speed limit of 50 kilometres per hour in Canada.

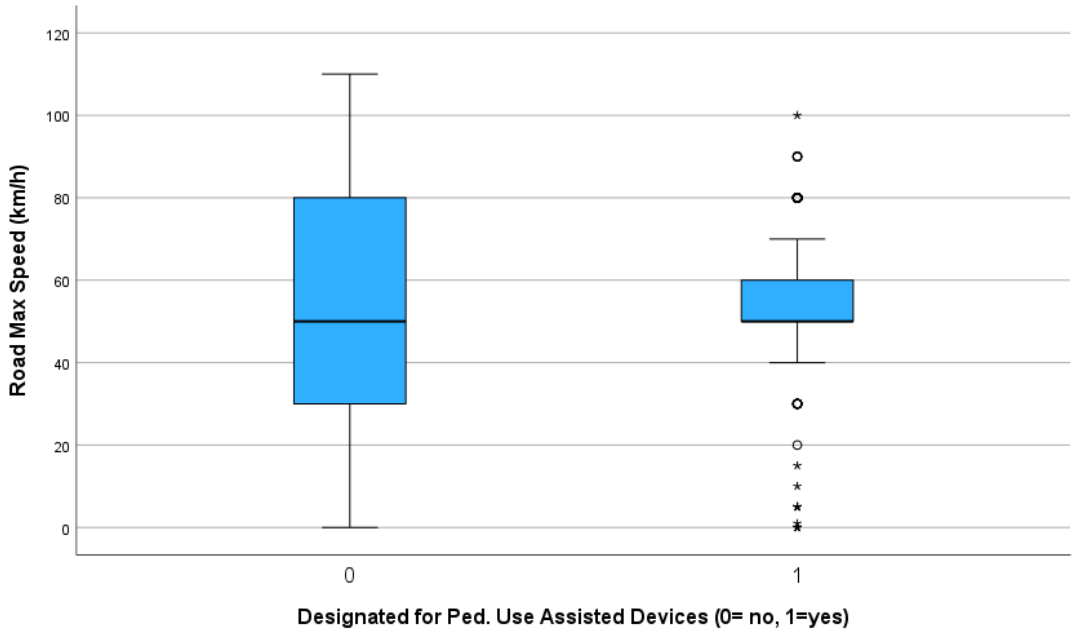

Figure 25: Posted Speed Limit

Figure 26 displays a boxplot with the daily train traffic at designated and non-designated crossings. The non designated group of crossings appears to have slightly less train traffic.

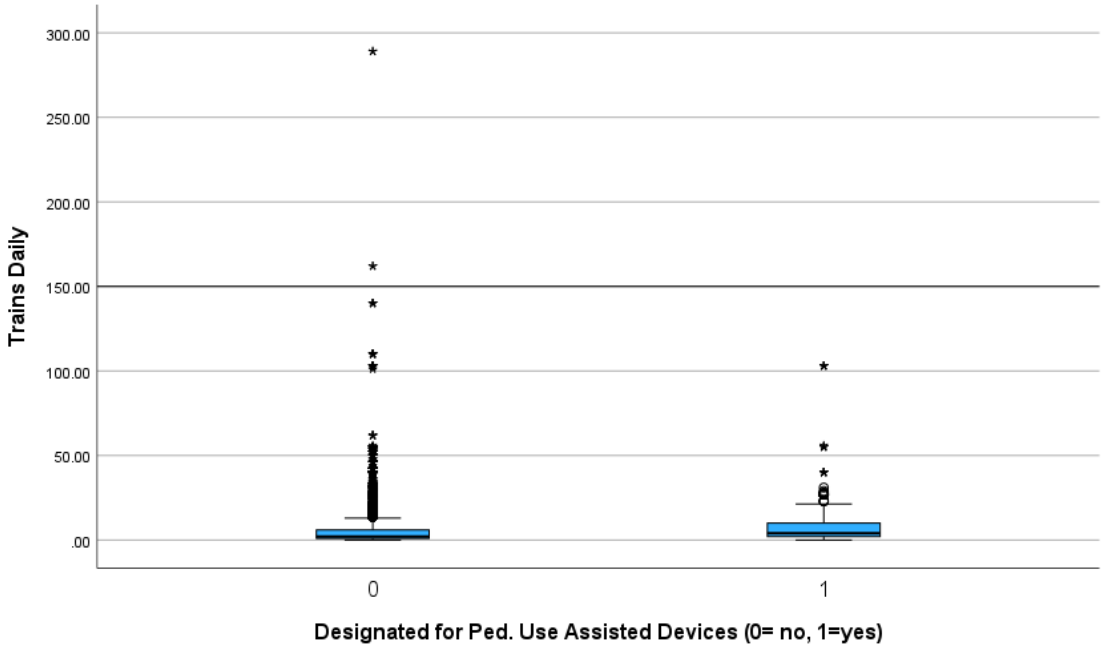

Figure 26: Daily Train Traffic

Maximum train speed is displayed in Figure 27. Here the maximum speed a train can travel is plotted. First, it can be observed that designated grade crossings have a wider range of maximum speeds. Second, the average maximum train speed is lower for designated grade crossings than those that are not.

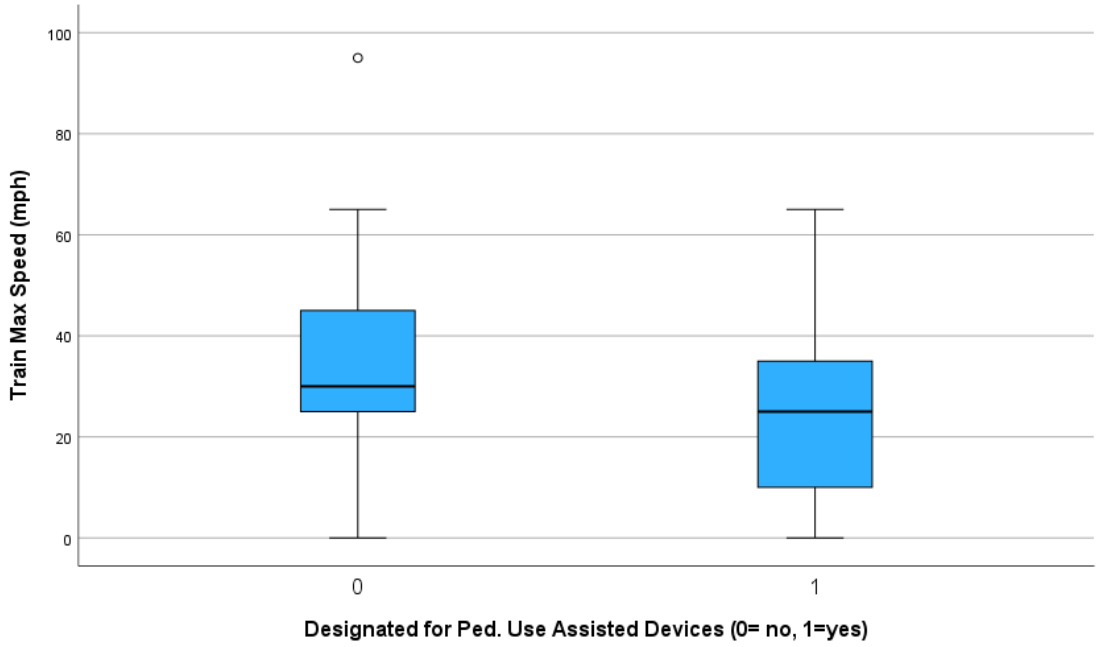

Figure 27: Maximum Train Speed

The location of crossings (rural vs urban) is plotted in Figure 28. On the left side of the chart, the rural grade crossing locations are plotted. It was observed that 103 out of 21,964 grade crossings are designated for pedestrians who use assistive devices and located in rural settings. On the left side of the chart, 190 of the 3191 grade crossings located in urban settings are designated for pedestrians who use assistive devices. The proportion of crossings that are designated is much greater in urban settings than rural locations. However, it should be recognized that about 35% of the grade crossings that have received this designation are located in rural settings.

Although rural locations would experience less pedestrian traffic and likely fall under the jurisdiction of the provincial road authority, they may be more problematic in the event of an entrapment. For instance, it has been documented that when an entrapment has occurred in the past, bystanders attempted to free and provide aid to the person using

the mobility device. In one event, the person was unsuccessful in freeing the wheelchair from the grade crossing and also sustained injuries. This event is outlined in TSB Investigation Report R18V0127 (Transportation Safety Board of Canada, 2019). It is unsure how many instances have occurred where a person has become immobilized due to the flangeway gap but has been freed by a bystander. On a provincial road with low traffic, it may be more likely that a person entrapped in the flangeway gap would be less likely to receive aid quickly or have the opportunity for a person to help free them.

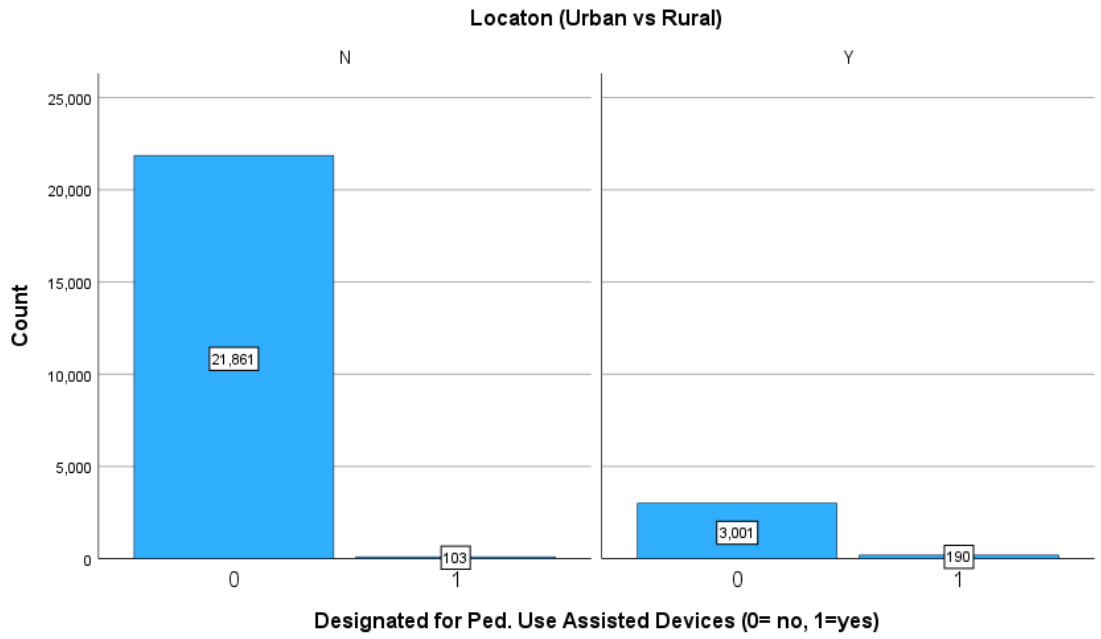

Figure 28: Location of Crossing

In addition to the box plots, SPSS was used to generate a logistic regression model and conduct a correlation study. The goal was to examine the road attributes and ascertain the significance of these characteristics to the designation. It was determined that these two tools were not useful in identifying relationships between grade crossing characteristic and

the designation. It is hypothesized that this is due to the large dataset and proportion of crossings that are not designated for pedestrians who use assistive devices. The results of these two statistical tools did not identify or indicate any relationships between the variables due to thousands of crossings having an overlapping combination of variables.

Table 14 displays a list of crossings that have consistent road characteristic/attributes with the current list of designated crossings. These crossings may be eligible for receiving the designation based on their consistent attributes with the current set of designated crossings. It should be noted that Table 14 is not an all-inclusive list, but rather has been prepared based on the statistical analysis portion of this work. This list of crossings was formed by filtering for crossings which had a cross product over 50,000, vehicle traffic equal to or greater than 25,000, more than two traffic lanes, and were in an urban setting. This criterion was selected based on characteristics that were found to have the highest positive relationship (larger Odds Ratio).

Table 14: Potential Crossings

Road Authority:	Location Information		
	Latitude:	Longitude:	Street Name:
British Columbia Highways	49.204 48.4473 49.19117	-124.0015 -123.495 -123.13406	Bowen Road Goldstream Ave. Sea Island Way
Calgary (AB)	50.90316 51.00661 51.0085	-114.07048 -113.99973 -113.9585	162nd Ave SW Barlow Trail S 50 Avenue 52 Street Se at 50 Ave Se
Chilliwack (BC)	49.16377	-121.95257	Young Rd
Duncan (BC)	48.7768	-123.706	Government St
Edmonton (AB)	53.59293 53.5181 53.46768 53.49694 53.50575 53.51796	-113.6151 -113.4944 -113.4912 -113.4862 -113.4428 -113.4185	170 Street 82 Avenue (Whyte Avenue) 34 Ave NW 99 St NW 75 St NW 50 St NW

Greater Sudbury (ON)	46.4985	-81.0071	Beatty St
Langley (BC)	49.11051 49.11141	-122.6722 -122.6686	Fraser Hwy (Production Way) 200Th St (Logan Ave)
London (ON)	42.996	-81.2351	Adelaide St
Magog (QC)	45.2661	-72.1556	Rue Merry
Okotoks (AB)	50.7253	-113.982	Northridge Dr Hwy #2A
Port Coquitlam (BC)	49.26925	-122.7906	Westwood St
Regina (SK)	50.48159 50.48129 50.4797	-104.5926 -104.59256 -104.59	Wb. Ring Rd (E. Of Winnipeg St) Ring Road E/B Lanes Ring Road
Richmond (BC)	49.1334 49.1701 49.1846 49.192	-123.1029 -123.1025 -123.1025 -123.1023	Steveston Hwy at Shell Westminster Hwy Cambie Rd Bridgeport Road
Salaberry-de-Valleyfield (QC)	45.2661	-74.1303	Rue Maden
Saskatoon (SK)	52.1439 52.13318 52.14347	-106.7 -106.6703 -106.65864	33Rd Street Idylwyld Dr 3rd Avenue
Sherbrooke (QC)	45.40205	-71.88895	King St.
SK - Department of Highways	52.12923 50.4695	-106.6789 -104.618	22 St W (Ave Fn) Albert Street (Hwy 6)
Thunder Bay (ON)	48.3808	-89.2647	Arthur St
Toronto (ON)	43.7844	-79.2833	Sheppard Ave E
Vancouver (BC)	49.27682 49.25889 49.26033	-123.08167 -123.04428 -123.03375	Venables St Renfrew St. Rupert St.
Windsor (ON)	42.2991 42.2994 42.3118 42.2491 42.3106	-83.0655 -83.0092 -83.0007 -82.963 -82.9505	Huron Church Rd Tecumseh Rd East Walker Rd Walker Rd Tecumseh Rd E

Winnipeg (MB)	49.8272 49.90997 49.90839 49.8945 49.85595 49.84083 49.92995	-97.20661 -97.18647 -97.18156 -97.113 -97.08425 -97.07645 -97.04565	Kenaston Boulevard (Highway 90) Notre Dame Avenue Notre Dame Ave Provencher Avenue Fermor Ave (Tch 1A) Bishop Grandin Boulevard Lagimodiere Blvd (Hwy 59)
York Region (ON)	43.86052	-79.31354	Hwy 7

Select road authorities that intend to designate a grade crossing for those with a disability could benefit from utilizing Table 14 along with public engagement with their community.

4.3 Producing a Flangeway Filler Replacement Schedule and Cost Estimate

Using the Transport Canada Inventory of Grade Crossings database, a preliminary replacement schedule and cost estimate was generated for the crossings that have been designated for persons who use assistive devices. The purpose of this was to evaluate the frequency that these products will be replaced at these locations and estimate the cost of this infrastructure addition over a thirty-year period. Several cash flow tables were generated for different scenarios to provide an estimate of the approximate government spending on installing and maintaining these products over thirty years. These cashflow diagrams would aid in budgeting for these products. It should be noted that the goal was to evaluate an order of magnitude with respect to the cost, rather than an exact or detailed estimate.

4.3.1 List of Assumptions

It should be noted that only the crossings currently designated for pedestrians who use assistive devices (n= 293) were considered in the cost estimation and replacement schedule. Additional crossings may be designated in the future which would increase the cost of installation and maintenance.

In addition, the cost included in labour to install these products was not included. The cashflow tables display the cost associated with material (purchasing the products and replacing parts). It should be noted that each road authority has different shared agreements and cost structures with railways. The cost of labour related to installing these products would likely be incurred by the railway companies. Recall that it was previously determined from the survey results that in many municipalities and provinces, railways control and are responsible for the maintenance and installation of any products at grade crossings.

Due to lack of information and research surrounding the performance and durability of these products, deterioration data from a manufacturer was used to estimate the frequency of replacements for each crossing. It should be recognized that this test was conducted in a climate different than Canada and likely in a location with different railway operations. However, from this test report, it was estimated that these products could withstand approximately 3,000,000 axle crossings before the product would require replacement due to vertical deterioration. This value was used in the cost estimate.

The number of trains, tracks and lanes was all provided in Transport Canada's Grade Crossing Inventory. These values aided in establishing the cost of the product and the number of parts requiring replacement. In addition, it was assumed that trains were

10,000 feet long (CN's restricted length). It should be noted that in Transport Canada's database, several locations were listed to have over 50 trains daily. These numbers likely reflect a single locomotive traversing the track, or trains transporting a small number of cars over a short distance. To account for this in the model, the locations that were listed to have 50 or more trains per day, were reduced by 50% to reduce the number of 10,000-foot trains the crossing would be experiencing daily. The locations that were described to have 25-50 trains per day were reduced by 40%. At all other locations, the value of trains per day provided by Transport Canada was used to estimate frequency of replacement.

The cost of purchasing these products and replacing parts was based off a single product cost which represented an average of costs from UNB's procurement of products for testing. It was assumed that the cost of replacement parts would remain the same over the 30-year period. However, discount rates of 3%, 8% and 10% were used for sensitivity analysis.

In Cash Flow Scenarios 3-5, Train traffic volumes were adjusted to account for an increase in train traffic. As it is difficult to assess the exact future growth in rail infrastructure in Canada, sensitivity rates of 10%, 25% and 50% increases were used.

Lastly, it was assumed that all crossings in Canada that are designated for pedestrians who use assistive devices would receive these products upfront and would require replacement based on their corresponding train traffic volumes.

4.3.2 Cash Flows- Scenario 1: No Increase in Train Volumes and No Discount Rate

The first scenario examined was the cost of installation and replacing parts, with no increase in train volumes. From an economic standpoint, this would represent the largest

potential cost (representing no risks or changes in the value of today's dollar). Due to the economic principle of the Time Value of Money (TVM) it is necessary to discount the cost of future replacements, which is accounted for in later scenarios. Recall that a sum of money is worth more now than the same sum of money at a future date.

Table 15 displays the expenditures rounded to the nearest thousand. Note that the upfront cost of installing these products on designated grade crossings is much greater than replacing the rubber flange insert which deteriorates due to flanged trained wheels.

Table 15: Cash Flow Diagram Values Scenario One

Year	Number of Replacements	Dollars ($)
0	(293 initial installations)	-6,734,000
1	48	-36,000
2	95	-61,000
3	97	-67,000
4	117	-71,000
5	107	-74,000
6	143	-89,000
7	132	-79,000
8	79	-55,000
9	122	-82,000
10	91	-60,000
11	217	-123,000
12	110	-72,000
13	114	-76,000
14	126	-79,000
15	83	-56,000
16	144	-88,000
17	103	-69,000
18	121	-81,000
19	96	-61,000
20	84	-56,000
21	294	-164,000
22	84	-60,000
23	119	-72,000
24	116	-76,000
25	87	-59,000
26	155	-95,000
27	89	-61,000
28	118	-74,000
29	112	-74,000
30	114	-73,000
Total Cost of Replacements		-2.25 million dollars
Total	3517 Replacements	-8.98 million dollars

Figure 29 displays the frequency of replacements per crossing. Here it is observed that most crossings will only require fewer than 10 flangeway rubber insert replacements over the 30-year period given the current train volumes.

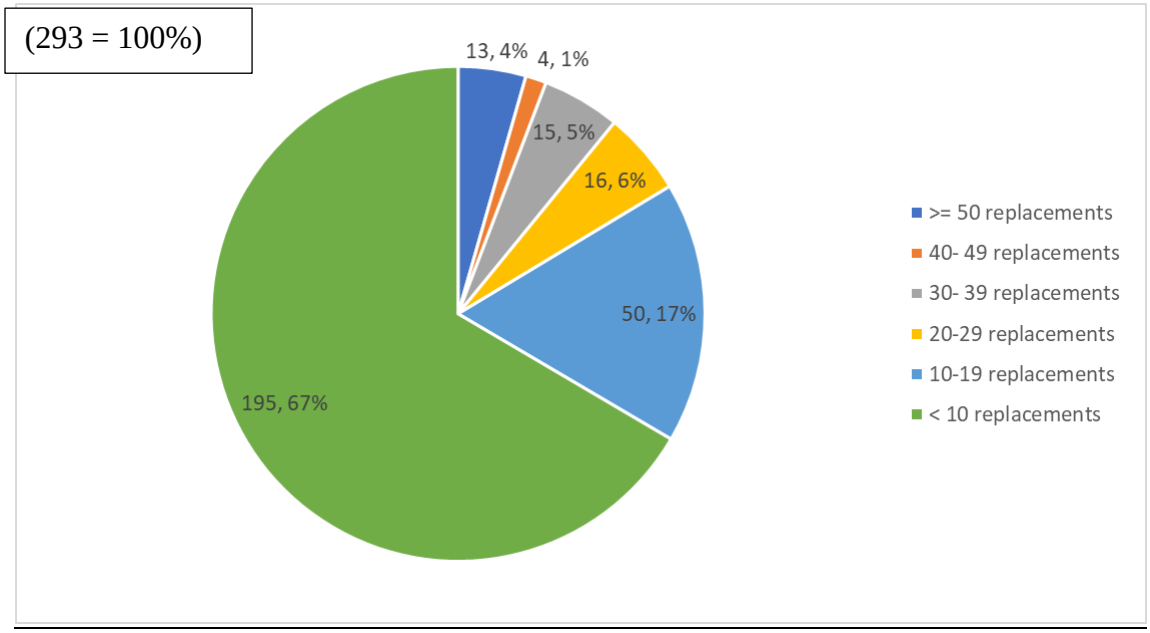

Figure 29: Designated Crossings and Number of Replacements

4.3.3 Cash Flows- Scenario 2: Considering Time Value of Money

This scenario displays cash flow including discount rates for future rubber insert replacements of 3%, 8% and 10%. This scenario attempts to account for the future cost of replacing the rubber flangeway inserts under varying future economic environments. Recall that this is a necessary step in estimating a potential future cost due to the TMV principle and these sensitivity rates are recommended for BCA analysis by the Government of Canada. Table 16 provides a summary table of the expenditures. In these scenarios 3% present represents a conservative value, while 8% and 10% are more optimistic discount rates. The final costs are represented as PV (Present Value).

Table 16: Summary of Cash Flows Scenario 2

Year	Number of Replacements	Dollars (Discount Rate 3%)	Dollars (Discount Rate 8%)	Dollars (Discount Rate 10%)
0	(293 initial installations)	-6,734,000.00	-6,734,000.00	-6,734,000.00
1	48	-35,000.00	-33,000.00	-32,000.00
2	95	-57,000.00	-52,000.00	-50,000.00
3	97	-61,000.00	-53,000.00	-50,000.00
4	117	-63,000.00	-52,000.00	-49,000.00
5	107	-64,000.00	-50,000.00	-46,000.00
6	143	-75,000.00	-56,000.00	-51,000.00
7	132	-65,000.00	-47,000.00	-41,000.00
8	79	-43,000.00	-30,000.00	-26,000.00
9	122	-63,000.00	-41,000.00	-35,000.00
10	91	-45,000.00	-28,000.00	-23,000.00
11	217	-89,000.00	-53,000.00	-44,000.00
12	110	-50,000.00	-29,000.00	-23,000.00
13	114	-52,000.00	-28,000.00	-22,000.00
14	126	-52,000.00	-27,000.00	-21,000.00
15	83	-36,000.00	-18,000.00	-14,000.00
16	144	-55,000.00	-26,000.00	-20,000.00
17	103	-42,000.00	-19,000.00	-14,000.00
18	121	-48,000.00	-21,000.00	-15,000.00
19	96	-35,000.00	-14,000.00	-10,000.00
20	84	-31,000.00	-12,000.00	-9,000.00
21	294	-88,000.00	-33,000.00	-23,000.00
22	84	-31,000.00	-11,000.00	-8,000.00
23	119	-37,000.00	-13,000.00	-8,000.00
24	116	-37,000.00	-12,000.00	-8,000.00
25	87	-28,000.00	-9,000.00	-6,000.00
26	155	-44,000.00	-13,000.00	-8,000.00
27	89	-28,000.00	-8,000.00	-5,000.00
28	118	-33,000.00	-9,000.00	-6,000.00
29	112	-32,000.00	-8,000.00	-5,000.00
30	114	-31,000.00	-8,000.00	-5,000.00
Total Cost of Replacements		-$1.45 million	-$813,000	-$677,000
Total	3517 Replacements	-$8.18 million	-$7.55 million	-$7.41 million

From these three scenarios, the total Present Value (PV) ranges from $7.41 to $8.18 million, which can be observed from Table 16. However, these three scenarios do not account for a potential increase in train traffic over the thirty-year period. In 2022, “rail traffic, as measured in gross ton miles, grew by 25% over the past decade – a rate double that of Canada’s overall economy.” (Railway Association of Canada, 2022). To address the potential future growth, which would make products deteriorate at a faster rate, Scenarios 3-5 examines the same scenario through a sensitivity analysis of train traffic increased by 10%, 25% and 50% over the 30-year time horizon.

4.3.4 Cash Flows- Scenario 3: 10% Increase in Train Volumes

This scenario displays several cash flows including discount rates for future rubber insert replacements of 3%, 8% and 10%, while accounting for a 10% increase in train traffic. Table 17 displays a summary of the cashflows per year, along with number of replacements.

Table 17: Summary of Cash Flows Scenario 3

Year	Number of Replacements	Dollars (Discount Rate 3%)	Dollars (Discount Rate 8%)	Dollars (Discount Rate 10%)
0	(293 initial installations)	-$6,734,000	-$6,734,000	-$6,734,000
1	53	- 36,000	- 34,000	- 34,000
2	106	- 63,000	- 58,000	- 56,000
3	104	- 66,000	- 58,000	- 55,000
4	143	- 81,000	- 67,000	- 62,000
5	155	- 84,000	- 66,000	- 61,000
6	86	- 48,000	- 36,000	- 33,000
7	141	- 72,000	- 52,000	- 46,000
8	130	- 66,000	- 46,000	- 39,000
9	111	- 58,000	- 38,000	- 32,000
10	219	- 93,000	- 58,000	- 49,000
11	111	- 53,000	- 32,000	- 26,000
12	125	- 59,000	- 33,000	- 27,000
13	126	- 55,000	- 30,000	- 24,000
14	101	- 44,000	- 23,000	- 18,000
15	162	- 65,000	- 32,000	- 24,000
16	133	- 52,000	- 24,000	- 18,000
17	108	- 45,000	- 20,000	- 15,000
18	106	- 41,000	- 18,000	- 13,000
19	303	- 98,000	- 40,000	- 28,000
20	84	- 33,000	- 13,000	- 9,000
21	119	- 39,000	- 15,000	- 10,000
22	131	- 45,000	- 16,000	- 11,000
23	118	- 40,000	- 14,000	- 9,000
24	145	- 45,000	- 15,000	- 10,000
25	143	- 43,000	- 13,000	- 9,000
26	88	- 28,000	- 9,000	- 6,000
27	150	- 45,000	- 13,000	- 8,000
28	64	- 20,000	- 6,000	- 4,000
29	240	- 59,000	- 15,000	- 9,000
30	130	- 35,000	- 9,000	- 5,000
Total Cost of Replacements		-$1.61 million	-$903,000	-$750,000
Total	3935 Replacements	-$8.34 million	-$7.64 million	-$7.48 million

Figure 30 displays the frequency of replacements per crossing based on a 10% increase in train traffic. It is observed that most crossings will only require fewer than 10 flangeway rubber insert replacements over the 30-year period given the current train volumes. It is also observed that with this increase in train volumes there is a larger proportion of crossings that will need to be replaced greater than 40 times but less than 50 (fourteen (14) crossings, compared to four (4) from the first scenario).

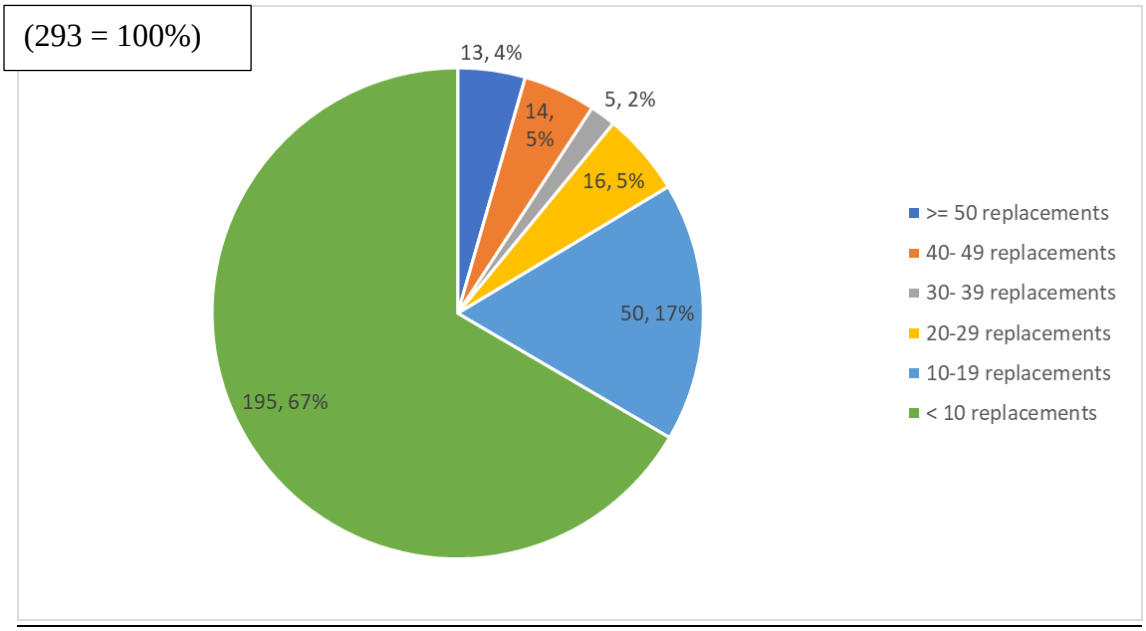

Figure 30: Designated Crossings and Number of Replacements 10% Increase in Traffic

4.3.5 Cash Flows- Scenario 4: 25% Increase in Train Volumes

This scenario displays examined the expenditures using discount rates for future rubber insert replacements of 3%, 8% and 10%, while increasing the current train volumes by 25%. This scenario examines the potential cost with a more conservative consideration for future train traffic. Table 18 displays the values depicted in the cashflow table.

Table 18: Summary of Cash Flows Scenario 4

Year	Number of Replacements	Dollars (Discount Rate 3%)	Dollars (Discount Rate 8%)	Dollars (Discount Rate 10%)
0	(293 initial installations)	-$6,734,000	-$6,734,000	-$6,734,000
1	66	- 44,000	- 42,000	- 42,000
2	130	- 78,000	- 71,000	- 68,000
3	142	- 85,000	- 74,000	- 70,000
4	126	- 76,000	- 63,000	- 59,000
5	169	- 88,000	- 69,000	- 63,000
6	138	- 75,000	- 57,000	- 51,000
7	147	- 77,000	- 56,000	- 49,000
8	113	- 62,000	- 42,000	- 37,000
9	232	- 96,000	- 63,000	- 53,000
10	148	- 71,000	- 45,000	- 37,000
11	171	- 79,000	- 47,000	- 38,000
12	99	- 47,000	- 27,000	- 21,000
13	158	- 68,000	- 37,000	- 29,000
14	157	- 67,000	- 35,000	- 27,000
15	118	- 50,000	- 25,000	- 19,000
16	115	- 48,000	- 23,000	- 17,000
17	320	- 110,000	- 49,000	- 36,000
18	118	- 46,000	- 20,000	- 14,000
19	122	- 46,000	- 19,000	- 14,000
20	140	- 50,000	- 20,000	- 14,000
21	178	- 60,000	- 22,000	- 15,000
22	156	- 51,000	- 18,000	- 12,000
23	98	- 36,000	- 12,000	- 8,000
24	158	- 49,000	- 16,000	- 11,000
25	90	- 66,000	- 20,000	- 13,000
26	107	- 35,000	- 10,000	- 7,000
27	136	- 40,000	- 12,000	- 7,000
28	158	- 44,000	- 12,000	- 7,000
29	155	- 41,000	- 11,000	- 7,000
30	122	- 34,000	- 9,000	- 5,000
Total Cost of Replacements		-$1.82 million	-$1.03 million	-$850,000
Total	4287 Replacements	-$8.55 million	-$7.76 million	-$7.58 million

Figure 31 displays the frequency of replacements per crossing based on a 25% increase in train traffic. It is observed that most crossings will only require fewer than 10 flangeway rubber insert replacements over the 30-year period given the current train volumes. It is also observed that with this increase in train volumes there is a larger proportion of crossings that will need to be replaced more frequently compared to the scenario with a 10% increase in traffic).

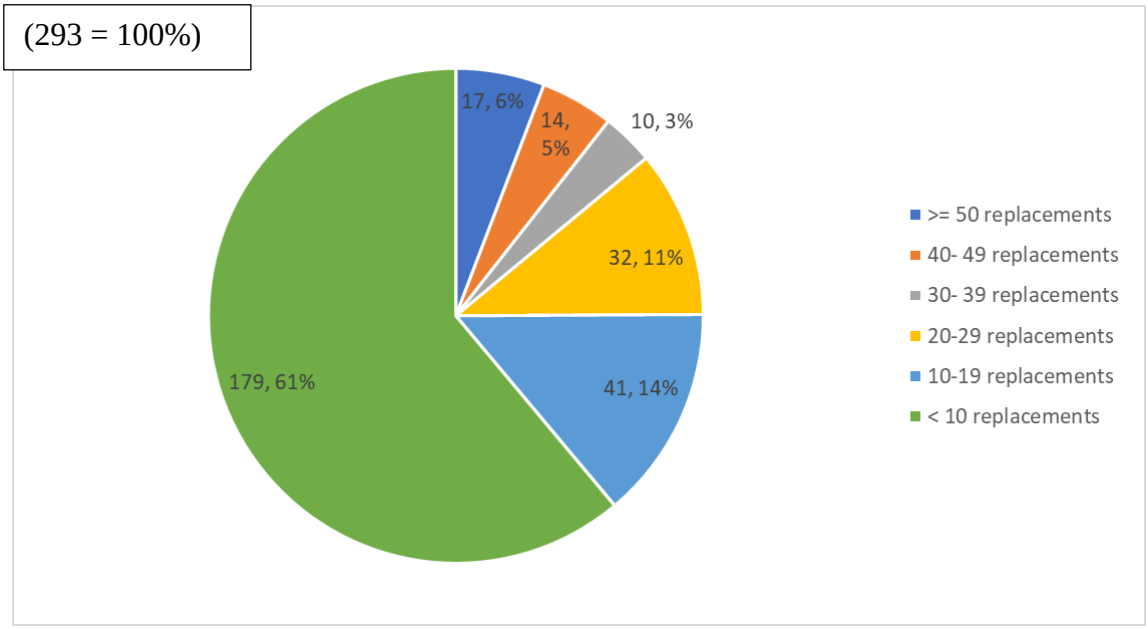

Figure 31: Designated Crossings and Number of Replacements 25% Increase in Traffic

4.3.6 Cash Flows- Scenario 5: 50% Increase in Train Volumes

This scenario displays several cash flows using discount rates for future rubber insert replacements of 3%, 8% and 10%, while increasing the current train volumes by 50%. This scenario examines the potential cost with the most conservative consideration for future train traffic. Table 19 displays the number of replacements and expenditures by year along with the total cost in terms of PV.

Table 19: Summary of Cash Flows Scenario 5

Year	Number of Replacements	Dollars ($) (Discount Rate 3%)	Dollars ($) (Discount Rate 8%)	Dollars ($) (Discount Rate 10%)
0	(293 initial installations)	-$6,734,000	-$6,734,000	-$6,734,000
1	85	- 60,000	- 57,000	- 56,000
2	150	- 93,000	- 85,000	- 82,000
3	177	- 104,000	- 90,000	- 85,000
4	185	- 105,000	- 87,000	- 81,000
5	164	- 88,000	- 70,000	- 64,000
6	164	- 94,000	- 70,000	- 63,000
7	270	- 127,000	- 91,000	- 80,000
8	143	- 76,000	- 52,000	- 45,000
9	143	- 76,000	- 50,000	- 42,000
10	175	- 82,000	- 51,000	- 42,000
11	187	- 87,000	- 52,000	- 43,000
12	176	- 81,000	- 46,000	- 37,000
13	145	- 63,000	- 34,000	- 27,000
14	330	- 124,000	- 64,000	- 50,000
15	138	- 60,000	- 29,000	- 23,000
16	170	- 69,000	- 33,000	- 25,000
17	147	- 59,000	- 27,000	- 20,000
18	179	- 68,000	- 29,000	- 21,000
19	164	- 60,000	- 25,000	- 17,000
20	177	- 65,000	- 25,000	- 18,000
21	255	- 81,000	- 30,000	- 21,000
22	156	- 54,000	- 19,000	- 13,000
23	183	- 60,000	- 21,000	- 14,000
24	184	- 57,000	- 19,000	- 12,000
25	128	- 42,000	- 13,000	- 8,000
26	180	- 55,000	- 16,000	- 10,000
27	138	- 41,000	- 12,000	- 7,000
28	337	- 85,000	- 23,000	- 14,000
29	158	- 44,000	- 11,000	- 7,000
30	153	- 42,000	- 10,000	- 6,000
Total Cost of Replacements		-$2.20 million	-$1.24 million	-$1.03 million
Total	5341 Replacements	-$8.94 million	-$7.98 million	-$7.77 million

Figure 32 displays the frequency of replacements per crossing based on a 50% increase in train traffic. It is observed that most crossings will only require less than 10 flangeway rubber insert replacements over the 30-year period given the current train volumes. It is also observed that with this increase in train volumes there is a larger proportion of crossings that will need to be replaced more frequently compared to the scenario with a 10% and 25% increase in traffic).

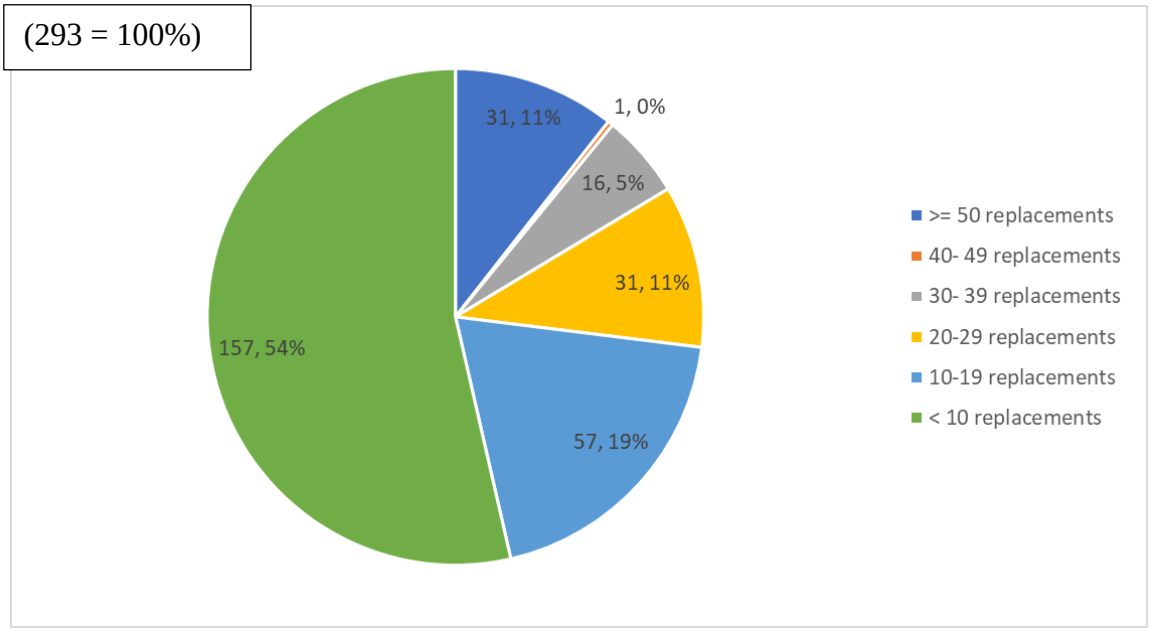

Figure 32: Designated Crossings and Number of Replacements 50% Increase in Traffic

4.3.7 Summary of Potential Cost

The goal of this preliminary cost evaluation was to develop a range of costs and an order of magnitude for installing flangeway fillers at designated crossings. A detailed cost estimate and full Benefit-Cost Analysis would be recommended before installing these products widespread to determine the net social benefit. However, this preliminary estimate

can be used to estimate approximate budgeting and PV of installing and maintaining these products. Table 20 displays a matrix summarizing the PV values from previous cashflow diagrams. Recall that PV applies to a series of cashflows (in this case expenditures) that occur at different times.

From the results of the cost analysis, it can be observed that an increase in train traffic has a relatively minor impact on the cost of the infrastructure over the analysis period. This is associated with the relatively small cost of replacing the flangeway filler inserts compared to the upfront cost of the full product. In addition, a few of the crossings with high train traffic accounted for the majority of forecasted replacements, therefore, the maintenance potential of a given crossing may be a factor in deciding which of the designated crossings are to receive flangeway fillers.

Table 20: Summary of Total Potential Costs (PV)

	0% discount rate	3% discount rate	8% discount rate	10% discount rate
No Increase in Train Volumes	$-8.98 million	$-8.18 million	$-7.55 million	$-7.41 million
10% Increase in Train Volumes	$-9.21 million	$-8.34 million	$-7.64 million	$-7.48 million
25% Increase in Train Volumes	$-9.53 million	$-8.55 million	$-7.76 million	$-7.58 million
50% Increase in Train Volumes	$-10.11 million	$-8.94 million	-$7.98 million	-$7.77 million

In a practical sense, the values shown in Table 20 and Tables 15-19 can be used by the Federal Government to estimate the potential RSIP funding to install these products Canada wide in today's dollars. Recall that the Transport Canada currently funds the Rail Safety Improvement Program (RSIP). This program provides funding for research or projects that improve infrastructure, increase safety, proposes new technologies,

addresses/prevents the impact of climate change, etc. Transport Canada has stated "Due to the limited amount of available funds in a given year, the applications received under the RSIP-ITR component are prioritized and the funds are allocated based on risk and identified safety issues, as well as the potential for the project to reduce collisions (fatalities, injuries and property damage)." (Government of Canada, 2022). It should be recognized that this source of funding is rather large when comparing to the expected annual replacement costs. For instance, between 2016-2019, the program committed $53.7 million for rail safety improvement projects (Transport Canada, 2020). However, only 77.8% of the committed budget was expended, resulting in lapsing funds (Transport Canada, 2020).

It is well documented that fatalities have occurred due to wheelchair users becoming immobilized by the flangeway gap every few years in Canada. There is potential for road authorities to request RSIP funding and install these products due to the potential of reducing fatalities and injuries to pedestrians. In addition, there has historically been room in the budget for additional projects.

Chapter 5- Discussion of Results

The following section will discuss the results of this work and provide recommendations for moving forward.

5.0 Existing Conditions

No municipality or province that provided a response to the survey stated that they use a methodology or a set of guidelines for deciding when to designate grade crossings for pedestrians who use assistive devices. Although Transport Canada has stated that it is the responsibility of the road authority to designate a crossing for persons who use assistive devices, there may be some ambiguity in terms of the perceived role of the road authority for initiating a grade crossing for a person who uses assistive devices.

The current set of designated crossings appear to have been selected based on a response to a citizen inquiry, some sort of internal analysis, selected based on location or due to a fatality. Guidance and clarification from Transport Canada for when this designation should be assigned is necessary. Figure 33 displays the standards prescribed to grade crossings with respect to cross-section. In Figure 33 it can be determined that there is a maximum allowance for flangeway depth and width of 75 mm for “Public sidewalks, paths and trails designated by the road authority for use by persons using assistive devices” (Transport Canada, 2019). Although this restriction (75 mm of width and depth) does not prevent the possibility of wheel entrapment it does create a smaller barrier for those using assistive devices.

a) Flangeway:		
Width	**Minimum**	65 mm
	Maximum for:	
	Public sidewalks, paths or trails designated by the road authority for use by persons using assistive devices	75 mm
	All other grade crossings	120 mm
Depth:	**Minimum**	50 mm
	Maximum for:	
	Public sidewalks, paths and trails designated by the road authority for use by persons using assistive devices	75 mm
	All other grade crossings	No limit
(b) Field side gap A space is permitted on the outer side of the rail at rural locations, except for public sidewalks, paths or trails designated by the road authority for use by persons using assistive devices		
	Maximum width	120 mm
	Maximum depth	No limit
(c) Elevation of the top of the rail with respect to the crossing surface The top of the crossing surface must be installed as close as possible to the top of the rail within the wear limits below:		
Wear limits:		
Public sidewalk, path or trail designated by the road authority for use by persons using assistive devices		
	Maximum distance of the top of the rail above crossing surface	13 mm
	Maximum distance of the top of the rail below crossing surface	7 mm
All other public grade crossings; the maximum distance of the top of the rail above or below the crossing surface		25 mm
Private grade crossings; the maximum distance of the top of the rail above or below the crossing surface		50 mm

Figure 33: Grade Crossing Surface Standards (Transport Canada, 2019).

In Section 12, Information Sharing- Road Authority of the Grade Crossing Regulations it states the following:

"A road authority must provide a railway company, in writing, with the following information in respect of a public grade crossing: …(n) an indication of whether the grade crossing includes a sidewalk, path or trail, and if so, whether the sidewalk path or trail has been designated for persons using assistive devices" (Transport Canada, 2021).

It should be noted that these two documents govern rail safety and are intended to be used in conjunction with one another. With the lack of clarification on what constitutes a grade crossing designated for persons using assistive devices, many municipalities or provinces may not feel the need or requirement to designate a crossing without citizen inquiry or an extreme event (fatality or injury between a wheelchair user and locomotive). It is likely that once some guidance is provided to road authorities additional crossings will receive this designation. Recall that less than 1% of crossings in Canada have been designated for persons using assistive devices, while the use of motorized wheelchairs is increasing 3-5% a year.

While flangeway fillers have been successfully deployed in some European countries, flangeway filler products do not have widespread adoption as a solution for removing or eliminating the flangeway gap in Canada. A few respondents (British Columbia, Moncton, and Vancouver) stated that they have used these products in the past or currently have some sort of product on a grade crossing in their network but are unaware of product information as they were installed by the railway company. Many provinces and municipalities that participated in the survey stated that they have not used these products or have any plans to test or procure them for their crossings.

It is hypothesized that there are essentially three reasons for these products not having widespread adoption. First, there is currently little published research surrounding flangeway filler use in North America or in climates with similar whether conditions to Canada. Without publications or test reports, their effectiveness is unknown, which limits the potential for a road authority to make an investment in these products.

Second, there is significant liability related to installing an untested product on a railway. In Canada, locomotives transport dangerous goods, passengers, and freight. It is unlikely that railway companies would be interested in installing any products that have not undergone significant testing to ensure they do not present a risk (e.g. derailment, operational challenges, etc.).

Third, there is a lack of awareness of the potential safety benefit these products offer for those using assistive devices and cyclists. The TSB has suggested that flangeway fillers may provide a solution to entrapment and two (2) Research Need Statements have been published to the Transportation Research Board, but little has been done to bring awareness to the topic through research publications.

A successful RSIP application to Transport Canada from UNB and NRC in 2022 involved testing several products currently on the market and taking one product to a field test. It is likely an application to undertake further phases of testing will be submitted to RSIP in the future to include a field test on active railways. Once there is more documentation of these products being effective and improving rail safety it is hypothesized that they will be installed at the locations that have been designated for persons using assistive devices.

5.1 Discussion of Statistical Analysis

A goal of the statistical analysis portion of this work was to examine the current set of crossings that have been designated for a person with a disability and determine what road characteristics or attributes appear to be correlated with the designation. Although regression and correlation techniques were not useful in identifying significant

characteristics other statistical tools were explored. From Section 4.2.3 Contingency Tables, some relationships were examined between specific crossing characteristics and the designation. These correlations were then applied to the original Transport Canada Inventory to filter for crossings that have these characteristics but have not been designated. Table 13: Grade Crossing Attributes and Odds Ratios summarizes the likelihood of the designation being assigned to a grade crossing based on the characteristics provided in the Grade Crossing Inventory.

5.2 Discussion of Potential Cost

The preliminary cost evaluation estimated the frequency of replacements and the associated cost to range between $7.41 and $10.11 million (PV), with an upfront cost of $6.73 million for all currently designated crossings. This analysis does not include the adoption of any new designated crossings over the analysis period. Although this does not provide a precise estimate, it accounts for various economic environments and variation in train traffic at crossings. The estimate was provided with a clear list of assumptions and the associated replacements costs were discounted at 3%, 8% and 10% (which was suggested by the Treasury Board of Canada Secretariat). There are many variables that make estimating the life span of flangeway fillers difficult. For instance, low quality train and vehicle traffic data at grade crossings, impact of the climate and weather conditions on degradation, and the potential of external damage (snowplows, vandalism, etc.). The effect of vehicle traffic, climate and external damage was not considered when preparing this estimate as there are no previously published reports demonstrating how these factors impact service life of flangeway fillers. Recall that the goal of this evaluation was to determine an order of

magnitude to assess if flangeway fillers would provide a reasonable solution with respect to their corresponding price.

Although a complete BCA was not conducted, it appears that these products potentially provide an economically reasonable solution. Recall that Value of Statistical life is additional costs that individuals would be willing to pay for a small risk reduction, that in aggregate, reduce the expected quantity of fatalities by one. In 2009, Policy Research Initiative (Government of Canada) conducted a comprehensive review of several VSL studies and suggested that this value is approximately $6.5 million in Canadian 2007 dollars (Policy Research Initiative, 2009). In today's dollars (2023) this would be approximately $9.2 million. It is well documented that there have been several instances of entrapment at rail crossings which have resulted in injury or death in Canada. It appears that these instances occur somewhere in Canada every few years. This does not include the instances where a person is entrapped and able to free themselves. Expanding the number of designated crossings to facilitate the installation of flangeway gap fillers may result in pedestrians feeling safer traversing at these crossings due to the decreased potential to be entrapped on the track.

It is important that municipalities and provinces are aware of the potential to use RSIP as a funding source for installing these products, if found suitable for the Canadian environment.

5.3 Additional Measures for Improving Rail Safety and Accessibility

There are additional measures road authorities and railway companies could consider to improve accessibility and rail safety. These items include but are not limited to sightline

improvements and frequent assessments, geometry considerations, and pavement/ballast evaluations and maintenance.

Providing appropriate sightlines is essential for motorist and pedestrians at grade crossings to ensure safety. In 2015, Transport Canada published a guide titled Determining Minimum Sightlines at Grade Crossings- A Guide for Road Authorities and Railway Companies. In the guide, Transport Canada states that "*These sightlines must, at minimum, provide crossing users with enough time to see and react to an oncoming train, from both the 'approach' and 'stop' positions*" (Transport Canada, 2015). The guide provides technical guidance that stakeholders can use to determine the minimum sightlines required at grade crossings. The guide prescribes a six-step methodology for calculating sightlines based on design vehicle, grade crossing geometry, railway design speed, approach gradient and other factors. Step Four of this process outlines how to calculate the departure time for pedestrians, cyclists and persons using assistive devices which is shown in Equation 4. This value (departure time) is associated with the time required for a pedestrian to traverse the crossing.

$$Tp = \frac{Cd}{Vp} \qquad \text{Equation 4}$$

Where, Cd= Grade crossing clear distance (m)

Vp= Average travel speed

The document suggests the value of 1.22 metres per second for pedestrian speed. It should be recognized that pedestrians who require mobility aids may require more time to traverse a crossing. According to values reported in literature, the typical speed of a

wheelchair user varies between 0.48 to 0.8 metres per second (Sonenblum, 2012), which is approximately two and a half times slower than the value suggested in the guide. It is recommended that when road authorities are conducting sightline inspections special consideration is given to crossings that have been designated for pedestrians who use assistive devices.

Road surface condition is also an important element when considering additional safety measures. For instance, the physical condition of sidewalks or paths located at a grade crossing should be maintained to ensure there are not additional damages that present barriers (potholes, larges cracks, uneven crossing surface, damaged or misplaced surface material). Each road authority has different agreements with the railways, however, in most instances, the railways are responsible for maintenance of crossing surface. Figure 34 displays an image of a crossing from a TSB investigation report where a wheelchair user was fatality injured. It can be observed that many defects in the pavement surface are present, which appear to present a larger and deeper barrier than the flangeway itself. It should be recognized that this presents a barrier and potential hazard for wheelchair users. Frequent inspections of crossings by foot or hi-rail are recommended to address this issue.

Figure 34: Damaged Crossing Surface (Transportation Safety Board, 2016)

TSB Railway Investigation Report R99S071 stated "If crossing surfaces are uneven, flangeway gaps can pose an even greater challenge to users of assistive devices. Specifically, the caster wheels on wheelchairs can rotate when the surface level changes. If this occurs at the crossing, the caster wheels can drop into the flangeway gap, immobilizing the wheelchair" (Transportation Safety Board, 1999). In addition, an uneven crossing surface can cause a wheelchair to be jolted when a person traverses the tracks, which can affect a person's ability to operate their device or cause additional issues. For instance, a user may lose control of the joystick or operating mechanism and drop or loose access to communication devices or personal items (drop cell phones, glasses, other personal devices). In this event, a person may stop on the tracks and attempt to retrieve their items.

Another potential improvement that may be possible in some instances is modifying the crossing geometry. The U.S. Department of Transportation and the Federal

Railroad Administration has recommended that wheelchair users cross railway tracks at a 90-degree approach angle. This has the potential to reduce the probability of a wheelchair caster wheel rotating and becoming immobilized in the flangeway gap. Figure 35 displays an image for clarification. This design consideration may be challenging to implement in urban locations due to the existing footprint and property boundaries. Therefore, this safety measure may be more appropriate for rural locations.

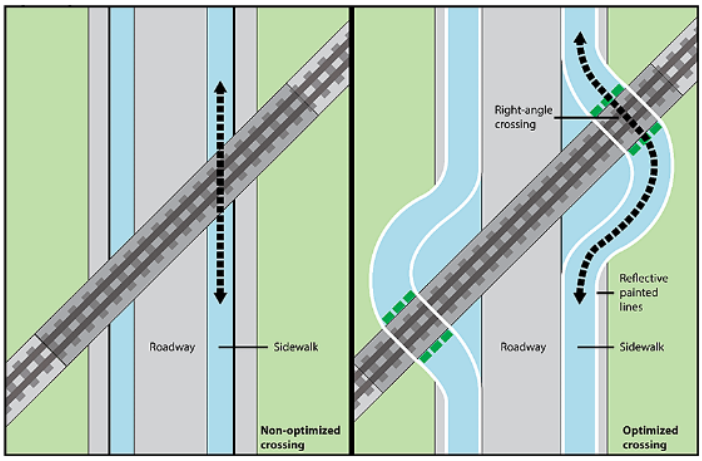

Figure 35: 90 Degree Approach Angle (Transportation Safety Board, 2016).

However, when crossing geometry can not be modified, pavement markings can also be used to identify the path of travel for pedestrians. In 2007, Transport Canada published a documented titled Pedestrian Safety at Grade Crossing Guide. The guide included several solutions aimed to increase pedestrian safety at grade crossings. One of the recommendations included the use of continuous white lines on both edges of the pedestrian crosswalk to clearly identify where pedestrians are permitted to traverse tracks. It should be recognized that in situations where the crossing geometry can not be modified these pavement markings can be positioned at 90-degrees to the tracks. Table 21 displays a list of grade crossings designated for pedestrians who use assistive devices which have a

grade crossing angle less than or equal to 45-degrees. These crossings have similar geometry to what is displayed in Figure 35. It is recommended these locations be further investigated for the potential to install pavement markings to facilitate a 90-degree crossing of the tracks.

Table 21: Designated Grade Crossings with Problematic Grade Crossing Angle

Location	Province	Street/Address	Lat/Long.	Crossing Angle (Degrees)
Ville de Lac-Megantic	QC	Rue Papineau	45.343832, -70.525284	**43**
Ile Perrot, Ville	QC	Boulevard Perrot Nord	45.396639, -73.964025	**30**
NBDTI	NB	Route 134	47.995298, -66.308281	**45**
Montréal, Ville	QC	Piétonnier (Authier-Devonshire)	45.49759, -73.673516	**32**
City of Calgary	AB	Applewood Drive	51.0474, -113.935	**45**
City of Calgary	AB	17 Avenue	51.03785, -113.95	**45**
City of Calgary	AB	23 Avenue	51.03273, -113.95844	**45**
City of Toronto	ON	Birchmount Road	43.7226, -79.2749	**40**
Montréal	QC	Rue St-Patrick	45.4399, -73.6469	**23**
City of Toronto	ON	Neilson Road	43.8211, -79.2302	**45**
Township of Asphodel - Norwood	ON	Cameron Line	44.3527, -78.109	**5**
City of Peterborough	ON	Pathway - George Street	44.299, -78.3188	**44**
City of Toronto	ON	Tapscott Road	43.8212, -79.241	**45**
TOWN OF BLACKFALDS	AB	Broadway Avenue	52.38157, -113.795465	**31**
City of Toronto	ON	Old Weston Road	43.6695, -79.4619	**20**
City of Medicine Hat	AB	Industrial Ave SE	50.03112, -110.652	**39**
City of Toronto	ON	Horner Ave	43.6085, -79.5152	**35**
City of Toronto	ON	Lake Shore Blvd E	43.655, -79.3378	**20**
City of Toronto	ON	Lake Shore Blvd E	43.657, -79.3331	**35**
City of Toronto	ON	Lake Shore Blvd E	43.65757, -79.3319	**30**
City of Windsor	ON	Howard Ave	42.29078, -83.013058	**29**
City of Windsor	ON	Dougall Ave	42.324326, -83.002167	**45**

5.4 Limitations

Limitations related to the analysis portion of this work are categorized below by objective.

5.4.1 Survey Limitations

Although many road authorities were contacted and asked to provide a response, many did not participate. In total, twelve (12) road authorities provided insight into practices or internal policies they use related to designating a crossing for a person who uses an assistive device, flangeway filler use, etc. It should be noted that approximately 30 road agencies were contacted via email. It is hypothesized that this may be due to a lack of consideration to this subject or uncertainty within the agencies. There appears to be a lot of ambiguity related to the shared responsibilities of municipalities/provinces and railway companies. The largest city in Canada (Toronto) has requested guidance from Transport Canada related to what constitutes a designated crossing and is waiting for a response. Cities with smaller technical staff and resources are likely consumed with other tasks or are unaware of the issue.

With further publications related to the issue it is possible that more cities may begin to develop practices or policies related to flangeway fillers and initiating crossings to be designated for persons who use assistive technology.

5.4.2 Statistical Analysis Limitations

Regression and correlation tools in SPSS were not useful for the completion of this work. Due to the inventory including over 25,000 crossings and many of them having a combination of similar road/ rail characteristics it appears that it is difficult to isolate significant variables statistically with these tools.

There appears to be some data quality issues related to the Transport Canada Grade Crossing Inventory. Many of the grade crossings in the Transport Canada Grade Crossing Inventory had little information related to speed limits, daily train traffic, AADT. Pedestrian volumes were also not included in this data set. It is recommended that this database is improved. Without a higher resolution of data, in-depth statistical analysis is difficult.

A confidential Excel database was also provided for this research from Transport Canada. In this database the location of designated crossings was listed along with some of the crossing features. When comparing this information to the Grade Crossing Inventory many inconsistencies existed. Several of these crossings could not even be located in the Grade Crossing Inventory due to incorrect street name, missing or incorrect latitude/longitude information, etc.

5.4.3 Cost Estimate Limitations

Deterioration assumptions were derived from a single product. Product costs were similar, so a cost for a single product was used. Note that there may be other products that are more or less expensive available on the market in the future.

A full Benefit Cost Analysis (BCA) would be helpful to examine the net social benefit of these products being installed. The criteria for installation would need to be determined to know the total number of crossings that could be eligible (or may benefit) from these fillers. BCA is the consideration of all costs and benefits (in terms of present value). This technique can also be referred to as Social BCA, because “BCA is based on the Hicks-Kaldor criterion of potential Pareto improvement” (Yevdokimov, 2022). Pareto

improvement describes as an improvement to a system that maximizes net benefits by causing no harm to anyone but improving or benefiting the condition of at least one person. There are four major steps in completing a BCA, which are project specification, identification of the project inputs and outputs, evaluation of benefits and costs, and comparison of costs and benefits (Yevdokimov, 2022). In this analysis, product costs were only considered which were capital costs. The Treasury Board of Canada Cost-Benefit Analysis Guide categorizes costs as either compliance, administrative or transitional. Generally, compliance costs are direct costs incurred by the private sector, administrative costs are incurred by the government and transitional costs are all other costs (Yevdokimov, 2022). Costs that were incurred by the private sector such as compliance costs were not considered in this analysis.

A clear benefit of these products is the potential for eliminating the possibility of a fatality. Since the 1990s, seven preventable collisions have occurred between disabled pedestrians and locomotives due to the flangeway gap issue. There is the potential for this infrastructure addition to have a significant benefit on pedestrian-rail safety by eliminating the possibility of these events. Value of Statistical Life (VSL) can be determined by calculating the amount of money that a group of individuals is willing to pay for small death risk reduction, that in aggregate, reduce the expected number of fatalities by one (Treasury Board of Canada Secretariat, 2018). There are additional social benefits beyond death risk reduction, including reduction of injury due to assistive device entrapment and subsequent escape, reduction of pedestrian anxiety about entrapment, and improved safety for other users, such as cyclists. The added benefit of these items would also have to be considered.

In BCA analysis, once all benefits and costs have been well-defined and evaluated, they are compared via Benefit Cost Ratio (BCR). This ratio can be calculated to compare costs and benefits numerically (Equation 5). It should be noted that when this ratio is greater than the value of one, it is implied that benefits outweigh costs, and the project should progress.

$$BCR = \frac{Present\ Value\ of\ Benefits}{Present\ Value\ of\ Costs} \qquad \text{Equation 5}$$

It is recommended that a full BCA is completed to better understand the impact of this infrastructure addition in economic terms.

Chapter 6- Conclusions and Recommendations

This chapter summarizes the research methods and key findings from the analysis of designated grade crossings for pedestrians who use assistive devices and flangeway fillers. This chapter will also include recommendations and necessary next steps for this research.

6.1 Summary of Work

This research provided an analysis of the current practices and procedures road authorities are using to designated crossings for those who use assistive devices and the past/current use of flangeway fillers in Canada. The literature review explored past accidents related to wheel entrapment at grade crossings and the use of flangeway filler products in other nations. A survey was administered to road authorities across Canada to create an inventory of practices and policies related to designating crossings and flangeway filler use. Then, a statistical analysis was conducted using the current set of designated pedestrian crossings to determine what attributes/ road characteristics demonstrate a relationship with the designation. This information will be helpful in providing road authorities with some guidance for when this designation may be appropriate. Lastly, a preliminary cost evaluation was conducted to determine the economic feasibility of installing these products at grade crossings designated for those who use assistive devices across Canada and could be adapted to test the cost implications of designating new crossings over time.

Ultimately, this work demonstrated that many road authorities in Canada are unsure what constitutes a designated crossing for persons with a disability and have limited experience designating grade crossings. Moreover, many municipalities/provinces have not used flangeway filler products despite the potential for these products to prevent

fatalities and remove barriers for those with a disability. Through the statistical analysis, road attributes that have a positive relationship with the designation were discovered by experimenting with different statistical tools and approaches. The economic evaluation suggests that these products have a relatively low annual cost compared to the rail safety improvement funding available through Transport Canada's RSIP. Although historically Transport Canada has expended much less than what has been budgeted for rail safety improvement projects, the initial upfront cost of installing these products ($6.73 million) may require an increase in the RSIP budget (depending on the cost of other ongoing projects/RSIP applications). Note that this cost estimate is for the existing designated crossings, and not for any new crossings that may be designated if new criteria is developed.

6.2 Research Methods

The survey was structured to gather information related to the process of designating a grade crossing for pedestrians with disabilities, the methodology or warrant system used and the road authorities' use of flangeway fillers. This survey was administered through MS Forms. To receive responses from the appropriate source, municipal/provincial departments related to transportation engineering or rail safety were contacted by email or phone. Each department that was contacted selected the appropriate participant to provide information on the agency's behalf. A research ethics board application was not necessary as respondents were providing information on behalf of their agency. Survey responses were collected between Spring and Summer of 2023.

The statistical analysis was conducted with two (2) sets of data. Transport Canada provided confidential data related to the current set of designated crossings in the form of an MS Excel spreadsheet. This was then used to isolate the designated crossings in Transport Canada's Grade Crossing Inventory. Box plots, contingency tables, and regression and correlation studies were produced to examine the relationship between road attributes (AADT, train traffic, number of lanes, tracks, etc.) and the designation. Relationships and observations were noted and used to ascertain additional crossings that may be eligible to receive the designation based on the combination of certain characteristics.

The economic evaluation relied on a manufacturer deterioration report and several assumptions related to train length, number of axles per train, etc. The number of rubber insert replacements these products will require per year was determined and the corresponding cost was calculated. Several operational and economic scenarios were explored to provide a range of potential costs. The cost of these products and the rubber inserts was based on a purchasing invoice UNB had received from pasting testing.

6.3 Survey Results

No municipality or province that participated in the survey stated that they have a methodology for assigning the designation or a set of guidelines they follow to make this decision. A few road authorities stated that they have used flangeway filler products at grade crossings in the past but stated that they are unaware of product specifications and manufacturer information as products have been rarely used and installed and purchased by the railway companies. Two municipalities stated that they have plans to designate

additional crossings in the future (Winnipeg and Vancouver). The survey demonstrated that many road authorities are unaware of the how the flangeway gap impacts those with a disability, the designation itself, and the potential for flangeway filler products to be a solution to wheel entrapment. It is hypothesized that due to the limited research on flangeway filler products and their use in Canada, many road agencies do not feel obliged to install or purchase these products for their grade crossings.

6.4 Statistical Analysis

From the statistical analysis several road characteristics were determined to have a relationship with the designation. These relationships were determined through contingency tables and box plots. A summary of some of the more significant road attributes is provided below.

- Urban locations: Urban locations are 13.4 times more likely to have received the designation compared to rural areas. Many rural roads fall under the jurisdiction of provincial road authorities. The survey that was conducted determined that many provincial road authorities overlook assigning this designation to a grade crossing due to low amounts of pedestrian traffic in rural areas.
- Two (2) or more traffic lanes: Crossings with more than two traffic lanes are 12.8 times more likely to have received the designation. It is hypothesized that this is the result of two factors. First, grade crossings located on larger facilities may receive the designation more often because larger road facilities are typically located in larger urban areas with greater technical staff and resources. Second,

there is a correlation between vehicle traffic (and therefore the number of lanes at a crossing).

- Train/vehicle cross product greater than 50,000: Crossings with a cross product of 50,000 or more were found to be 9.3 times more likely to have received the designation. This suggests that busy grade crossings are more likely to be designated for pedestrians who use assistive devices.
- 25,000 or more vehicles per day: Crossings with more than 25,000 vehicles per day are 7.1 times more likely to have received the designation. High vehicle traffic is related to whether the designation is assigned to a grade crossing (with an exception to provincial freeways where little pedestrian traffic is experienced).
- Locations with two (2) or more tracks: Crossings with two or more tracks are 2.7 times more likely to have received the designation. This could be due to a variety of reasons. First, the greater the number of tracks at a location, the more obstacles in the path of travel for a person. Second, for each additional set of tracks, the crossing distance becomes one standard gauge larger (1435mm) which increases the time it takes for a person in a wheelchair to traverse a crossing.

Once these observations were noted, Transport Canada's Grade Crossing Inventory was filtered to assess if additional crossings have a combination of these variables. The prepared list of potential crossings is not intended to be an all-inclusive list of crossings that should receive the designation, however, a starting point for road authorities who have not yet designated a crossing or wish to evaluate more crossings.

6.5 Flangeway Filler Replacement Schedule and Cost Estimation

The preliminary cost evaluation estimated the frequency of replacements and expenditures over the 30-year period. Several economic environments and variations of train volumes were explored, focused on the existing inventory of designated crossings. It was estimated that the total cost of this infrastructure addition will range between $7.41 to $10.11 million dollars (PV over 30 years, upfront cost of $6.73 million and varying replacement expenditures). This work provides evidence that these products are a relatively economical solution when considering the total RSIP funding available for road authorities and the historical differences in past budgets and expenditures. A complete BCA would aid in estimating the net benefit, especially if considering the potential for new designated crossings.

6.6 Recommendations and Next Steps

1. Improve the Quality of Transport Canada Databases

The current quality of data within the Transport Canada Grade Crossing Inventory made a detailed statistical analysis difficult. Several grade crossings were missing information related to the road attributes and had incorrect street names or latitude/longitude information. Little information could be gathered from statistical tools like regression models or correlation studies given the current quality of the data. Other items could also be added to the inventory (for instance pedestrian traffic, road skew, etc.). In addition, it would be beneficial for Transport Canada's Grade Crossing Inventory to reveal what crossings are designated for those who have a disability. Currently, this piece of

information is not publicly available but would be in the interest of those who use assistive devices.

2. Engage with People Who Use Assistive Devices

It is well documented that the flangeway gap causes barriers for people using wheelchairs. Many instances of entrapment which has caused injury or death are documented in reports published by the Transportation Safety Board. It would be beneficial to gather input from people who rely on an assistive device to determine the scope of this issue. Furthermore, entrapment is not documented unless it has resulted in injury or death and the number of near misses is unknown. It would be beneficial to gather information on how common entrapment occurs.

3. Develop a Warrant System/Methodology for Assigning the Designation

Many road authorities have yet to designate a crossing. It is hypothesized that this due to a lack of warrant system or guidance from Transport Canada on when this is appropriate. Once the quality of data withing the Grade Crossing Inventory is updated, more advanced statistical tools could be used to ascertain what attributes are correlated with the designation. The largest city within Canada is currently waiting for guidance from Transport Canada on when this is appropriate, and many smaller communities with less technical staff are likely unaware of what constitutes a designated crossing. Having a detailed methodology or warrant would provide a standard/system for assessing crossings, rather than waiting for pedestrian inquiries or an event to occur that prompts the designation being assigned. This reactive method of designating crossings introduces risk to citizens, as wheelchair entrapment would potentially occur before a road authority is notified.

4. Field Testing of a Flangeway Filler on an Active Track

Currently, flangeway filler products do not have widespread adoption in Canada. In 2022, UNB and NRC began a research project to test several products for use in the Canadian environment. Based on this testing, a product has been identified to work effectively given the testing methodology. Further testing and an in-field test on an active track would be beneficial to encourage road authorities to invest in these products. The current lack of published research and limited testing has restricted the potential for an agency to make an investment in these products.

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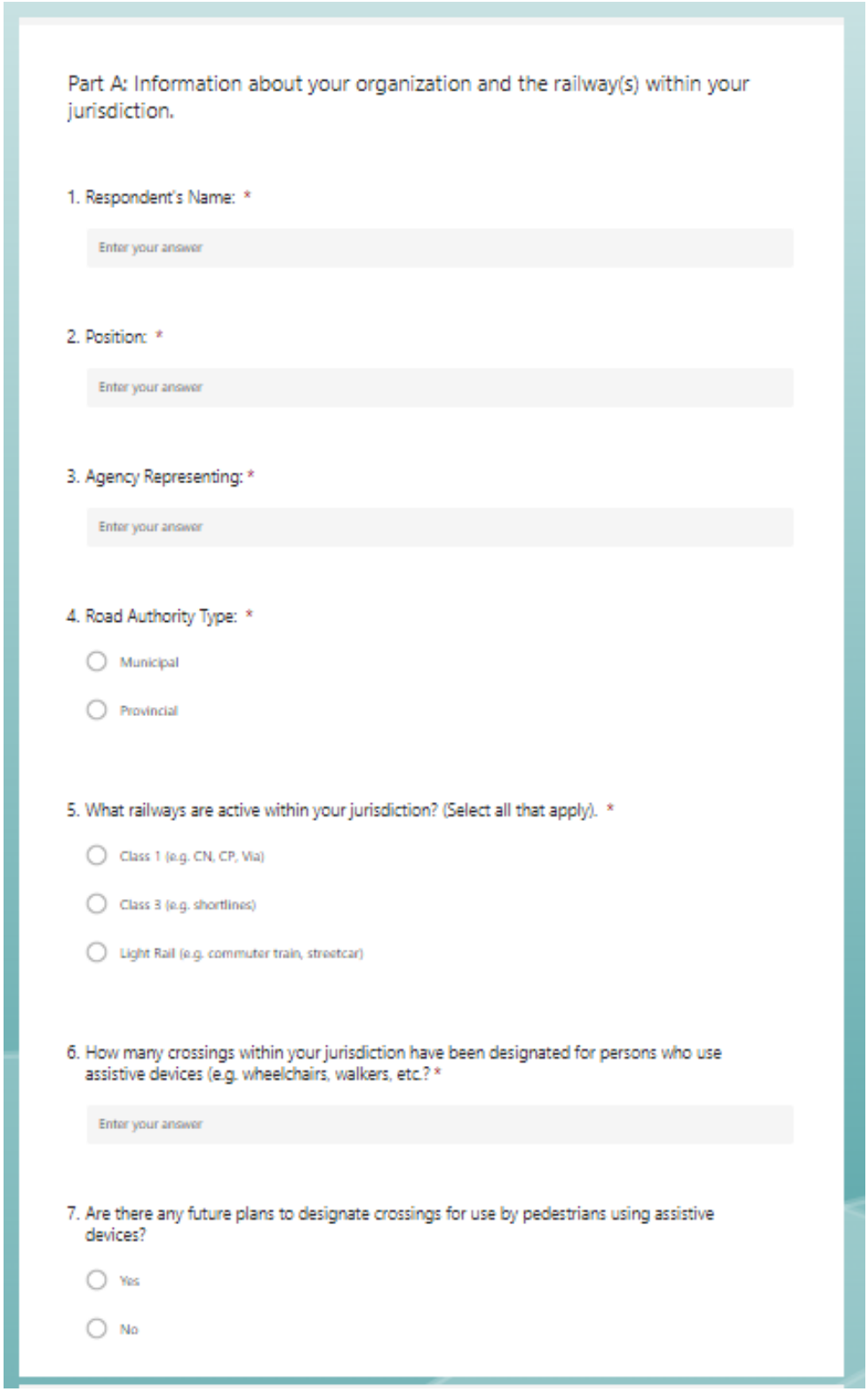
Appendix A- Survey



Part A: Information about your organization and the railway(s) within your jurisdiction.

1. Respondent's Name: *

Enter your answer

2. Position: *

Enter your answer

3. Agency Representing: *

Enter your answer

4. Road Authority Type: *

- Municipal
- Provincial

5. What railways are active within your jurisdiction? (Select all that apply). *

- Class 1 (e.g. CN, CP, Via)
- Class 3 (e.g. shortlines)
- Light Rail (e.g. commuter train, streetcar)

6. How many crossings within your jurisdiction have been designated for persons who use assistive devices (e.g. wheelchairs, walkers, etc.? *

Enter your answer

7. Are there any future plans to designate crossings for use by pedestrians using assistive devices?

- Yes
- No

Section 2

Part B: Understanding the designation process.

Recall that road authorities have jurisdiction over which crossings are designated for persons who use assistive devices. The following is intended to understand the process of assigning this designation.

8. What is the process to initiate the designation of a grade crossing for persons who use assistive devices? Please describe in terms of prevalence (Never, Rarely, Sometimes, Often, Almost Always). *

	Never	Rarely	Sometimes	Often	Always
Designation through internal analysis	○	○	○	○	○
In response to citizen inquiry	○	○	○	○	○
In response to request from different level in government	○	○	○	○	○
In response to railway request	○	○	○	○	○
other	○	○	○	○	○

9. Please elaborate on any other process or reason for initiating the designation (if applicable).

Enter your answer

10. Does your road authority use a formal or informal methodology (such as a warrant system) for designating grade crossings for person who use assistive devices? *

- ○ Yes
- ○ No

11. If answered "Yes" to Question 10, please describe this methodology.

Enter your answer

12. What is the typical time interval between a crossing receiving this designation and the grade crossing surface being modified (flangeway gap reduced)? Select the most applicable answer. *

- ○ Within a month
- ○ 1-6 months
- ○ 6-12 months
- ○ > 12 months
- ○ Does not apply because no designated crossings.

Part C: Use of flangeway fillers at grade crossings.

Flangeway fillers are rubber or foam products that can be used to reduce or eliminate the flangeway gap at grade crossings. The current use of these products in Canada is not well documented. The purpose of the following questions is to create an inventory of products currently in use across Canada.

13. Have flangeway filler products been installed on any grade crossings under the jurisdiction of your road authority? Specifically, products that eliminate or reduce the flangeway gap to provide a smoother crossing surface for wheelchairs and cyclists. *

- ◯ Yes
- ◯ No

14. If answered yes to the previous question, please provide specific product names and manufacturer information:

Enter your answer

15. Has your road agency received applications to include flangeway fillers from railway companies at grade crossings? *

- ◯ Yes
- ◯ No
- ◯ I don't know.

16. Has there been communication or interest expressed by railways in installing these products at grade crossings within your agency's jurisdiction? *

- ◯ Yes
- ◯ No

17. Are there plans at your agency to work with railways to test or procure flangeway fillers? *

- ◯ Yes
- ◯ No

Appendix B- Survey Instructions

Instructions: *You are invited to provide information for the inventory. There are 17 questions, and it should take approximately 10 minutes to complete. Please provide information directly into the survey below. If you have any questions, please contact me, William Morrison, at wmorris2@unb.ca*

Description: *Inventory of Canadian practices for designating rail crossings for persons using an assistive device and documenting use of flangeway fillers.*

We are creating an inventory of Canadian road agency practices for designating railway grade crossings for pedestrians using assistive devices (e.g. wheelchairs) as part of a research project at the University of New Brunswick undertaken by me, William Morrison (wmorris2@unb.ca), supervised by Trevor Hanson in the Department of Civil Engineering.

According to the Canadian Grade Crossing Regulations, road agencies are responsible for assigning this designation to crossings and notifying the railways. We wish to better understand how this designation process works across Canada. We are also documenting the use of flangeway fillers. Results will be summarized by jurisdiction, compiled into a thesis and publicly presented in publications and conferences, and respondents will be acknowledged in published work.

Curriculum Vitae

William Robert Morrison

UNIVERSITIES ATTENDED:

Graduate (2022-2024):	**Master of Science in Civil Engineering**
	University of New Brunswick
Undergraduate (2017-2022)	**Bachelor of Science in Engineering (Civil)**
	University of New Brunswick

PUBLICATIONS: none

CONFERENCE PRESENTATIONS:

Morrison, W, (June 2023) Motorcycle Use in Developing Nations and Potential Safety Improvement Strategies. Presented at 2023 CARSP/ITE Conference. Winnipeg, Manitoba