The Open Transportation Journal
DOI: 10.2174/012667121236330324123010582 8, 2025, 19, e26671212363303
ISSN: 1874-4478

RESEARCH ARTICLE OPEN ACCESS

Adopting a Safe Systems Approach to Road Safety: Using the Consolidated Framework for Implementation Research to Examine Injury Prevention and Transportation Professionals' Perceptions of Vision Zero in Five Canadian Municipalities

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Abstract:

Aims: The aim of this research is to highlight the perceptions and experiences of injury prevention and transportation professionals regarding Vision Zero and how the adoption of this strategy influences their work. Our results are useful to road safety researchers and practitioners who are interested in barriers and facilitators to implementing Vision Zero in the Canadian context.

Background: Road traffic collisions are a leading cause of injury in Canada. Vision Zero is a Safe Systems Approach (SSA) that accommodates human vulnerability and error, with the goal of zero deaths and injuries.

Objective: This paper enhances knowledge of Vision Zero in Canada and examines key barriers and facilitators using the Consolidated Framework for Implementation Research (CFIR).

Methods: Qualitative data were collected from injury prevention and transportation professionals in five municipalities: Vancouver, Calgary, Peel Region, Toronto, and Montréal. Interviews and virtual focus groups gathered data from participants across sectors: policy/decision-making, transportation, public health, non-profit, university researcher, community associations, and private. Thematic analysis was used to analyze the data.

Results: Data mapped onto six CFIR constructs across three domains: 1) Innovation, 2) Outer Setting, and 3) Implementation Process. Innovation Complexity, Local Attitudes, Local Conditions, and Assessing Context were identified as barriers and facilitators. Innovation Evidence Base and Partnerships and Connections were identified solely as facilitators.

Conclusion: Vision Zero implementation is complex and requires evidence. Local Attitudes and Local Conditions highlight the importance of partnerships for Vision Zero to be accepted and understood. Further, Vision Zero is a facilitator for road safety work. The CFIR domains and constructs elevate our understanding of how Vision Zero is implemented. Results are useful to municipalities interested in adopting and implementing Vision Zero in Canada.

Keywords: Road safety, Transportation, Vision Zero implementation, CFIR, Safe Systems Approach (SSA), Canada.

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Cite as: McCullogh E, Richmond S, Pike I, Fuselli P, Torres J, Hagel B, Macpherson A. Adopting a Safe Systems Approach to Road Safety: Using the Consolidated Framework for Implementa- tion Research to Examine Injury Prevention and Transportation Professionals' Perceptions of Vision Zero in Five Canadian Municipalities. Open Transp J, 2025; 19: e26671212363303. http://dx.doi.org/10.2174/0126671212363303241230105828

Received: October 16, 2024
Revised: November 27, 2024
Accepted: December 06, 2024
Published: January 03, 2025

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1. INTRODUCTION

Road traffic collisions are a leading cause of injury in the Canadian context [1] and globally [2, 3], which is concerning given that "road transport is central to economic growth and sustainable development worldwide, linking families to schools, workers to jobs, producers to consumers, communities to education and health care facilities" [4]. In 2004, the WHO released a *World Report on Road Traffic Injury Prevention,* drawing international attention to this significant public health concern. This was followed by the WHO global launch of the *Decade of Action for Road Safety 2011-2020* plan that sparked international commitment and investment to follow "a collective roadmap indicating critical areas for engagement" [5]. Collaboration across sectors such as transportation, health, education, and private was identified as crucial for the efficacy of this approach, and, according to the WHO, "this successful multi-cooperation should pave the way for progress in achieving national targets" [5].

More recently, the WHO released an updated global plan, *Decade of Action for Road Safety 2021-2030* [3], which more firmly calls on governments and stakeholders to prioritize and implement a Safe System approach (SSA) that aims to "dramatically improve road safety through an integrated, comprehensive process that recognizes the fallibility and vulnerability of human beings" [6]. A central tenant of the SSA is, "road safety should not be approached as a stand-alone issue but as an integrated component of many different policy agendas" [3]. Further, a SSA recognizes how layers and spheres of road safety components (*e.g.*, roads, speeds, road users, and vehicles) are interconnected and that an inclusive transportation system "provides safety for pedestrians, cyclists, and all vehicle operators and occupants regardless of their abilities" [6].

An example of a SSA for road safety is Vision Zero, which "sets the ultimate goal of zero fatalities and serious injuries on our roadways" [7]. The holistic and comprehensive SSA is necessary for achieving Vision Zero, a strategy that has been adopted by provinces, municipalities, and regions throughout Canada [8, 9]. Further, since its inaugural national adoption in Sweden in 1997, Vision Zero has been used to inform road safety strategies at varying levels of government in Norway, the Netherlands, Germany, Poland, Lithuania, Australia, the United States, and India, to name a few [10]. Success has varied, with Norway [11], the Netherlands [12], and Germany [13] seeing a clear reduction in the number of road crash fatalities, for example, while results in Poland [14] and initial attempts in Australia fell short [15]. Of significance are the contextual differences in which Vision Zero is applied, and increasing our knowledge of these particularities in the Canadian context underlies the motivation for this current research.

This paper utilizes data collected for a pan-Canadian project examining barriers and facilitators to built environment (BE) change broadly from the perspectives of injury prevention and transportation professionals [16, 17]. A novel finding of this study is that Vision Zero was identified by participants as a significant factor in their road safety work. This research makes an important contribution to the literature on Vision Zero in the Canadian context because currently, there are no studies that center the experiences of injury prevention and road safety professionals regarding Vision Zero's impact on their road safety work. Thus, the aims of this paper are to highlight these factors so as to increase our knowledge of *how* Vision Zero is understood and applied in Canada, identify barriers to and facilitators of the implementation of Vision Zero in the Canadian context from the perspectives of our participants, and to elevate our understanding of these barriers and facilitators by mapping them onto the Consolidated Framework for Implementation Research (CFIR) [18]. Currently, the CFIR has not been used to examine qualitative data pertaining to Vision Zero. However, Vision Zero is an innovation that requires implementation, which is why we chose an implementation science framework [19, 20], such as the CFIR [18], to contextualize our findings.

Given the lack of research on implementing Vision Zero in the Canadian context at the municipal level and our participants' discussions of Vision Zero when asked about barriers and facilitators, broadly, findings presented in this paper highlight key learnings that can support municipalities in the adoption and successful implementation of Vision Zero in Canada. In addition, this study increases our knowledge of Vision Zero as an innovation for road safety, as well as the implementation context, by examining the perceptions of injury prevention and transportation professionals through the CFIR lens. The results are useful for municipalities in the midst of implementing a Vision Zero approach and can also encourage the adoption of Vision Zero across Canada because they provide previously unknown insights about barriers and facilitators from the professionals working at the ground level advocating for these changes.

2. BACKGROUND INFORMATION

In this section, we provide an overview of Vision Zero as a SSA to road safety to situate our results within the broader context of road safety, as well as a summary of Vision Zero adoption and implementation in the Canadian context, broadly, and within the municipalities represented in our study, specifically. Vision Zero was adopted by the Swedish Parliament in 1997 as an innovative road safety strategy and aims to eliminate deaths and serious injuries by changing the structure and function of the road transportation system [21, 22]. Vision Zero is a novel approach that prioritizes safety over mobility and reduces costs by emphasizing the responsibility of system designers, declaring that "the fatalities and serious injuries that result from preventable crashes are morally unacceptable" [23]. This strategy was the result of the Swedish Road Administration's work on developing a SSA for road safety, a response to the ineffectiveness of past traffic safety measures that "focused on adapting the individual to the road transport system rather than adapting the road transport system to the individual" [24].

According to the Government of Sweden, "Vision Zero is an approach wherein the responsibility for transport safety is shared between individual transport system users and "system designers" (the entities that shape the system, such as the automotive industry, lawmakers, and infrastructure owners)" [25]. Emphasis on shared responsibility across sectors is an integral and unique feature of the Vision Zero approach [24, 26, 27]. In other words, Vision Zero is a contract between road users and system designers, where road users behave within the system limits and system designers guarantee road users' safety [22, 28, 29]. Further, the connection between Vision Zero and the application of a public health perspective to road safety was also emphasized [30], which is reflected in the WHO commitments to road safety globally [3, 5, 31]. In addition, as a long-term goal for road safety, elements of Vision Zero were adopted by the United Nations *Decade of Action for Road Safety 2011-2020* and *2021-2030*, calling for "radical alternatives to those entailed by the traditional approach to road safety" [32].

From the perspective of injury prevention, the Vision Zero approach aligns with the goals of preventing road traffic injuries and deaths [33] and, more broadly, "reducing the negative impact of the transportation system on human health" [25]. As noted by Amit and colleagues, "road safety is an important and evolving public health issue" [34], which also prioritizes vulnerable road users (VRUs) who experience disproportionate safety risks and injury rates due to the current system of roads [9, 35, 36]. According to Christie, "if we do not increase efforts to improve safety for pedestrians and cyclists, then we may not be able to mobilize these modes to achieve other societal goals aimed at health and wellbeing" [25]. VRUs are of particular importance for this study because injury prevention and transportation professionals' discussions of Vision Zero emphasized the need to prioritize the safety of groups who experience disproportionate vulnerability and injury rates due to the design of the BE. Further, the emphasis on human health, more broadly, is reflected in the *Renewed Commitment to Vision Zero: Intensified Efforts for Transport Safety in Sweden* [25], which recognizes the interdependence between transport, health, and safety. The prioritization of safety over cost has led to the adoption of Vision Zero in other areas of public health and safety [37, 38], such as workplaces and construction and mining industries [23].

2.1. Safe Systems Approach (SSA) and Vision Zero

As noted above, a SSA offers a new way of thinking about road safety [22, 39, 40]. Developed by the International Transport Forum (ITF) of the Organization for Economic Co-operation and Development (OECD), the SSA for road safety is characterized by four underlying principles: 1) People make mistakes that can lead to crashes. The transport system needs to accommodate human error and unpredictability; 2) The human body has a known, limited physical ability to tolerate crash forces before harm occurs. The impact forces resulting from a collision must, therefore be limited to prevent fatal or serious injury; 3) Individuals have a responsibility to act with care and within traffic laws. A shared responsibility exists with those who design, build, manage and use roads and vehicles to prevent crashes resulting in serious injury or death and to provide effective post-crash care; and 4) All parts of the system must be strengthened in combination to multiply their effects, and to ensure that road users are still protected if one part of the system fails [41]. Vision Zero is an example of such an approach, "which can be used to guide the selection of strategies and then the setting of goals and targets" [22].

The four SSA principles, which apply to every part of the road system, are operationalized in concert with the five pillars of road safety: 1) management; 2) safer roads and mobility; 3) safer vehicles; 4) safer road users; and 5) post-crash response [42]. Road safety strategies, such as the WHO global plan for the *Decade of Action for Road Safety 2011-2020* outline a set of national-level activities for implementing road safety strategies according to these five pillars [5]. However, it is important to note that the more recent global plan for the *Second Decade of Action for Road Safety 2021-2030* includes speed management as a sixth pillar:

Managing speed is critical to the effective implementation of the Safe System approach. It is a cross-cutting risky factor and is addressed through actions relating to different elements of the Safe System, such as multimodal transport and land use planning, infrastruc-ture, vehicle design and road user behaviour [3]. This illustrates how Safe System implementation requires "reducing reliance on a single pillar of action" and "encouraging a broad range of interventions" [41].

2.2. Critics of Vision Zero

Despite the appeal and success of Vision Zero, it has received criticism in spheres of academic literature and public debate. For example, focus on individual road users as a cause of collisions (SSA principle 1) and, thus, partially responsible for making changes to their driver

behaviour (SSA principle 3) has been challenged; specifically, McIlroy and colleagues argue that "the fallibility of drivers should not be a central theme to a road safety philosophy, and that the blame should not be apportioned to only the road users and system designers" [4]. Alternatively, a multitude of organizations and actors contribute to system outcomes and the interconnections (or lack thereof) are of equal importance when crafting road safety strategies and policies [43, 44]. In addition, Abebe and colleagues outline three types of arguments against Vision Zero: 1) moral arguments, 2) arguments concerning the (goal setting) rationality of Vision Zero, and 3) arguments aimed at the practical implication of the goals [23]. The authors provide robust descriptions and literature illustrating the depth and breadth of these arguments, content which falls outside the scope of this current paper. Thus, below, we provide a brief overview of the three argument types with accompanying examples.

Moral criticisms include claims that it is morally acceptable to die on the road, given that driving is a risky activity in which people voluntarily engage [45]; however, Abebe and colleagues assert, "most of those who are killed and seriously injured in road traffic did not wish to take any risks. They had no other choice than to travel in the risk traffic system that we have" [23]. It has also been argued that some Vision Zero measures restrict the freedom, autonomy, and privacy of road users, thus making it unjust [46, 47]. Critics questioning the rationality of Vision Zero have argued that the goal, "no one shall be killed or seriously injured as a consequence of accidents in road traffic" [32], is unrealistic and, thus, an irrational pursuit resulting in counterproductive investment [48]. Vision Zero has also been criticized as irrational because it does not provide precise or serviceable goals for public policy [49, 50]. Lastly, practical criticisms include the ways in which safety is measured [51, 52], that there is *too little* responsibility assigned to system designers [24], and that there is *too much* responsibility assigned to system designers, which "will reduce drivers' sense of responsibility and make them drive more dangerously" [23].

Despite the range of criticisms, Vision Zero has achieved international recognition [10] and been identified as "an effective policy to prevent road traffic injury by the WHO in 2004" [33]. Thus, increasing our understanding of *how* Vision Zero is understood and implemented across a variety of contexts is crucial [37, 53-55].

2.3. Vision Zero in the Canadian context

Several cities and provinces across Canada of various sizes, both urban and rural, have adopted Vision Zero [56]; however, road safety efforts began prior to Vision Zero implementation. For example, the Canadian Council of Motor Transport Administrators (CCMTA) introduced *Canada's Road Safety Strategy 2025* designed to continue, "national effort in addressing important road safety issues in Canada by providing a framework for governments and other road safety stakeholders to establish their own road safety plans, objectives, and interventions" [57]. As asserted in the national strategy, "each province and territory will take ownership of its own individual strategy, while cooperating and collaborating with all levels of government, as well as with other stakeholders" [34]. Further, Parachute, Canada's national charity dedicated to injury prevention, has taken a national lead to "share current research and best practices in road safety, support data-driven models, create and disseminate evidence-based resources, and bridge key multisector players together to increase the overall awareness and effectiveness of the Vision Zero approach" [56]. To date, British Columbia, Manitoba, and Quebec are the only provinces that have adopted Vision Zero, along with 25 cities and three regions [58].

Municipalities included in the scope of this study have adopted Vision Zero as a road safety strategy: Vancouver, Calgary, Peel Region, Toronto, and Montréal (Table **1**). Consistent across municipal policies is the understanding that "death and serious injuries are not inevitable. They are preventable" [58]. Further, municipal road safety strategies all contain an iteration of an action plan with emphasis or focus areas explaining *how* Vision Zero goals will be actioned and achieved (Table **2**), where emphasis areas are identified by "types of collisions identified as primary safety concerns through public consultation and review of Regional and local municipal collision data" [59]. While there is some variation across municipal road safety strategies VRUs, such as pedestrians and cyclists, are consistently prioritized, as well as the need for collaboration and partnerships to effectively implement Vision Zero goals [6].

Table 1. Date of Vision Zero adoption and accompanying road safety plan by municipality.

Municipality	Population*	Land Area (km^2)*	Date of VZ Adoption	Vision Zero Plan
Vancouver	662 248	115.176	December 2016	*Moving Towards Zero Safety Action Plan* [60]
Calgary	1 306 784	820.617	November 2018	*Safer Mobility Plan* [61]
Peel Region	1 451 022	1 247.449	December 2017	*Vision Zero Road Safety Strategic Plan 2018-2022* [59] *2020 Vision Zero Road Safety Strategic Plan Update – Year Three* [65]
Toronto	2 794 356	631.098	July 2016	*Vision Zero: Toronto's Road Safety Plan 2017-2021* [58] *Vision Zero 2.0 – Road Safety Plan Update* [66]
Montréal	1 762 949	4 670.098	September 2016	*2022-2024 Plan d'action Vision Zéro décès et blessé grave/2022-2024 Vision Zero Deaths and Serious Injuries Action Plan* [62]

Note: *Statistics Canada [90].

Table 2. Vision zero action plans and emphasis areas by municipality.

Plan/Refs.	Action Plan	Emphasis Areas
Vancouver [60]	1. Enhanced Data 2. Evaluation and Prioritize Locations 3. Engineering Action Plan 4. Education and Public Outreach 5. Enforcement	1. Transportation-fatality, collision, and injury data 2. Intersections 3. Rectangular rapid flashing beacons, accessible pedestrian signals, leading pedestrian intervals 4. Cooperate with safety partners 5. Work with Vancouver Police Department to address priority intersections
Calgary [61]	1. Engagement 2. Engineering 3. Education 4. Enforcement 5. Evaluation and Innovation	1. Collect stakeholder and citizen feedback 2. Road safety reviews, audits, and screenings 3. Online content to inform public of traffic countermeasures 4. High-visibility targeted enforcement 5. Evaluate interventions and research of emerging best practices
Peel Region [59, 65]	1. Engineering 2. Education 3. Enforcement 4. Empathy	1. Intersections 2. Aggressive Driving 3. Distracted Driving 4. Impaired Driving 5. Pedestrians 6. Cyclists
Toronto [58, 66]	1. Engineering Safety Measures 2. Education Safety Measures 3. Technological Safety Measures 4. Enforcement Activities	1. Pedestrians 2. School Children 3. Older Adults 4. Cyclists 5. Motorcyclists 6. Aggressive Driving and Distraction
Montréal [62]	1. Mobility Planning 2. Street Infrastructure 3. Users 4. Vehicles 5. Land Use Planning	1. Unexpected Behaviours 2. Vehicle Characteristics 3. Deficient Traffic Signals 4. Visual Obstructions at Intersections 5. Impaired Cognitive State of User

2.3.1. Prioritization of VRUs

As illustrated in the results, the safety of VRUs is a priority for the participants in this study, which is also reflected in the municipal road safety plans and highlights a concerning trend: "globally, the burden of road traffic fatalities and injuries is disproportionately borne by pedestrians, bicyclists, and motorcyclists, who account for more than half of all deaths on the road" [23]. For example, the Vancouver *Moving Towards Zero Safety Action Plan* [60] prioritizes locations for road safety interventions according to VRUs, such as older adults and children, and the Calgary *Safer Mobility Plan* [61] identifies targets for reducing VRU (pedestrian, cyclist, and motorcyclist) collisions. The Montréal *Vision Zero Deaths and Serious Injuries Action Plan* "is an essential way to ensure the safety of all users, beginning with the most vulnerable" [62] and, in Toronto, "the Plan prioritizes the safety of pedestrians, statistically our most vulnerable road users, through a range of initiatives from the creation of Pedestrian Safety Corridors and Senior Safety Zones with lower speed limits to physical modifications and intersections" [58]. In addition, the Peel Region *Road Safety Strategic Plan* shows a commitment to, "working together to eliminate traffic deaths and make our streets safe for everyone in the Region, no matter where you live and how you choose to travel" [59]. However, it is important to note that road users who experience a disproportionate risk of road-related injury and death are not inherently vulnerable; they are *made* vulnerable by the existing system of roads that prioritize motor vehicles [17, 63], and Vision Zero's emphasis on changing the system of roads as well as road user behaviour can lead to significant structural changes.

2.3.2. Commitment to Collaboration

As noted above, a central tenant of Vision Zero is its emphasis on collaboration and partnerships in order to achieve road safety goals, which are articulated in municipalities' Vision Zero plans and strategies. For example, the Calgary *Safer Mobility Plan* states, "ongoing partnership and cooperation are instrumental in achieving maximum impact campaigns and initiatives to achieve our traffic safety targets" [61], while the Peel Region *Vision Zero Road Safety Strategic Plan 2018-2022* was deve-loped, "through a collective effort from a number of key stakeholders including Peel Public Health, Peel Regional Police, the Ontario Provincial Police, local municipalities, partner agencies, and community groups that share a common interest in improving road safety" [59]. In Toronto, the *Road Safety Plan 2017-2021* asserts a similar commitment:

> Key to our success will be the strength of partnerships. Through collaboration with other agencies, orders of government, stakeholder groups, and members of the public we will continue to develop new solutions and identify emerging concerns to effectively improve the safety of our transportation system [58].

The Montréal *Vision Zero Deaths and Serious Injuries Action Plan* states, "Vision Zero is an undertaking that involves multiple partners at the local, regional, provincial, and even federal level, who share the responsibility for decision making, for the implementation of the planned actions and accountability" [62]. Lastly, the B.C. *Road Safety Strategy 2025* asserts, "road safety is a shared responsibility that involves collaboration and engagement with many road safety partners" [64], which is reflected in the Vancouver *Moving Towards Zero Safety Action Plan* [60].

2.3.3. Updated Vision Zero plans: Region of Peel and City of Toronto

Peel Region [65] and the City of Toronto [66] released follow-up reports highlighting the successes and challenges of their first Vision Zero strategies. The Toronto *Vision Zero 2.0 – Road Safety Plan Update* "reiterates that human life should be prioritized over all other objectives within all aspects of the transportation system" and offers "a renewed emphasis on data-driven decision making and prioritization" [56]. While the first City of Toronto Vision Zero action plan highlighted four priorities (engineering, education, technological, and enforcement), the updated plan draws solutions from the five Es: 1) engineering, 2) enforcement, 3) education, 4) engagement and 5) evaluation [66]. A notable change is the addition of an evaluation component, aligning with the evidence-based focus of SSAs on road safety.

The Toronto Vision Zero 2.0 plan also includes an *Equity Impact Statement*, which highlights how Vision Zero "is an important mechanism to remove barriers for equity-seeking groups by prioritizing vulnerable road users" [66]. It is important to note that the language of equity-*seeking* has been contested and replaced by equity *deserving* because,

To seek something is to ask for something from someone else. And if equity is a right, which it is, no one should be put into the position of having to ask for it. The act of asking for something puts the asker in a vulnerable position [67].

However, the Toronto Vision Zero 2.0 plan heightens a focus on equity by cross-referencing collision data with neighborhood demographics and "use this analysis to target improvements where they will benefit residents most vulnerable to serious injury or death" [66].

The Peel Region *2020 Vision Zero Road Safety Strategic Plan Update – Year Three* identified challenges related to the COVID-19 pandemic: "while overall traffic volumes dropped significantly, goods movement increased, many residents shifted to walking and cycling, and open roads gave rise to an increase in speeding" [65]. As a result, the total number of collisions overall decreased in 2020 but the number of fatal collisions increased. The plan shows how road traffic changes were addressed in the Region and provides updates on road safety interventions (*e.g.*, automated speed enforcement, automated school bus arm camera and micro-mobility) that were implemented to address concerns across the original six emphasis areas (Table **2**). The report also highlighted efforts by Regional councilors to connect with Ontario's Ministry of Transportation representatives to "discuss the need for provincial funding for public transit projects and goods movement infrastructure in Peel" [65].

The following section will detail the data collection and analysis procedures employed for this research, which examines injury prevention and transportation professionals' perceptions of Vision Zero in their municipality. As previously noted, the motivation for this work is to highlight *how* practitioners (those responsible for implementing Vision Zero interventions) understand Vision Zero and its effectiveness. To recall, the larger project from which these data are derived sought to explicate barriers and facilitators to BE change, broadly, and did not specifically focus on Vision Zero. However, participants discussed Vision Zero and how it showed up in their work, findings that are relevant to road safety efforts in the Canadian context. Further, according to Fuselli, "for Vision Zero to be successful, there needs to also be an overarching agreement on the issues and the systems nature of the problems and the required solutions" [56], and our paper contributes to this aim.

3. MATERIALS AND METHODS

Data utilized for this study included qualitative data from key informant (KI) interviews and virtual focus groups (VFGs). Interview and VFG data were collected for a larger pan-Canadian study examining barriers and facilitators to BE changes in five Canadian municipalities: Vancouver, Calgary, Peel Region, Toronto, and Montréal [16, 17]. Qualitative data, such as data derived from interviews and virtual focus groups, provides more detailed descriptions of barriers and facilitators to BE change and, in the case of this project, allowed participants to offer details that included Vision Zero. Thus, a significant theme highlighted in those data was Vision Zero and how it influenced road safety work, particularly with regard to BE changes that enhance the safety of VRUs. This current research more fulsomely examines data pertaining to Vision Zero and how injury prevention and transportation professionals perceive its effectiveness and influence in the context of their road safety work.

3.1. Data Collection

We utilized interview and focus group data for our study. The *Human Participants Research Protocol* was approved by York University's Office of Research Ethics (e2019-174).

The procedures performed were in accordance with the ethical standards of York University (Canada), the Canadian Institutes for Health Research, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants.

Purposeful sampling techniques [68, 69] were employed by a member of the research team in each municipality to recruit participants for KI interviews and VFGs. Research team members responsible for conducing the KI interviews were master's level graduate students supervised by the second, third, fifth, sixth, and seven authors. There was a mix of male and female graduate students involved. Professional road safety colleagues of research team members were contacted during the first round of recruiting, followed by a snowball sampling technique [70] that asked confirmed participants to circulate the opportunity to contribute to this research to other members of their professional networks. E-mail, Twitter, and LinkedIn were used to contact potential participants. The average response rate was 87%. Those who chose not to participate did not provide a reason. Lastly, saturation did not guide our data collection, as it is not required to yield useful and meaningful results [71].

Table 3. Number of participants by sector [17, 64].

-	Policy/Decision-maker (current and former city councillors; chiefs of staff; policy advisors)	Transportation (managers of traffic operations; traffic safety analysts; traffic and transportation engineers; transportation project managers)	Police Services (traffic operations)	Public Health (chronic disease and injury prevention specialists; health promoters and planners; BE specialists)	University Researcher (population health)	Non-profit (active travel; sustainable neighbour-hoods; school travel planning)	Schools/ Schoolboard (teachers; administrative staff)	Community Association (active & safe travel programs)	Private (road safety; engineer)
Vancouver	0	2	0	2	1	4	3	0	1
Calgary	3	2	0	2	0	6	1	1	1
Peel	1	6	0	5	0	0	0	0	0
Toronto	1	4	2	4	0	3	3	0	1
Montréal	5	1	0	1	3	7	3	0	1
Total	**10**	**15**	**2**	**14**	**4**	**20**	**10**	**1**	**4**

Table 4. Number of KI and VFG participants by municipality [17, 64].

-	KI Interviews	VFG Participants	KI and VFG	Total
Vancouver	6	11	4	13
Calgary	14	12	10	16
Peel	6	9	3	12
Toronto	9	13	4	18
Montréal	7	14	0	21
Total	**42**	**59**	**21**	**80**

We conducted KI interviews with 42 participants and five VFGs with a total of 59 participants, all of which were injury prevention and transportation professionals working across several sectors involved in road safety: policy/decision-making, transportation, public health, police services, non-profit, university research, community associations, and private (Table **3**). Participants were made aware of the purpose and scope of the research. Only the interviewer and interviewee were present for the interviews. There were no repeat interviews; however, several participants (n=21) participated in a KI interview and VFG to ensure that the VFGs were populated. The KI interviews were conducted in person prior to the VFGs. The focus groups were initially planned in person with different participants, but due to pandemic challenges with recruitment, we reached out to KI interview participants and offered them the opportunity to patriciate in the VFG. The questions guiding the research, from which these data are derived, were informed by the first iteration of the CFIR [72, 73] and asked, *what are the barriers and facilitators to BE change at a local level?* The design prioritized the perspectives and experiences of injury prevention and transportation professionals because, in the field of health and well-being scholarship, "qualitative research offers rich and compelling insights into the real worlds, experiences, and perspectives of patients and health care professionals" [74].

Semi-structured KI interviews were conducted from January to December 2019 by members of the research team in each municipality (Table **4**). A semi-structured interview guide was used by research team members to guide the one-on-one conversations conducted in-person or virtually (*i.e.*, Skype or Zoom). In Calgary, one interview was conducted with two participants and in Peel Region, three interviews were conducted each with two participants to accommodate participants' time. Interviewers attended virtual group meetings to ensure consistency and discuss the interview guide, which asked participants to describe barriers and facilitators experienced in their road safety work. Interview times ranged from 30-90 minutes. Interviews were audio recorded and then transcribed verbatim by the interviewer. French transcripts from Montréal participants were translated into English and reviewed by the Montréal research team leader to ensure accuracy.

Due to restrictions related to the COVID-19 pandemic, focus groups were conducted virtually from July to November 2020. VFGs were facilitated using a third-party platform called *Upwords* [75], which supported an online discussion board for participants to respond to interview questions and other participants' contributions within the span of one week (Monday-Friday). The number of participants per VFG varied by municipality (Table **4**). Similar to the KI interview guide, participants were asked to reflect on barriers and facilitators they experienced in their road safety work within their organization and sector. In addition, the VFG interview guide asked specifically about the impact of Vision Zero and how it influenced participants' work. The change in the interview guide was due to the rise in Vision Zero discussion and uptake among road safety professionals in Canada [9, 57]

and was prompted by researchers added to the team after KI interviews were complete. Responses from participants were monitored and follow-up questions were asked by the first author and an *Upwords* facilitator. During this process, the first author identified themes and made handwritten notes. The VFG platform created a transcript of participants' conversations. VFG and KI interview participants were given the opportunity to review their transcripts and make changes. No participants asked for changes to be made to their transcript.

3.2. Data Analysis

KI interview and VFG data were analyzed inductively using thematic analysis (TA), which is a flexible and well-suited approach that adapts to the "varying needs of a wide variety of research projects" [74]. The flexibility of TA facilitated the identification of patterns across the data [76]. Using this inductive process, we extracted data that explicitly mentioned Vision Zero, specifically, data pertaining to Vision Zero and *how* it was perceived by injury prevention and transportation professionals working across sectors in road safety. Further, TA is useful when utilizing the CFIR [18] to analyze qualitative data because it enables clear and meaningful organization of themes and codes across the CFIR domains and constructs.

The first author familiarized themselves with the data by reading and re-reading interview and VFG transcripts. Handwritten notes were made during this stage. Using NVivo (QSR International Pty Ltd, version 12.6.1, 2019), data pertaining to Vision Zero were identified before being coded according to the CFIR. A combination of semantic and latent coding was conducted whereby the first author reviewed each data extract in relation to the CFIR domains and constructs and organized the data accordingly. The first author reviewed and circulated the CFIR-informed codes to the second and last authors before solidifying the domains and constructs under which each data extract was housed. This process is akin to the organizing and solidifying of themes in the TA process [76]. Results were written and organized according to the CFIR domains and constructs, which involved "weaving together the analytic narrative and data extracts" [77].

3.3. Analytical Framework

We utilized the Consolidated Framework for Implementation Research (CFIR) [18] to situate and analyze our findings within the broader landscape of implementation science and road safety. To recall, Vision Zero is a contract between road users and system designers [22, 28, 29] and the *implementation* of this contract rests on the safe design of the entire road system by designers, road users following the rules for using the road transport system set by designers, and "if the road users fail to obey these rules due to lack of knowledge or acceptance or ability, or if injuries occur, the system designers are required to take necessary further steps to counteract people being killed or seriously injured" [29]. To date, the CFIR has not been used to examine the implementation of Vision Zero as an innovation, nor has it been used to contextualize practitioners' perceptions of the efficacy of Vision Zero in the Canadian context.

Broadly, implementation science is an emerging field of diverse researchers who seek to understand how to better translate research into practice [20, 53, 78, 79]. Beginning in the health field, implementation science "is the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice and, hence, to improve the quality and effectiveness of health services" [20]. To do so, implementation science moves beyond individual care to also account for the provider, the organizations, systems, and policy levels [20, 79]. Implementation science utilizes a range of models and frameworks [80], such as the CFIR, which offer efficient ways of generalizing findings across diverse settings and contexts [19, 81].

The CFIR is "a practical theory-based guide for systematically assessing potential barriers and facilitators to guide tailoring of implementation strategies and adaptations for the innovation being implemented" [72], and Vision Zero, as a philosophy, contract, and approach, is an "innovative road safety policy" [32]. Thus, we chose to utilize the CFIR to examine the adoption and influence of Vision Zero in the Canadian urban context from the perspectives of injury prevention and transportation professionals. The CFIR provides an entry point into exploring how Vision Zero was adopted and implemented, as well as the impact Vision Zero uptake had on municipalities' road safety strategies. In other words, the CFIR is useful for contextualizing *what* our participants' perceptions reveal about *how* Vision Zero influences their road safety work and what barriers and facilitators they experience.

Since its initial development [73], the CFIR has become one of the most frequently cited implementation science frameworks [82], consisting of 5 domains – intervention characteristics, individual characteristics, inner setting, outer setting, and process – and 37 operationally defined constructs [72]. As an approach to implementation science, the CFIR "embraces the reality that contextual factors are active," and there are "dynamic forces working for and against implementation efforts in the real world" [18]. However, more recently, Damschroder and colleagues released an updated CFIR that expands the number of constructs within the five domains to more adequately address equity-related determinants in implementation: 48 constructs and 19 subconstructs across five domains (with one domain including two subdomains) [18]. Changes to the original CFIR framework were informed by a literature review examining uses of the CFIR, as well as a survey of the authors included in the literature review, to "elicit in-depth feedback about their experience using the CFIR" [18].

There are some significant modifications made to the language used in the updated CFIR that increase its utility, making it more flexible and applicable to a variety of innovations. For example, Damschroder and colleagues shift the language from *patients* in the first iteration to *recipients*, referring to "individuals intended to benefit from the innovation" [18]. Further, the language of *stakeholders* has been removed and, instead, refers to "people who have influence and/or power over the outcome of implementation efforts" [18]. This enhanced focus

aligns with the municipal road safety plans represented in this study, which prioritizes the safety of VRUs (*e.g.*, pedestrians, cyclists, children, and older adults) in how road systems and safety interventions are designed and implemented [23, 39].

4. RESULTS

Data gathered from participants about Vision Zero mapped onto six CFIR constructs across three domains: 1) Innovation, 2) Outer Setting, and 3) Implementation Process (Table **5**). The majority of data mapped onto the Outer Setting Domain; specifically, Local Attitudes, Local Conditions, and Partnerships and Connections constructs, aligning with Vision Zero as a cross-sectoral and systems level approach to road safety.

4.1. Innovation

Data collected from participants about Vision Zero mapped onto two constructs within the Innovation domain: 1) Innovation Evidence Base and 2) Innovation Complexity.

4.1.1. Innovation Evidence Base

Several participants discussed how Vision Zero is an evidence-informed approach to road safety, which maps onto the second construct under the first domain. For example, a Peel Region (public health) participant explained the reason for adopting Vision Zero: "Vision Zero was selected as it is evidence-informed and there was consensus among various departments and regional council to pursue." A Toronto (transportation) participant discussed the Vision Zero 2.0 plan: "my latest work at the city was developing Vision Zero 2.0, which is the update to the road safety plan. So, refocusing our road safety efforts and putting a stronger data-driven lens on it." In addition, another Toronto (transportation) participant explained how Vision Zero 2.0 improved on the original iteration:

Our Vision Zero 2.0 plan looks at the data in a deeper way. It brings the conversation of equity forward as well, which wasn't forward in our Vision Zero plan in 2016, either. And it emphasizes actions that are not just about the pavement markings and signage changes that we can make but that we need to do geometric changes.

This passage highlights the important connections between data and equity for VRUs. It also shows how transportation professionals in Toronto perceive Vision Zero as a road safety strategy.

4.1.2. Innovation Complexity

As an innovation, Vision Zero is complex and requires many components working together, as demonstrated by the number of items in municipalities' Vision Zero action plans (Table **2**). For example, a Calgary (non-profit) participant described elements of their road safety plan: "Vision Zero Calgary is working towards a safer BE, including retrofitting residential streets with calming measures, working on city initiative for 30km/hr residential blanket bylaw with specific design measures to reduce speed through infrastructure." In addition, a Vancouver (public health) participant explained how Vision Zero is being integrated into the City traffic plan:

The traffic plan includes focused speed management, working with police enforcement, and really stepping back to have a more integrated approach. It looks not only at the drivers but also the children who are at risk, trying to redesign the road network better.

This highlights the complexity of the road traffic system and how road safety strategies (*e.g.*, speed reduction) implemented for Vision Zero influence road safety on several levels.

4.2. Outer Setting

Participants discussed the contexts in which Vision Zero is implemented and how this influences the implementation process. Data significant to the Outer Setting domain mapped on to three constructs: 1) local attitudes, 2) local conditions, and 3) partnerships and connections.

4.2.1. Local Attitudes

Participants discussed how Vision Zero requires support from the local communities in which road safety interventions are implemented, as stated by a Calgary (transportation) participant: "for Vision Zero to succeed, it needs to be safe for everyone and we need buy-in from all users." Further, a Peel Region (public health) participant emphasized the importance of "having all partners with a shared understanding of Vision Zero, and in practice making safety the priority in decision making." According to a Vancouver (public health) participant, shifting local attitudes requires.

Making sure people are aware that we're humans that inherently make mistakes and that we're creating a system and putting policies in place that aren't focused on the individual behavior so much as changing the system in which we act, work and play.

This observation was echoed by a Peel Region (public health) participant: "we need more information and education about Vision Zero."

In the Calgary context, a challenge to changing local attitudes and increasing understanding about a SSA is how these changes are messaged: "the language regarding Vision Zero is so important so that people are brought together rather than split into groups" (Calgary, transportation). Another Calgary (transportation) participant explained concerns with how Vision Zero prioritizes active transportation and that the messaging positions drivers as responsible for road traffic injuries and deaths:

Vision Zero in North America (in my experience) has been so strongly focused on active transportation that I'm concerned it has contributed to opposition from those who self-identify as "motorists" (even if they often walk or cycle) and quickly devolves to blaming other users rather than everyone agreeing that the system could be better for everyone.

This messaging risks motorists rejecting or resisting Vision Zero, which is problematic because "this biased presentation of what Vision Zero is has contributed to misunderstanding and opposition of something that should be good for all" (Calgary, transportation).

4.2.2. Local Conditions

Local conditions include economic, environmental, political, and/or technological factors that enable or constrain the uptake of an innovation [18]. A Calgary (policy/decision-maker) participant explained how political support is needed for Vision Zero to be effective: "being able to control a majority on Council would allow us to craft Council direction that requires exactly what we needed, a Vision Zero approach, rather than one balanced against competing/different political views." A Vancouver (transportation) participant shared similar views: "I wish Vision Zero would be embedded upstream in all decisions made at the political level. Silos amongst and within different tiers of government would be eliminated in the interest of safety first." As previously noted, B.C. has adopted Vision Zero at the provincial level; however, a Vancouver (non-profit) participant expressed concerns about the lack of political commitment:

I wish our provincial and municipal governments took their Vision Zero commitments more seriously, that investment decisions were looked at with this lens, that budgets were aligned with resolving the harm being done, that reporting and tracking were more complete, and that we didn't just accept a high number of vehicle-related injuries and deaths as being normal or an acceptable price to pay.

This shows how, in order for Vision Zero to be effectively implemented, political commitment and action are required, a sentiment echoed by a Montréal (uni-versity) participant: "I wish for adoption of the Zero Vision by the National Level. This would result in a safer environment for active travel."

Table 5. Themes mapped onto CFIR 2.0 domains and constructs [18].

-	Domain	Construct	Construct definition *The degree to which:*	Barrier	Facilitator
I.	**Innovation** The "thing" being implemented (*e.g.*, a new clinical treatment, educational program, or city service).	**A. Innovation Source**	The group that developed and/or visibly sponsored use of the innovation is reputable, credible, and/or trustable		
		B. Innovation Evidence Base	The innovation has robust evidence supporting its effectiveness		√
		C. Innovation Relative Advantage	The innovation is better than other available innovations or current practice		
		D. Innovation Adaptability	The innovation can be modified, tailored, or refined to fit local context or needs		
		E. Innovation Trialability	The innovation can be tested or piloted on a small scale and undone		
		F. Innovation Complexity	The innovation is complicated, which may be reflected by its scope and/or the nature and number of connections and steps	√	√
		G. Innovation Design	The innovation is well designed and packaged, including how it is assembled, bundled, and presented		
		H. Innovation Cost	The innovation purchase and operating costs are affordable		
II.	**Outer Setting** The setting in which the Inner Setting exists (*e.g.*, hospital system, school district, community).	**A. Critical Incidents**	Large-scale and/or unanticipated events disrupt implementation and/or delivery of the innovation		
		B. Local Attitudes	Sociocultural values (*e.g.*, shared responsibility in helping recipients) and beliefs (*e.g.*, convictions about the worthiness of recipients) encourage the Outer Setting to support implementation and/or delivery of the innovation	√	√
		C. Local Conditions	Economic, environmental, political, and/or technological conditions enable the Outer Setting to support implementation and/or delivery of the innovation	√	√
		D. Partnerships & Connections	The Inner Setting is networked with external entities, including referral networks, academic affiliations, and professional organization networks		√
		E. Policies & Laws	Legislation, regulations, professional group guidelines and recommendations, or accreditation standards support implementation and/or delivery of the innovation		
		F. Financing	Funding from external entities (*e.g.*, grants, reimbursement) is available to implement and/or deliver the innovation		
		G. External Pressures	External pressures drive implementation and/or delivery of the innovation *Use this construct to capture themes related to External Pressures that are not included in the subconstructs below:*		
		1. Societal Pressure	Mass media campaigns, advocacy groups, or social movements or protests drive implementation and/or delivery of the innovation		
		2. Market Pressure	Competing with and/or imitating peer entities drives implementation and/or delivery of the innovation		
		3. Performance Measurement Pressure	Quality or benchmarking metrics or established service goals drive implementation and/or delivery of the innovation		

(Table 5) contd.....

-	Domain	Construct	Construct definition *The degree to which:*	Barrier	Facilitator
III.	**Inner Setting** The setting in which the innovation is implemented (*e.g.*, hospital, school, city). There may be multiple Inner Settings and/or multiple levels within the Inner Setting (*e.g.*, unit, classroom, team).	**A. Structural Characteristics**	Infrastructure components support functional performance of the Inner Setting *Use this construct to capture themes related to Structural Characteristics that are not included in the subconstructs below:*		
		1. Physical Infrastructure	Layout and configuration of space and other tangible material features support functional performance of the Inner Setting		
		2. Information Technology Infrastructure	Technological systems for tele-communication, electronic documentation, and data storage, management, reporting, and analysis support functional performance of the Inner Setting		
		3. Work Infrastructure	Organization of tasks and responsibilities within and between individuals and teams, and general staffing levels, support functional performance of the Inner Setting		
		B. Relational Connections	There are high quality formal and informal relationships, networks, and teams within and across Inner Setting boundaries (*e.g.*, structural, professional)		
		C. Communications	There are high quality formal and informal information sharing practices within and across Inner Setting boundaries (*e.g.*, structural, professional)		
		D. Culture	There are shared values, beliefs, and norms across the Inner Setting *Use this construct to capture themes related to Culture that are not included in the subconstructs below:*		
		1. Human Equality-Centeredness	There are shared values, beliefs, and norms about the inherent equal worth and value of all human beings		
		2. Recipient-Centeredness	There are shared values, beliefs, and norms around caring, supporting, and addressing the needs and welfare of recipients		
		3. Deliverer-Centeredness	There are shared values, beliefs, and norms around caring, supporting, and addressing the needs and welfare of deliverers		
		4. Learning-Centeredness	There are shared values, beliefs, and norms around psychological safety, continual improvement, and using data to inform practice		
		Note: *Constructs E – K are specific to the implementation and/or delivery of theinnovation*			
		E. Tension for Change	The current situation is intolerable and needs to change		
		F. Compatibility	The innovation fits with workflows, systems, and processes		
		G. Relative Priority	Implementing and delivering the innovation is important compared to other initiatives		
		H. Incentive Systems	Tangible and/or intangible incentives and rewards and/or disincentives and punishments support implementation and delivery of the innovation		
		I. Mission Alignment	Implementing and delivering the innovation is in line with the overarching commitment, purpose, or goals in the Inner Setting		
		J. Available Resources	Resources are available to implement and deliver the innovation *Use this construct to capture themes related to Available Resources that are not included in the subconstructs below:*		
		1. Funding	Funding is available to implement and deliver the innovation		
		2. Space	Physical space is available to implement and deliver the innovation		
		3. Materials & Equipment	Supplies are available to implement and deliver the innovation		
		K. Access to Knowledge & Information	Guidance and/or training is accessible to implement and deliver the innovation		
IV.	**Individuals** The roles and characteristics of individuals	**A. High-level Leaders**	Individuals with a high level of authority, including key decision-makers, executive leaders, or directors		
		B. Mid-level Leaders	Individuals with a moderate level of authority, including leaders supervised by a high-level leader and who supervise others		
		C. Opinion Leaders	Individuals with informal influence on the attitudes and behaviors of others		
		D. Implemented Facilitators	Individuals with subject matter expertise who assist, coach, or support implementation		
		E. Implementation Leads	Individuals who lead efforts to implement the innovation		
		F. Implementation Team Members	Individuals who collaborate with and support the Implementation Leads to implement the innovation, ideally including Innovation Deliverers and Recipients		
		G. Other Implementation Support	Individuals who support the Implementation Leads and/or Implementation Team Members to implement the innovation		

(Table 5) contd.....

-	Domain	Construct	Construct definition *The degree to which:*	Barrier	Facilitator
		H. Innovation Deliverers	Individuals who are directly or indirectly delivering the innovation		
		I. Innovation Recipients	Individuals who are directly or indirectly receiving the innovation		
	Characteristics Subdomain	**A. Need**	The individual(s) has deficits related to survival, well-being, or personal fulfillment, which will be addressed by implementation and/or delivery of the innovation		
		B. Capability	The individual(s) has interpersonal competence, knowledge, and skills to fulfill Role		
		C. Opportunity	The individual(s) has availability, scope, and power to fulfill Role		
		D. Motivation	The individual(s) is committed to fulfilling Role		
V.	**Implementation Process** The activities and strategies used to implement the innovation.		*The degree to which individuals:*		
		A. Teaming	Join together, intentionally coordinating and collaborating on interdependent tasks, to implement the innovation		
		B. Assessing Needs	Collect information about priorities, preferences, and needs of people *Use this construct to capture themes related to Assessing Needs that are not included in the subconstructs below*		
		1. Innovation Deliverers	Collect information about the priorities, preferences, and needs of deliverers to guide implementation and delivery of the innovation		
		2. Innovation Recipients	Collect information about the priorities, preferences, and needs of recipients to guide implementation and delivery of the innovation		
		C. Assessing Context	Collect information to identify and appraise barriers and facilitators to implementation and delivery of the innovation	√	√
		D. Planning	Identify roles and responsibilities, outline specific steps and milestones, and define goals and measures for implementation success in advance		
		E. Tailoring Strategies	Choose and operationalize implementation strategies to address barriers, leverage facilitators, and fit context		
		F. Engaging	Attract and encourage participation in implementation and/or the innovation *Use this construct to capture themes related to Engaging that are not included in the subconstructs below:*		
		1. Innovation Deliverers	Attract and encourage deliverers to serve on the implementation team and/or to deliver the innovation		
		2. Innovation Recipients	Attract and encourage recipients to serve on the implementation team and/or participate in the innovation		
		G. Doing	Implement in small steps, tests, or cycles of change to trial and cumulatively optimize delivery of the innovation		
		H. Reflecting & Evaluating	Collect and discuss quantitative and qualitative information about the success of implementation and/or the innovation *Use this construct to capture themes related to Reflecting & Evaluating that are not included in the subconstructs below:*		
		1. Implementation	Collect and discuss quantitative and qualitative information about the success of implementation		
		2. Innovation	Collect and discuss quantitative and qualitative information about the success of the innovation		
		I. Adapting	Modify the innovation and/or the Inner Setting for optimal fit and integration into work processes		

4.2.3. Partnerships and Connections

According to participants, collaboration between stakeholders within and across sectors is necessary for Vision Zero to be effective. A Toronto (transportation) participant explained,

What we are emphasizing in this era of having Vision Zero as one of our key mandates is that road safety is everyone's responsibility. We see staff in traffic operations having a traffic safety role, and we see staff in road operations having a road safety role.

This passage illustrates the importance of internal collaboration and networking with external partnerships. A Peel Region (public health) participant affirmed the importance of "clear goals and objectives, shared understanding of the Vision Zero philosophy, and partnership across disciplines and departments (internal and external)," while a Montréal (policy/decision-maker) participant described, "continuous collaborative processes between cities and civil society organizations (as in Vision Zero) and other organizations" as necessary. In addition, a Montréal (non-profit) participant commented on how collective action across sectors targeting speed reduction results in a plethora of positive road safety impacts:

By reducing the speed of cars, we reduce noise and pollution, we reduce stress for pedestrians and cyclists, we reduce stress for older drivers, and we reduce the number of accidents and their severity. It's totally in phase with Vision Zero.

This passage shows how partnerships and connections positively influence road safety work, resulting in a variety of benefits that align with Vision Zero.

Peel Region has a dedicated Vision Zero team and strategy led by Peel Region Public Works, which includes Peel Public Health. A Peel Region (transportation) participant described the support across organizations for one of their Vision Zero projects:

One of our largest projects is a Vision Zero project. We have support from our locals (Brampton, Mississauga, and Caledon), and then we have a larger group of stakeholders that include our health services people, who are co-chairing with us, and also the Ontario Provincial Police (OPP), and Peel Regional Police, along with the Canadian Automobile Associate (CAA) and Mothers Against Drunk Driving (MADD), and a bunch of other groups that contribute to our cause of trying to eliminate injury and fatal collisions on our roadway.

A Toronto (police services) participant also described the importance of partnerships for Vision Zero work: "with something like Vision Zero, different partners have different roles to play. If everyone plays their role well and it's coordinated well across sectors, I think it has a better chance of improvement." These results align with a SSA and the need for coordination of all relevant stakeholders and sectors.

4.3. Implementation Process

Several participants' responses mapped onto the Assessing Context construct within the Implementation Process domain, which refers to the phase of implementation that collects information specifically to identify barriers and facilitators. For example, a Peel Region (policy/decision-maker) participant explained, "not all residents understand the impacts of not doing Vision Zero," while a Toronto (non-profit) participant stated, "sometimes policies/regulations are not in line with transportation equity principles of Vision Zero, so this can limit the types of projects that get approved." In addition, a Toronto (transportation) participant discussed challenges with recruiting expertise to implement Vision Zero programming: "with Vision Zero and active transportation still being relatively new focus areas, it is difficult to find consultants with the required expertise and experience to roll out these programs."

Alternatively, some participants discussed facilitators for implementing Vision Zero programming and projects. For example, a Calgary (policy/decision-maker) explained the importance of funding: "with full control over the City's Transportation department budget, we would be able to fund an implementation plan that more closely aligned with Vision Zero because we could allocate the needed funds to support traffic calming." This was affirmed by a Vancouver (public health) participant: "we really wanted to be strategic in what we were funding. We didn't want to just fund pedestrian or cyclist education initiatives, unless, there was a Vision Zero component in that." In addition, a Toronto (policy/decision-maker) emphasized the importance of political support for Vision Zero:

We have a City Councillor who has been active in supporting the expansion of cycling infrastructure, advancing Vision Zero initiatives, *etc*. He's the champion for stuff like strengthening our Vision Zero Program or doing other things to make it safer for pedestrians and cyclists across the city.

This passage illustrates the importance of political will and advocacy in order to successfully implement Vision Zero interventions. Overall, these results illuminate some contextual challenges for implementing Vision Zero.

5. DISCUSSION

Our results show that Vision Zero has influenced some road safety work in the municipalities represented. It is important to reiterate that these results pertain to municipal adoption of Vision Zero in lieu of national adoption. Municipalities have fewer resources at their disposal for road safety but are still able to make geometric changes and implement safety measures such as traffic calming and automated speed enforcement [61, 66]. However, it is our hope that lessons learned in these settings will contribute to national Vision Zero adoption in Canada.

Utilizing an implementation science framework, such as the CIFR, increases our knowledge of the implementation climate for Vision Zero in these municipal settings (Table **5**) and highlights important barriers and facilitators from the perspectives of injury prevention and transportation professionals working across sectors (Table **3**) on road safety goals. Data mapping onto Innovation Complexity, Local Attitudes, Local Conditions, and Assessing Context were described as both barriers and facilitators, while data mapping onto Innovation Evidence Base and Partnerships and Connections were described solely as facilitators. Overall, this shows that these injury prevention and transportation professionals have experienced important facilitators to the adoption of Vision Zero, while simultaneously observing how adopting Vision Zero facilitates road safety work in their municipalities.

5.1. Vision Zero and the CFIR

Given that KI interview and VFG data were collected for a larger pan-Canadian project examining barriers and facilitators to BE change, our results highlight meaningful connections between Vision Zero and modifying the BE to improve VRU safety in Canada. Results from the larger study utilized the first iteration of the CFIR [73] and identified cross-sectoral collaboration and data and evidence as significant facilitators for BE changes for VRUs [17]. Those findings align with the results of this current work that map onto the Innovation Evidence Base within the Innovation Domain and Partnerships and Connections within the Outer Setting domain. Utilizing the CFIR as the lens through which to examine these data provides insight helpful for municipalities by highlighting significant contextual factors that influence the adoption and implementation of Vision Zero, such as the importance of making evidence-informed changes (Innovation Evidence Base) and ensuring that the public is educated

about the aims of Vision Zero and accompanying BE changes (Local Attitudes).

The updated CFIR [18] uses the language of *innovation* instead of *intervention*, aligning more so with Vision Zero as a broad SSA for road safety. It is important to note that, as an innovation and SSA, components of Vision Zero are relevant to all domains and constructs across the CFIR; however, these results highlight the particular perceptions of Vision Zero from the perspectives of professionals working across sectors involved in road safety and, thus, illustrate the most significant implementation factors for Vision Zero from their unique positions. As noted in Section 4.0, most data mapped onto the Outer Setting Domain, illustrating that, for these participants, the specific contexts in which Vision Zero is adopted and attempted are significantly influenced by contextual particularities, thus requiring more municipality-specific knowledge about the nature of resistance and opportunities for support for Vision Zero implementation.

It is also important to note that the updated CFIR includes *Human Equality-Centredness* as a subconstruct under the Inner Setting domain; specifically, it is housed under the Culture construct, which defines *Human Equality-Centredness* as "shared values, beliefs, and norms about the inherent worth and value of all human beings" [18]. Given the focus of municipal Vision Zero policies on protecting VRUs, the innovation, as a whole, maps onto this subconstruct. For example, "life and health should never be placed at risk in exchange for other benefits" [59]; however, participants in this study focused more so on the need for local buy-in and understanding of road safety goals and strategies. The remainder of our discussion will more closely examine the relationships between the CFIR constructs onto which our data is mapped and illuminate relevant connections to the SSA.

5.2. Collaboration and Complexity

Several data mapped onto the Partnerships and Connections constructs within the Outer Setting domain, demonstrating how participants viewed collaboration across sectors and partner groups as facilitators to the uptake and implementation of Vision Zero. This aligns with an integral component of a SSA, which is sharing responsibility. As stated by Elvik and Nævestad, "road safety management operates through a partnership model that is adaptive and accountable" [83]. Data also mapped onto the Innovation Complexity construct within the Innovation domain, which is "reflected by its scope and the nature and number of connections and steps" [18], and illustrates how Vision Zero, as a multifaceted systems-based approach, is perceived as complex by participants. According to the Government of Sweden, "cooperation is essential to successful safety improvement" [25], and coordination across sectors involved in health and safety highlights the "nexus between transport and health practitioners and experts who have a responsibility of shaping the system" [26]. Such complexity is also acknowledged in the Montréal Vision Zero plan: "road safety in urban settings is complex and a major challenge that requires continuous collaborative effort by Montréal and its partners" [62]. Further, complexity is identified in the fourth SSA pillar, "all parts of the system must be strengthened in combination to multiply their effects, and to ensure that road users are still protected if one part of the system fails" [41], which also emphasizes the high importance of ensuring effective implementation for the safety of road users.

Parachute, the national lead on Vision Zero in Canada, also stresses the importance of cross-sectoral collaboration as necessary for successful SSA programing [84] and works to "connect key road safety stakeholders to increase the overall awareness and effectiveness of the Vision Zero approach" [9]. Further, Fuselli explains that, in Canada, each level of government has unique road safety responsibilities and that when implementing Vision Zero, "it is important to understand the governmental jurisdictional responsibilities and address each one, taking a collaborative approach to Vision Zero and road safety as a whole" [57]. As previously noted, cross-sectoral collaboration has been identified as a facilitator for BE change in other road safety work in the Canadian context [17]. Our results support and align with the Parachute mission, while also highlighting how injury prevention and transportation professionals perceive the multi-faceted and complex nature of Vision Zero and a SSA. The Montréal *2022-2024 Vision Zero Deaths and Serious Injuries Action Plan* also emphasizes the importance of partnerships and connections:

> The experience acquired over the recent years has underlined the need to improve cooperation among the partners involved in the Vision Zero effort. A variety of actions could help improve decision-making and implementation processes, including establishing new committees or adding partners to existing committees and working groups [62].

As noted by participants, Peel Region has a dedicated Vision Zero Team representing multiple sectors and stakeholders involved in road safety work. Thus, not only does Vision Zero require that "a well-established interdepartmental and multisectoral partnership administers plans, strategies, and responsibilities" [83], but its adoption at the municipal level can also facilitate increased connection and cooperation in the Canadian context.

5.3. Local Attitudes, Conditions, and Evidence

Participants commented on the importance of local acceptance and understanding of Vision Zero goals, as well as the need for evidence-informed changes to guide Vision Zero interventions and programming. According to Damschroder and colleagues, Local Attitudes refer to "socio-cultural values (*e.g.*, shared responsibility in helping residents) and beliefs (*e.g.*, convictions about the worthiness of recipients)" [18], which are influenced by the Local Conditions (*e.g.*, economic, environmental, political, and/or technological). Regarding local acceptance, "cultural practices, health inequities, social influences, emotions, and attitudes all come into play when we choose our modes of travel" [8], and increasing local community understanding

of Vision Zero goals is required for successful implementation and acceptance, which is another helpful insight for municipalities interested in adopting Vision Zero.

Given the necessity of partnerships and connections emphasized by participants, the priority of VRUs, and the importance of local acceptance of Vision Zero programs, centering equity in road safety work is pivotal [63, 85]. According to Damschroder and colleagues, it is important for implementation researchers and practitioners to recognize their own positionality (*i.e.*, who we are) in relation to the local communities the innovation is aimed at serving, and the CFIR provides constructs that help users account for these important dimensions. In other words, "being deliberate in collaborating with communities and deeply knowledgeable equity researchers" [18]. Participants in this study did not identify collaboration activities with specific equity-deserving [67] groups; however, the *B.C. Road Safety Strategy* specifically outlines efforts to engage Indigenous communities in their collaborative road safety work: "we recently expanded our Steering Committee membership to include representation from the Ministry of Indigenous Relations and Reconciliation in recognition of the unique road safety challenges faced by Indigenous communities" [64]. This provides context for the contributions from Vancouver participants who are working not only in a municipal setting that has adopted Vision Zero, but provincially as well.

5.4. Lessons for Municipalities

According to participants, the adoption of Vision Zero has been a facilitator for changes to road transport systems that prioritize the safety of VRUs. In addition, participants' contributions identify key barriers and facilitators to the implementation of Vision Zero as a road safety innovation (Table **5**), which can help municipalities in their plans to adopt and implement Vision Zero as a road safety strategy. Previous research on Vision Zero in the Canadian context [56, 84] is sparse; however, the significance of collaboration and coordination across sectors and partners is consistent. To recall, Vision Zero is an example of a SSA, a systems-level approach to change which necessarily involves multiple organizations, agencies, and communities [3, 6, 32, 83]. Thus, the cultivation and maintenance of partnerships across these entities is crucial for the success of Vision Zero, aligning with the central tenants of the SSA, as well as the contributions from our participants.

In addition, our participants emphasized the importance of local buy-in and knowledge about Vision Zero with regard to successful implementation, another important takeaway for municipalities. Engaging in meaningful dialogue with local communities is an important facilitator [53, 86-89], as well as ensuring that messaging about the Vision Zero approach and associated projects is clear and understood. As noted by our participants, Local Attitudes and Local Conditions can function as both barriers to and facilitators of Vision Zero acceptance. Thus, it is important for municipalities to communicate the goals and intentions of Vision Zero, broadly, and of particular projects, specifically to help ensure local community acceptance and support.

6. LIMITATIONS

A limitation of our research is that our results do not reflect a fulsome picture of how Vision Zero is perceived and implemented in other communities across Canada or even within the particular municipalities included in the scope of this work. The larger project from which these data were derived focused on BE change broadly; the scope of that study was not specifically aimed at explicating the influence and perceptions of Vision Zero. Additional work is required to comprehensively understand the impact of Vision Zero and how it is perceived by injury prevention and transportation professionals. Another limitation is the sampling techniques employed for the larger study, which included purposeful and snowball methods [68-70] and may have resulted in more similar perceptions about Vision Zero than with random sampling. Further, the interview guide was not pilot-tested and interviewer characteristics (*e.g.*, bias, assumptions, reasons and interest in research topic) were not reported. Different members of the research team conducted the KI interviews and asked slightly different probing questions, which resulted in some variation across participants' responses. Utilizing *Upwords* [75] to facilitate VFGs allowed participants to contribute remotely but did not enable the same rich conversations as in-person dialogue and may have influenced responses. Participants were not asked to review the themes determined by thematic analysis. Lastly, the research team consists of injury prevention researchers, which may have influenced participants' responses.

CONCLUSION

The results of our study show that Vision Zero has enabled road safety work in the municipalities represented, with participants identifying key facilitators such as community buy-in and partnerships. Further, utilizing the CFIR to examine our participants' contributions more clearly shows that the contextual particularities in which Vision Zero is implemented (*e.g.*, Local Attitudes, Local Conditions, and Partnerships and Collaboration) have a significant impact on its successful adoption and implementation. However, Vision Zero has been adopted unevenly in the Canadian context at provincial, municipal, and regional levels, and the results of our study are the first to shed some light on how Vision Zero is understood and adopted across sectors in these municipalities. To recall, "for Vision Zero to be successful, there needs to also be an overarching agreement on the issues and systems nature of the problems and the required solutions", aligning with components of a SSA and requiring more information from road safety practitioners implementing Vision Zero.

Examining our results through the CFIR lens is a first step towards elevating our understanding of the landscape of Vision Zero implementation in Canada. As noted above, our participants emphasized the importance of partnerships and collaboration for Vision Zero work, which is an integral component of a SSA and also reflected in municipal Vision Zero plans: "the Vision Zero Road Safety Plan will increase efficiency and effectiveness of efforts and foster greater collaborations among partner agencies who have all committed to sharing responsibility and lending support to

the plan". Further, the updated CFIR highlights the importance of road safety work for VRUs' safety and health, aligning with Vision Zero philosophy and reinforcing the importance of understanding the needs of local communities, working with them in partnership to ensure that road safety innovations are understood, accepted, and successfully implemented. As stated by Damschroder and colleagues, "implementation researchers are uniquely positioned to address oppression by seeing to understand how it manifests across all domains as a determinant to equitable implementation." This is reflected in municipalities' Vision Zero plans. For example, "no matter how we choose to travel – by car, bike, transit, or walking – we all have a right to a road system that is safe and inclusive for everyone."

Overall, our research shows that Vision Zero has meaningfully guided some road safety work across these municipalities and the CFIR was useful for clearly organizing our participants' contributions in relation to implementation. However, more research is required to increase our knowledge of the implementation landscape for Vision Zero in these municipalities and others across Canada. We used the CFIR, but there are several other implementation science frameworks that can assist researchers and practitioners in implementing Vision Zero projects, keeping equity and VRUs at the forefront. In Canada, this research is of particular importance for municipalities due to the lack of national adoption. Further, given that partnerships and collaboration are critical to the success of Vision Zero, and the focus of Vision Zero programming is to reduce injury rates for VRUs and equity-deserving groups, *how* partnerships and connections are cultivated and supported with local communities is pivotal. Future work should be focused here, in the Canadian context, and globally.

AUTHORS' CONTRIBUTION

P.F., J.T. and B.H.: Study conception and design were contributed; E.M. and A.M.: Manuscript draftwas presented; I.P.: Conceptualization was provided; S.A.R: Methodology was adopted. All authors reviewed the results and approved the final version of the manuscript.

LIST OF ABBREVIATIONS

BE	=	Built environment
CARSP	=	Canadian Association of Road Safety Professionals
CCMTA	=	Canadian Council of Motor Transport Administrators
CFIR	=	Consolidated Framework for Implementation Research
ITF	=	International Transport Forum
KI	=	Key informant
MADD	=	Mothers Against Drunk Driving
OPP	=	Ontario Provincial Police
OECD	=	Organization for Economic Co-operation and Development
SSA	=	Safe System approach
TA	=	Thematic analysis
TAC	=	Transportation Association of Canada
VFG	=	Virtual focus group
VRU	=	Vulnerable road users
WHO	=	World Health Organization

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Human Participants Research Protocol was approved by York University's Office of Research Ethics, Canada (e2019-174).

HUMAN AND ANIMAL RIGHTS

The procedures performed were in accordance with the ethical standards of York University (Canada), the Canadian Institutes for Health Research, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

CONSENT FOR PUBLICATION

Informed consent was obtained from all participants.

STANDARDS OF REPORTING

COREQ guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The data and supportive information are available within the article.

FUNDING

This study was funded by Canadian Institutes of Health Research (CIHR), Funder ID: CIHR Team Grant, Environments and Health: Intersectoral Prevention Research, Awards/Grant number: [#IP2-150706] (CHASE).

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

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