Toward a New Zealand-centric good practice guide for vulnerable road users in temporary traffic management (TTM) environments: An integrative review

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ABSTRACT

This integrative review seeks to inform a future New Zealand (NZ) good practice guide to enhance temporary traffic management (TTM) for vulnerable road users (VRUs). It responds to the industry's shift from a prescriptive national standard to a more flexible, risk-based framework. This transition necessitates a focused development of good practice guidelines, especially as existing TTM research and guidance are predominantly vehicle-centric. This review synthesises data from 32 peer-reviewed publications, 73 pieces of grey literature, and 33 relevant NZ literature provisions.

The review found that existing Temporary Traffic Management (TTM) standards are notably deficient, especially in addressing the needs of VRUs. Analysis of United States (US) and international guidelines reveals underlying uniformity lacking comprehensive VRU considerations. The guidance is marred by ambiguity and a lack of iteration, impeding effective contemporary VRU safety management. There is a notable absence of focused, prominent guidelines for VRUs within TTM, underscoring the need for a more evidence-based, adaptable approach to TTM standards that are explicitly oriented towards VRU safety and utility.

A critical analysis of the review findings has resulted in 16 broad recommendations for an NZ good practice guide to enhance TTM for VRUs, including a bespoke risk management process. First, practical TTM guidance should be modular, catering to distinct audience needs, and layered, balancing outcome-focused, process-oriented, and prescriptive expectations. Furthermore, a focus towards the Check and Act aspects of the Plan-Do-Check-Act (PDCA) cycle is necessary, as current guidance is inadequate in both these areas, and a cornerstone of good practice is iteration. The significance of understanding the *why* behind VRU vulnerabilities needs emphasis, with a clear linkage of that *why* to any prescription. There is a need to cater for those with disabilities in TTM more effectively, as they are the most vulnerable and often the most disenfranchised. Finally, a sequential VRU-in-TTM-specific risk treatment process allows a more targeted application of evidence-based control measures for practitioners.

This research advances NZ's TTM for VRUs by integrating global best practices. It can guide future policies aimed at safer TTM environments for VRUs. Furthermore, this approach to developing good practices for TTM in NZ can serve as a blueprint for other areas of TTM requiring more mature exploration.

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ATTESTATION OF AUTHORSHIP

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor used artificial intelligence tools or generative artificial intelligence tools (unless it is clearly stated, and referenced, along with the purpose of use), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning."

Signed	**Date**
	15/12/2023
David Francis Tilton	

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I would also like to thank my supervisor, Tago Mharapara, for his guidance, support, and insightful feedback.

ABBREVIATIONS

Abbreviation	Definition
AADT	Annual Average Daily Traffic *Measure used for generalising the traffic volume of a road*
ABDC	Australian Business Deans Council
ADA	The Americans with Disabilities Act of 1990 (U.S)
ADOT	Arizona Department of Transportation (U.S)
AGTTM	Austroads Guide to Temporary Traffic Management (Australia)
AMD	Audible Message Device
ALARP	As Low As Reasonably Practicable
ARROWS Project	Advanced Research on Road Work Zone Safety
ARTBA	American Road and Transport Builders Association (U.S)
ASAP Project	Appropriate Speed Saves All People Project
ATSSA	American Traffic Safety Services Association (U.S)
CAS	Crash Analysis System *Specifically, New Zealand's centralised crash analysis database administered by Waka Kotahi (NZ Transport Agency) (Waka Kotahi, 2023a)*
Caltrans	California Department of Transportation (U.S)
CBD	Central Business District
CEDR	Conference of European Directors of Roads
CLOCS	Construction Logistics and Community Safety (UK)
CNG	Cycling Network Guidance (Waka Kotahi, 2023f)
CoPTTM	The Code of Practice for Temporary Traffic Management (New Zealand)
DDoT	District of Columbia Department of Transportation (U.S)
DSI	Death and Serious Injury [Crashes]
EED	Engineering Exception Decision *"A written decision made following consideration of all factors, including the safety of all concerned, to vary a code of practice(s), standard(s) or guideline(s), to suit a particular situation." (Waka Kotahi, 2019a, p. ix)*
ERA-NET ROAD II	European Research Area Network on Road Transport

ERF	European Union Road Federation
ETSC	European Transport Safety Council
EU	European Union
FAO	Food and Agriculture Organization
FENZ	Fire and Emergency New Zealand
FHWA	Federal Highway Administration (U.S)
FMEA	Failure Modes Effects Analysis
FSGV	Forschungsgesellschaft für Straßen- und Verkehrswesen *(The Research Society for Roads and Transport (Germany)*
GPG	Good Practice Guide
GPS	Government Policy Statement on Land Transport *The latest iteration was published in September 2020 (Te Manatu Waka (Ministry of Transport), 2020)*
H&S	Health and Safety
HSWA	Health and Safety at Work Act 2015
IEEE	Institute of Electrical and Electronics Engineers
IRIS Project	Incursion Reduction to Increase Safety in Road Work Zones Project
ISO	International Standards Organisation
ITF	International Transport Forum
LGA	Local Government Act (1974, 2022) *The Local Government Act 2002 supersedes the 1974 Act. However, numerous provisions of the 1974 Act remain in place and were not retracted, including provisions that have implications for local authorities' oversight of Temporary Traffic Management. Both Acts (1974 and 2022) are referenced within this text together – or, where appropriate, where the specific provision is from one of the versions of the Act that is specifically referenced.*
LPVs	Low-Powered Vehicles
LTMA	Land Transport Management Act 2003
MDOT	Michigan Department of Transport (U.S)
MITMA	Ministerio de Transportes, Movilidad y Agenda Urbana (Spanish Ministry of Transport, Mobility and Urban Agenda)
MnDOT	Minnesota Department of Transportation (U.S)
MoDOT	Missouri Department of Transportation (U.S)

MOLIT	Ministry of Land, Infrastructure and Transport (South Korea)
MTO	Ontario Ministry of Transportation (Canada)
MUTCD	Manual on Uniform Traffic Control Devices (U.S)
NCDOT	North Carolina Department of Transportation (U.S)
NHDOT	New Hampshire Department of Transportation (U.S)
NYDOT	New York Department of Transportation (U.S)
NZ	New Zealand
NZGTTM	The New Zealand Guide to Temporary Traffic Management
NZQA	New Zealand Qualifications Authority
NZTA	Waka Kotahi (NZ Transport Agency) *The formal name Waka Kotahi is used primarily in recent documentation – the acronym NZTA was present in the documentation before 2022. Older documentation may refer to Transit New Zealand.*
ODOT	Oregon Department of Transport (U.S)
OECD	Organisation for Economic Cooperation and Development
OHS	Occupational Health and Safety
OSHA	The Occupational Safety and Health Act of 1970 (U.S)
PCBU	Person Conducting a Business of Undertaking *Health and Safety at Work Act (2015)*
PCD	Pedestrian Channelising Device *Primarily a term used in the United States and Canada*
PDCA	Plan-Do-Check-Act [cycle]
PIARC	Permanent International Association of Road Congresses
PNG	Pedestrian Network Guidance (Waka Kotahi, 2023f)
PRAISE	Preventing Road Accidents and Injuries for the Safety of Employees
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROWAG	Public Rights-of-Way Accessibility Guidance
PSALSAR	Protocol, Search, Appraisal, Synthesis, Analysis and Report
RCA	Road Controlling Authority *As defined in the Land Transport Management Act 2003 – "in relation to a road, means the Minister, Department of State, Crown entity,*

	State enterprise, or territorial authority that controls the road. In relation to a road within Auckland that is controlled by Auckland Transport, means Auckland Transport”. *Referred to in some New Zealand legislation as a public road controlling authority*
SALAR	Swedish Association of Local Authorities and Regions
SD	Standard Deviation
SDOT	Seattle Department of Transportation (U.S)
SLR	Systematic Literature Review
STARs Project	Scoring Traffic at Roadworks Project
TCD	Traffic Control Device
TCP	Traffic Control Person *Primarily a term used in the United States and Canada*
TA (or TLA)	Territorial Authority *Sometimes referred to as a Territorial Land Authority* *A city council or district council under the Local Government Act 2002*
TAO	Transport Authority Organisation *This term is not referred to in legislation; however, it is defined in the New Zealand Guide to Temporary Traffic Management (NZGTTM) as a “Road Controlling Authority (RCA), Rail Access Authority (RAA), Public Transport Authority (PTA) or other authority” (Waka Kotahi, 2023c)*
TEM	Trans-European North-South Motorway Project
TfL	Transport for London
TGSI	Tactile Ground Surface Indicators *Sometimes referred to colloquially (and in this research) as tactile pavers.*
TMP	Traffic Management Plan *This term has a range of alternative forms across territories, such as transportation management plan, traffic control plan, and traffic guidance scheme. A complete list of variations can be found in Table 10.*
TPAR	Temporary Pedestrian Access Routes *Primarily a term used in the United States*
TRID	Transport Research International Documentation
TRSBS	Temporary Road Safety Barrier System

TRVK	Swedish Transport Authority (Trafikverket)
TSL	Temporary Speed Limit
TTM	Temporary Traffic Management *In other territories, alternate terminology is used; however, when used as an acronym across this paper, only TTM is used. A complete list of variations can be found in Table 10.*
UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
U.S	United States [of America]
V-Dem	Varieties of Democracy Project (Papada et al., 2023)
VDOT	Virginia Department of Transportation (U.S)
VKT	Vehicle Kilometres Travelled
VRU	Vulnerable Road User(s) *A range of terms within the VRU domain are outlined in Table 10.*
VTrans	Vermont Agency of Transportation (U.S)
VTU	Vulnerable Transport User(s) *May also be referred to as Vulnerable Non-Motorised Transport Users.* *See Vulnerable Road User(s) (VRU)*
WisDOT	Wisconsin Department of Transportation (U.S)
WSDOT	Washington State Department of Transportation (U.S)

CHAPTER 1: INTRODUCTION

Despite significant safety incidents, including fatalities (Clent & Piper, 2019; Guildford & Kitchin, 2019; Owen, 2018) and the publication of a 2014 report on cycling safety by Waka Kotahi (New Zealand Transport Agency) (Waka Kotahi) (2014), there remains a void in guidelines for vulnerable road users in TTM environments in New Zealand (NZ). Filling this void becomes even more imperative with an impending ideological shift by New Zealand's TTM sector from a compliance-focused approach (following a prescriptive set of rules) to a risk-based approach – founded on principles and processes (Waka Kotahi, 2022). Such a cultural shift implores TTM designers and practitioners to understand how risk materialises in TTM environments and how to keep road users and workers safe without a prescriptive recipe. Of the most concern in that equation are vulnerable road users (VRUs) – those with the lowest tolerance for harm and the tightest margin for error.

The complexity of vulnerable road users (VRUs) navigating temporary traffic management (TTM) environments hinges on irregular traffic patterns, new hazards, and limited space, heightening the risk for these users. To align with NZ's legal mandate and uphold the moral obligation regarding introducing risk to public spaces, safeguarding road workers and the public becomes paramount (WorkSafe NZ, 2022b). Unfortunately, Waka Kotahi's Crash Analysis System (CAS) data indicates a disproportionate representation of pedestrians and cyclists in severe accidents within TTM zones (Waka Kotahi, 2023a).

This research aims to integrate international standards from peer-reviewed academic research and grey literature on the safety of vulnerable road users within TTM. The goal is to craft NZ-specific guidelines aligned with global best practices. The guidelines must address NZ's unique TTM concerns, such as the legislative framework, geography, and urban design. However, before developing NZ-specific guidelines for vulnerable road users within TTM environments, I will conduct an integrative literature review to assess the current state of peer-reviewed and practitioner knowledge.

An integrative review is a systematic and rigorous method for synthesising existing knowledge on a specific topic (Cronin & George, 2020). It critically examines peer-reviewed academic research and grey literature to provide new insights and recommendations (Torraco, 2016). This approach is particularly valuable when dealing with fragmented research areas and different research paradigms (Whittemore & Knafl, 2005).

Background and Context

New Zealand's demographic and geographic considerations accentuate vulnerable road users' challenges in TTM contexts. With an ageing populace and growing urbanisation (Cochrane & Maré, 2017; Stats NZ, 2022), there has been a noticeable increase in vulnerable road users, as evidenced by the rising numbers of cyclists (Lv et al., 2021). In addition to policy shifts in urban transport, cyclist numbers have primarily grown due to environmental and health concerns (Chowdhury & Costello, 2016; Wooliscroft & Ganglmair-Wooliscroft, 2014). Between 2018 and 2022, active travel modes like cycling grew by 5%, with areas like Auckland reporting higher growth (TRA, 2022).

Aligned with this growth, there has been significant investment in cyclist infrastructure. National spending on walking and cycling rose over 40% annually from 2014 to 2017 (Waka Kotahi, 2018). However, with growing cyclist infrastructure comes spatial challenges in road construction. Limited space for road works amplifies TTM challenges, creating a higher risk of accidents (Steele & McTiernan, 2010; Turner et al., 2010).

Despite several revisions, the NZ Code of Practice for Temporary Traffic Management (CoPTTM) has not adequately evolved to meet the changing demands of TTM, particularly regarding vulnerable road users (Waka Kotahi (NZ Transport Agency), 2019a). The newer New Zealand Guide to Temporary Traffic Management (NZGTTM), set to replace the CoPTTM, does not include detailed guidance for these users in TTM contexts (Waka Kotahi, 2019a, 2022, 2023c). The non-inclusion of such guidelines in NZ’s premiere national TTM document becomes even more concerning when considering tragic incidents like the 2019 cyclist fatality in Christchurch, which would call for more robust, evidence-based TTM practices (WorkSafe NZ, 2022a).

Objective of the present review

This integrative review has four main objectives. The first is collating, synthesising, and evaluating peer-reviewed academic research and grey literature on vulnerable road users within TTM environments. Second, identify how researchers and practitioners have studied vulnerable road users within TTM environments. Third, summarise the key findings of the research. Lastly, identify limitations of the existing research regarding vulnerable road users within TTM frameworks. To address these objectives, this integrative review was guided by the following questions:

1. How have researchers and practitioners studied vulnerable road users within TTM environments?
2. What are the key research findings on vulnerable road users within TTM environments?
3. Identify key research gaps and methodological limitations within the existing literature on vulnerable road users in TTM environments?

Significance

The value of this research is to inform and enhance the framework for TTM guidelines, with a focus on improving the understanding and integration of safety considerations for vulnerable road users. This aligns well with NZ's overarching discourse on transport and infrastructure. The increase in accidents involving vulnerable road users signifies the urgent need for a systematic overhaul of national guidelines (Soathong et al., 2019).

The evolution from CoPTTM to NZGTTM crystallises the urgency for TTM approaches that are risk-informed and context-specific. This investigation is anticipated to imbue risk-assessment processes with salient evidence-backed insights, laying the foundation for a well-defined protocol of best practices.

Exploring vulnerable road user safety intricacies within TTM setups and disseminating a rigorous, evidence-driven guide can trigger broader policy discussions and determinations. The domains of urban design and planning could potentially harness these findings. By integrating the resultant guide into developmental strategies, urban areas may be moulded to be both safer and more accommodating. Furthermore, as the reorientation of New Zealand TTM standards moves from centralisation to de-centralisation, pioneering a robust and detailed good practice guide in this critical area will likely guide subsequent good practice formulation in other facets of TTM. From a broader perspective, the potential global applicability of the findings is clear - limited centralised good practice is readily accessible in this realm. The distilled good practice guide could establish a benchmark for nations with analogous demographics.

When juxtaposed with urban planning, the realm of environmental conservation emphasises the promotion of active transit modes such as walking and cycling. These modes counterbalance carbon emissions and foster community health and engagement (Handy et al., 2014). However, TTM schemes, if inadequately implemented, could deter the adoption of these modes by perpetuating a risk perception (Pucher & Buehler, 2016). Consequently, proficient TTM transcends operational coordination, extending into a societal obligation, a benchmark determining a society's commitment to equitable, sustainable transport for all constituents (Tuckett et al., 2018).

This research is not just about road safety. It can influence broader policy discussions, infrastructure development, and transportation practices. Furthermore, it could serve as a reference for other countries. It aims to create safer and more welcoming environments for vulnerable road users in New Zealand and beyond.

Methodology

This research employs an integrative methodology, incorporating grey literature and academic research to generate recommendations for evidence-based guidelines catering to New Zealand's legislative context. The process follows several interrelated steps:

1. The first step involves identifying territories with contexts comparable to New Zealand regarding economic, democratic, and legislative factors. The research aims to capture diverse but relatable TTM practices and insights from global regions by selecting relevant territories.
2. Once the comparable territories are identified, exploring the grey literature related to TTM in these regions commences. The grey literature contains valuable insights from non-

traditional academic sources such as government reports, industry guidelines, and standards.

3. The exploration of grey literature helps uncover the varied terminologies used to define TTM-related concepts in different territories. Understanding these terminologies is essential for conducting a targeted academic literature search later.
4. Another crucial aspect of the grey literature exploration is the analysis of the review cycles of TTM standards and practices. Understanding how frequently these standards are updated informs the timeline for the academic literature search. This analysis ensures that the academic research incorporates the most recent and relevant findings.
5. Exploring relevant New Zealand legislation ensures that subsequent review and distillation of literature findings are legislatively appropriate.
6. Armed with the identified terminology, informed by the review cycle analysis and the legislative framework, the research proceeds to conduct a systematic academic literature search. This search spans various academic databases and peer-reviewed journals. The aim is to gather a comprehensive range of evidence-based research relevant to the research question and associated disciplines.
7. The methodology then uses an integrative review approach to synthesise the gathered data effectively. The integrative review method permits the incorporation of diverse data types, allowing for a comprehensive understanding of the multifaceted challenge (Whittemore & Knafl, 2005).
8. Through thematic analysis and integrating empirical findings with theoretical perspectives, the research develops recommendations for eventual evidence-based guidelines for vulnerable road users in TTM environments. These guidelines are tailored to the New Zealand context and legislative setting, considering the diverse insights gathered from comparable territories and relevant academic research.

Summary

The necessity for this research arises from the challenges faced by vulnerable road users navigating the shifting landscape of New Zealand's TTM frameworks. As NZ transitions from the

CoPTTM to the NZGTTM, a pressing requirement for evidence-informed, tailored guidelines emerges. By amalgamating international standards, scholarly research, and grey literature, this integrative review addresses the current deficiency in thorough guidelines for vulnerable road users navigating TTM environments. Beyond the immediate concern of road user safety, this research has broader implications for urban design, infrastructure planning, transportation policies, and the establishment of global best practices. The supplementary goal is to lay a groundwork for evidence-supported guidelines that provide an example to other TTM areas on safely and robustly navigating a TTM framework that is less reliant on centralised governmental standards and leverages international evidence for local good practice.

CHAPTER 2: LITERATURE REVIEW

Understanding Temporary Traffic Management (TTM)

Definition and Purpose of TTM

TTM operates within the road corridor to facilitate tasks like road maintenance or construction while ensuring uninterrupted road functionality (FHWA, 2005; Strnad et al., 2019; Thomas et al., 2023). The evolving nature of TTM, marked by potential shifts in road layouts and introduced hazards, heightens its complexity (Elvik et al., 2009b). As highlighted by Rahman et al. (2017) and Yang et al. (2015), TTM surpasses mere rules; it is a synthesis of engineering, psychology, law, and social constructs, striving to harmonize the demands of safety assurance, traffic continuity, and transient activities within limited space (Strnad et al., 2019). Contrastingly, Waka Kotahi's NZGTTM offers a narrower perspective on TTM, emphasising the "controls deployed" rather than considering its holistic components (Waka Kotahi, 2023c). Accordingly, for this research, I define TTM as *temporary measures applied to preserve the safety of road workers and users while an activity impacting the normal operation of the road reserve is undertaken.*

Legal Foundations and Obligations

A matrix of laws, regulations, and national strategies steers TTM in New Zealand. The Health and Safety at Work Act 2015 (HSWA 2015) is central to this structure, which demarcates the roles of Persons Conducting a Business or Undertaking (PCBUs) in safeguarding their workforce and others who interact with it. HSWA 2015 remains the primary vehicle for prosecution for inadequate TTM, as evidenced through case law. This foundational safety tenet sets the premise for international comparisons, evidenced by the European Union's [1] Safety Framework Directive 89/391/EEC, which mandates risk assessment-driven safety management (European Parliament and of the Council, 1989). The TTM framework in New Zealand also draws from the Land Transport Act 1998, the Local Government Act (1974, 2002), and the Land Transport Management Act (LTMA) 2003 – a testament to a broader ambition of eliminating road-related harm and fostering diverse transport modes (Te Manatu Waka (Ministry of Transport), 2021).

[1] Such comparisons can be drawn across a range of other territories which are explored across the main literature review methodology itself – refer to the section *Occupational Health and Safety (OHS) legislative context*

Further legislative elaborations pertinent to TTM are explored in the *New Zealand Legislative Literature* section.

In the broader strategic landscape, the Road to Zero strategy (2020-2030) amplifies the legal tapestry by prioritising human welfare in road transport planning, emphasizing principles like planning for human errors and prioritising safety in decision-making processes (Waka Kotahi, 2019b). These guiding principles reflect broader ambitions of achieving zero harm and adapting roadways for diverse transport modalities (Soathong et al., 2019; Thomas et al., 2023)

Thus, TTM in New Zealand transcends traffic coordination. It embodies legal and moral commitments to guarantee the safety of road users and workers. Such obligations are cemented in a transport philosophy anchored in zero harm and evolving road infrastructures for emerging transport expectations (Koorey & Lieswyn, 2016). This ideological framework interlocks with the legal mechanisms shaping TTM, necessitating that any ensuing TTM practices or standards duly respect this intricate merger of legislative provisions and transport philosophies, notably within New Zealand's jurisdictional context.

Safety Considerations and Road Function Preservation

Within Temporary Traffic Management (TTM), the dual imperative is safety assurance and road function preservation. Prioritising safety for the public and workers remains essential (Rista et al., 2017). This commitment steers TTM methodologies through risk management to address potential hazards when altering road environments (FHWA, 2017; Rista et al., 2017; Strnad et al., 2019). The interplay between safety imperatives and maintaining transport efficacy presents a dichotomy. While safety measures are vital, they sometimes challenge transportation continuity (Vyas & Varia, 2023). Balancing construction activities with traffic function preservation demands precise planning and execution (Elvik et al., 2009b). Spatial constraints and stakeholder engagements compound the intricacy of TTM installations (Yu et al., 2019). Even minor road adjustments can have amplified traffic impacts (Griffith & Lynde, 2002), necessitating a safety-centric approach to TTM. This often leads to the compromise of vulnerable road users when attempting to minimise road network disruption (Ropaka et al., 2020; Vlahogianni et al., 2012).

The tension between safety and traffic flow underscores the need for detailed guidelines for TTM practitioners, especially with changes to centralized practices in New Zealand.

The interface between Road Users, Activities, and Hazards

In all TTM environments, there is an interface between road users, the activity being undertaken (that has given rise to the need for TTM) and the hazards it generates. Drawing from the Federal Highway Administration (FHWA) (2005a), Waka Kotahi (2023c), and the NZ Qualifications Authority (NZQA) (2023), such hazards can be categorised as either:

- *Environmental hazards* are present due to intrinsic settings like road users, geometry, vegetation, and intersections.
- *Activity hazards* arise from specific operations affecting the road's standard function, including construction or public events.
- *Implementation hazards* are introduced while addressing other hazards, such as traffic equipment or TTM workers, which can generate risks of their own.

Addressing these hazards requires TTM experts to discern and mitigate risks from the intertwined dangers in different contexts. Every situation showcases an interface between road users, activities, and resulting risks. Effective communication between TTM personnel and road users is pivotal for safe navigation (Kummetha et al., 2020; Vignali et al., 2019). The transient nature of road users amplifies TTM's reliance on psychological factors to guide user behaviour towards safety (Johnston et al., 2003; Kane et al., 1999; Sommers & McAvoy, 2013; Steinbakk et al., 2017). Although some enforcement mechanisms exist within TTM, most rely on voluntary compliance (Ullman & Brewer, 2014)

The Role of TTM in Risk Reduction

TTM's core purpose revolves around risk reduction. ISO 31000 defines risk as the *"effect of uncertainty on objectives"* (International Standards Organisation, 2018, p. 1). Fowler et al. (2011) articulate risk as the *"probability or exposure to a hazard, together with the consequences of such exposure"* (p. 27). However, while TTM aims to diminish risks, it can concurrently introduce new hazards. For instance, while safeguarding workers, a temporary barrier might hinder drivers' sightlines or restrict vulnerable road users, creating fresh risks that demand management. This intricate interplay mandates a comprehensive TTM strategy accounting for anticipated and unforeseen outcomes of every TTM measure.

The lowest total risk principle, recently incorporated in the NZGTTM, somewhat addresses this challenge and demands that any TTM seeks to result in the lowest possible total risk in any given situation (Waka Kotahi, 2023c). It is an evolution of the *as low as reasonably practicable* (ALARP) principle, aiming to reduce risks to a justifiable level under prevailing conditions (Peace, 2021) but to do so considering *all* risks (including those introduced). Aven (2016) refers to this as the *optimal risk* concept and attempts to weigh the pros and cons of risk mitigation measures, and the MIRi Index embodies this by assessing factors such as probability, exposure, and outcomes (Fowler et al., 2011). Each of these models shares a common intent – to ensure risk is managed as best as possible and that any measures introduced to manage risk do not inadvertently make it worse. This is precisely the challenge of providing effective TTM and its role in risk reduction.

Importance of effective TTM for safety and functionality

Effective TTM relies on traffic control devices (TCDs) (Ha & Nemeth, 1995; Khalil & Samir, 2018). However, if implemented carelessly without efficacy, their deployment may not assure improved safety and could elevate overall environmental risk (Alsultan et al., 2022). This aligns with observations from Transport for London (2019), which caution against the misconception that selecting any traffic management arrangement from national standards suffices. Such an approach is indefensible and likely to fail legal scrutiny unless it is substantiated that all other options have been evaluated and justifiably dismissed. Emphasis should be on a nuanced application, grounded in the deeper understanding of each control's intent and its ramifications, especially within the high-uncertainty domain of TTM (Botterill & Courtenay, 2004). Often, in such contexts, the focus shifts towards increasing decision-making certainty to reduce risk; however, the opposite effect results – an adherence to prescriptive rules devoid of actual risk reduction (Hopkins, 2011).

Centralisation through standards and practices

Good practice centralisation institutionalises collective knowledge into actionable standards, known as *epistemic governance* (Jasanoff, 2004). The knowledge-action gap is a complexity of this process, where standards might not lead to effective actions (Wehrens, 2014). This is even more pronounced in environments where the democratisation of expertise dilutes evidential clarity regarding good practices (Collins & Evans, 2016). Incorporating psychological principles like those described by Strnad et al. (2019) can augment TTM standards, bridging this gap. Centralised standards, typically crafted by experts, require broad stakeholder input, especially tacit knowledge (Polanyi, 1966), to ensure adaptability and real-world relevance. A potential drawback of centralised systems is their potential for rigidity and subsequent conflict with adaptive governance principles (Folke et al., 2005). Living documents, like the NZGTTM, should be continually revised to remain relevant to the TTM industry's evolving demands. Centralising good practice in TTM requires a multidimensional approach that merges various insights, mitigates the knowledge-action gap, includes diverse expertise, and adapts to dynamic circumstances.

Understanding TTM – A Summary

The exploration of New Zealand's TTM has showcased its multifaceted nature. Legal obligations in TTM extend to ethical dimensions, especially concerning vulnerable road users. When merged with legal requirements and societal expectations, risk interpretation promotes equitable risk management, resonating with adaptive governance principles (Folke et al., 2005).

The impending risk-based approach shift in New Zealand's TTM demands re-evaluating rule layers, promoting their optimal coordination for genuine safety outcomes. This coordination encompasses epistemic governance (Jasanoff, 2004) to amalgamate collective wisdom into actionable standards. A comprehensive, integrated TTM approach is vital to ensure safety, equity, and adaptability, highlighting the need for robust, legal, and ethically sound integrated frameworks. The NZGTTM does provide a more pliable platform than the CoPTTM to integrate these considerations and balance innovation and epistemic governance appropriately, fitting well with the intent of this research and its subsequent NZ-centric Good Practice Guide for the Treatment of Vulnerable Road Users in TTM.

Vulnerable Road Users

Defining Vulnerable Road Users (VRU)

VRUs comprise pedestrians, cyclists, and people with disabilities, who face increased TTM risks owing to physical exposure, unpredictable settings, and lack of protective gear (Čabarkapa, 2020; Yannis et al., 2020). While some literature uses *Vulnerable transport users* or *vulnerable non-motorised transport users* (Cooke et al., 2022; Glensor, 2018; Ward et al., 2021), these terms essentially denote the same user group. In New Zealand, *Vulnerable Road Users* remain prevalent, with *Vulnerable Transport Users* emerging more recently (Auckland Transport, 2019; Kutela et al., 2023).

The VRU category extends to unregistered motorised modes without significant safety structures, like electric scooters, equestrian riders, and those on animals or animal-drawn carts (Bennett et al., 2019). Factors exacerbating their vulnerability include limited visibility, behavioural variability, and a lack of safety features that motor vehicles have (D'Apuzzo et al., 2021). The diversity of those who use walkways and cycleways is extensive, including people on foot and pedestrians on wheels, such as those pushing baby strollers, pulling wheeled suitcases, and using hand trucks, skates, skateboards, and hoverboards (Jimenez et al., 2018). In New Zealand, the category of Low-Powered Vehicles (LPVs) includes a range of devices from power-assisted pedal cycles to mobility devices with motors up to 1,500W, some of which do not currently fall into any New Zealand class but are considered in overseas categories such as Personal Mobility Devices or Powered Mobility Devices (Kiwirail, 2023b; Lieswyn et al., 2017). Further increasing the potential diversity of VRUs is that they do not undergo licensing or eyesight tests (Shaw et al., 2023).

Although motorcyclists share many VRU characteristics and are recognised as such by the European Parliament and of the Council (2010)[2], their similar road behaviour with regular vehicles sets them apart. Hence, they fall outside this research's purview. Road workers could technically fit the VRU definition when on foot, as noted by PIARC (2012). However, the approaches for treating them and road users in TTM settings differ significantly, leading to their

[2] It is noted this definition also uses the term 'non-motorised' which would exclude a range of vulnerable road users types such as mobility scooters and electric scooters.

exclusion from this research. A comprehensive categorization of VRUs is provided in Appendix B.

For this research, I have defined VRUs as *Road users at heightened risk in road corridor settings due to their inability to consistently travel similarly to vehicular traffic, environmental unpredictability, and limited protective measures inherent to users of registered vehicles.*

The presence of Vulnerable Road Users

Roadways, once predominantly for vehicles, are increasingly embracing an ethos that seeks accommodation and freedom for all transport modes. Both societal shifts towards diverse transportation methods and policy initiatives drive this change. Central and local New Zealand governments, as evidenced by documents like the Government Policy Statement on Land Transport (GPS), accentuate pedestrian, cycling, and public transport priorities (Te Manatu Waka (Ministry of Transport), 2020). This shift suggests a move away from vehicle-centric views (De Gruyter, 2019). Financial commitments by the government indicate an ideological change, recognising all users, particularly those most at risk. Infrastructure changes by Auckland Transport (2019) and Wellington City Council (2022) show roads evolving into spaces shared by varied transport modes, aligning with a push towards zero emissions. Some have gone further, such as Auckland Transport who have conducted a safety trial utilising smart signage at intersections to improve the visibility and awareness of bikes and motorbikes, serving as an example of initiatives aimed at reducing deaths and serious injuries specifically for VRU groups (Mackie, 2023).

Integrating Vulnerable Road Users (VRUs) within these spaces presents complications. While new infrastructures cater to VRUs, with broader footpaths, separate cycle paths, and VRU-friendly intersections (Hui et al., 2017), complications arise when these environments require TTM to be implemented. Accustomed to safer restructured roads, VRUs suddenly face less predictable settings. This sudden introduction to TTM environments can also be attributed to their growing numbers and the infrastructure changes tailored for them.

However, it is more than infrastructure. The increase in VRUs reflects societal leanings towards ecological awareness, health, and inclusiveness. The rise in cycling, for instance, represents environmental and health consciousness (Woodcock et al., 2013), while the surge in electric scooter usage signifies technological progress and social acceptance of varied mobility options (K. Wang et al., 2022). Understanding VRUs' behaviours, needs, and vulnerabilities becomes crucial in this context. They are integral to the road network, necessitating TTM approaches prioritising their safety and mobility in line with inclusive transport paradigms.

Vulnerable Road Users in TTM

Construction and infrastructural developments inevitably disrupt regular road patterns in expanding urban environments (Handy et al., 2002). In Auckland alone, more than 1200 road work sites alter typical road conditions daily (Auckland Transport, 2023), resulting in modified environments for all road users, especially vulnerable ones.

The urban densification trend and an inclination towards sustainable transportation means that VRUs often navigate through road works (Brumec, 2015). The frequent encounters between VRUs and construction sites stem from urban plans emphasising pedestrian pathways, cycling lanes, and public transit systems (Noland & Quddus, 2006). However, these road works, vital for urban transformation, temporarily challenge VRU safety (Garrard et al., 2008). The very TTM measures meant to facilitate urban development can pose risks to VRUs (Hui et al., 2017).

Research into VRUs in TTM settings reveals heightened risks for these individuals (Rasanen & Summala, 1998; Soathong et al., 2019). Data from Waka Kotahi's Crash Analysis System (CAS) indicates a disproportionate representation of pedestrians and cyclists in severe accidents within TTM zones (Waka Kotahi, 2023a). The data utilised for this analysis is provided in Appendix A. A notable caveat on CAS data is that it does not explicitly categorise crashes at TTM sites but within temporary speed limit environments, which likely leads to underreporting, as not all TTM sites deploy temporary speed limits, and not every severe TTM accident occurs within these confines (Thomas et al., 2023). International research faces similar challenges, with Shaw et al. (2016) noting that crashes involving highway workers are often miscoded as pedestrian incidents in the U.S, while the Swedish STRADA[3] database underreports bicycle accidents, particularly those occurring near roadworks (Niska & Eriksson, 2014; Shaw et al., 2016). These data

[3] Swedish Traffic Accident Data Acquisition

limitations hinder a comprehensive understanding of the prevalence of VRU harm in TTM environments, and it seems these limitations are not isolated to NZ.

Between 2001 and 2021, there were 21,413 reported death and serious injury (DSI) crashes on NZ's roads, with 10,552 (49.3%) sustained by vulnerable road users (Figure 1).

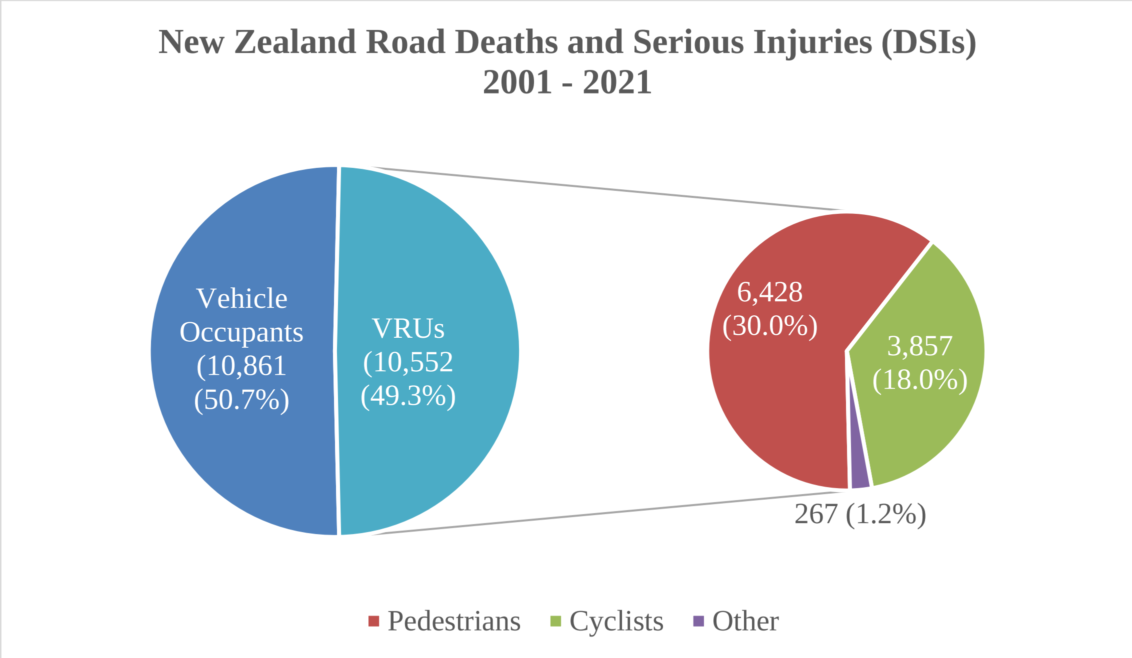

Figure 1 - NZ Road DSIs - 2001 – 2021 (Waka Kotahi, 2023a)

The overarching death and serious injury statistics paint a confronting picture – vulnerable road users make up almost half of those who are killed or seriously injured on our roads. A third of all those killed and injured are people on foot. Cycling deaths might seem lower; however, approximately 3% of on-road fatalities attributed to cyclists significantly exceed their participation in the roading network, as cycling makes up only 1.6% of all time travelled (Waka Kotahi, 2014).

It is necessary to look at the rate of VRU death and serious injury crashes in TTM sites, which can also be gleaned from the CAS. Across the same period (2001 – 2021), there were 746 documented death and serious injury crashes at worksites with a temporary speed limit deployed; 108 (14.5%) were sustained by vulnerable road users. This presents a markedly different picture to holistic DSI statistics, where VRUs comprise significantly more. One explanation is the nature of data reporting, which only captures sites with TSLs, as sites without temporary speed limits are prominent and arguably more likely to have severe implications for VRUs if higher [permanent posted] speeds are present.

Linear regression analyses were initially conducted to examine trends across various DSI variables, including TTM DSIs. These preliminary analyses yielded low R-squared values for most variables, suggesting a weak relationship between the variables and time. Consequently, linear trend analysis was deemed unsuitable for these variables and not included in the broader discussion. A notable exception was the proportion of TTM DSIs to overall DSIs, which has steadily climbed over the last two decades (Figure 2).

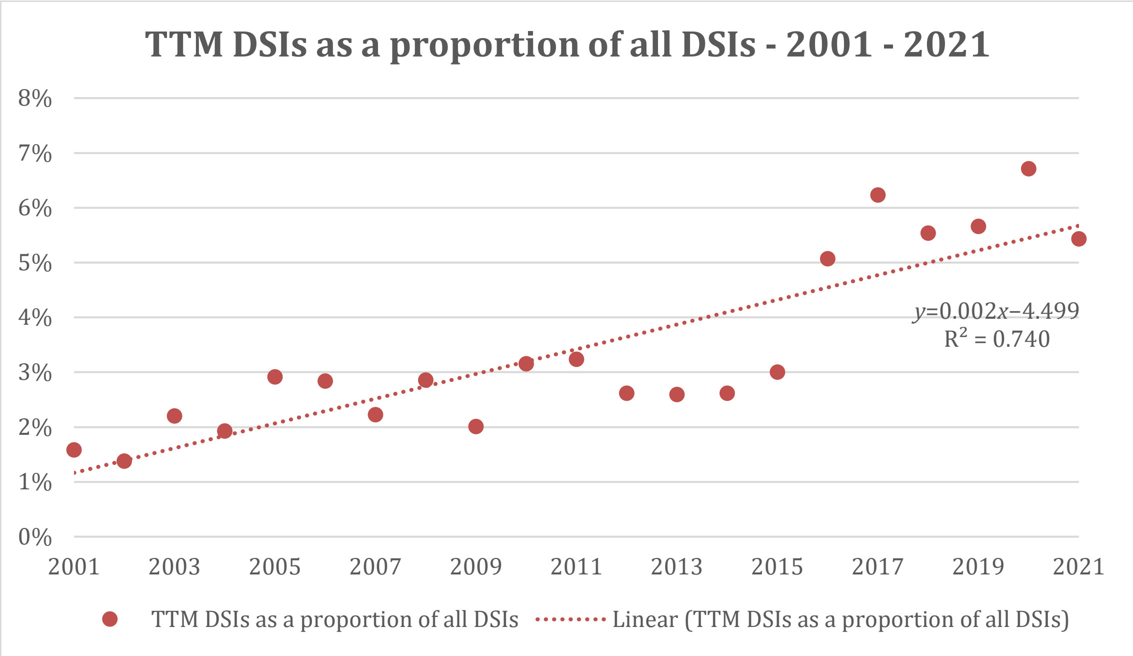

Figure 2 - TTM Deaths and serious injuries as a proportion of all road deaths and serious injuries (2021 - 2021)

The data reveals a significant upward trend in the proportion of TTM-related DSIs relative to all DSIs, increasing by approximately 0.2% annually. This is supported by a high R^2 value of 0.74 and a statistically significant F-statistic of 54.036 ($p < .001$), affirming the trend's robustness (refer to Appendix A).

The correlation matrix suggests several key relationships that could influence the increasing trend in TTM DSIs as a proportion of all DSIs. Specifically, the correlation between VRU DSIs at TTM sites and TTM DSIs is strong (r=.898, p<.001), as are pedestrian DSIs in TTM environments (r=.892, p<.001)[4]. This indicates that VRU DSIs at TTM sites, specifically pedestrian ones, play a significant role in the upward trend in deaths and serious injuries in TTM.

Comparatively, the correlation between all VRU DSIs and overall DSIs is r=.801 (p=.013), slightly lower than the TTM-specific equivalent. Interestingly, no such correlation exists between all pedestrian DSIs and overall DSIs (which does exist in the TTM realm). The heat maps shown in Table 1 and Table 2 highlight these respective correlations.

	All TTM DSIs	**VRU DSIs in TTM sites**	**Pedestrian DSIs in TTM sites**
VRU DSIs in TTM sites	.898 (<.001)		
Pedestrian DSIs in TTM sites	.892 (<.001)	.926 (<.001)	
Cyclist DSIs in TTM sites	.257 (.260)	.509 (0.19(	.509 (.019)

Table 1 - Correlations of VRUs DSIs (and subsets) with overall DSIs

	All DSIs	**VRU DSIs**	**Pedestrian DSIs**
VRU DSIs	.801 (<.001)		
Pedestrian DSIs	0.530 (.013)	.732 (<.001)	
Cyclist DSIs	.417 (.060)	.462 (.035)	-.260 (.256)

Table 2 - Correlations of VRUs DSIs in TTM sites (and subsets) with all DSIs in TTM sites

In summary, deaths and serious injuries occurring in TTM sites are increasing (as a proportion of all DSIs on NZ roads). Data suggests that the increase of DSIs in TTM sites is heavily influenced by harm to VRUs, especially pedestrians. This same correlation (with pedestrians) is not evident outside of TTM sites specifically, which indicates that harm to pedestrians in TTM environments is a specific area of concern.

An analysis by Soathong et al. (2019) of pedestrian crashes in New Zealand shows that fatal and serious injury crashes for pedestrians remain relatively high in NZ compared to some of the best-performing countries. In Sweden, single-vehicle accidents are the most common type among unprotected road users, including pedestrians and cyclists (SALAR, 2019). The United States

[4] Cyclist TTM DSIs do not share this same correlation.

reported an average of 120.4 work zone pedestrian fatalities per year from 2015 to 2019, with about 20% of these being workers on foot (Shaw & Oneyear, 2021). Germany's statistics for 2020 indicate that cyclists were involved in about 35% of all accidents with injuries (Berghoefer et al., 2023).

The risk is not just confined to VRUs but extends to all road users in TTM settings. Work zone crash risk increases by 20% to 30% compared to normal operations, and individual motorists' crash risk increases significantly during daytime and nighttime (Rista et al., 2017). The elderly are also at increased risk, with Yeon-Hong et al. (2015) reporting a 6.4% increase in accidents and an 8.1% increase in the death toll involving the elderly in 2012 compared to the previous year.

The proportion of fatalities involving non-motorised road users in the United States increased from 13% in 2003 to nearly 17% in 2012 (Shaw et al., 2016). Pedestrian fatalities in work zones increased from 98 in 2012 to 122 in 2018, and one in every five fatal crashes involved a pedestrian fatality (ATSSA, 2020). In Sweden, nine out of ten cycling accidents related to road works occur in urban areas, and cyclists have been the largest group of seriously injured road users since 2008 (Niska & Eriksson, 2014). In London, 78% of people killed or seriously injured near roadworks were those who walk or cycle (TfL, 2019).

These international findings resonate with the NZ context and emphasise the need for a comprehensive approach to improve the safety of VRUs in TTM settings. The data suggests that TTM sites are particularly hazardous for VRUs, and this risk is not adequately mitigated in current practices. Given the increasing trend of TTM-related DSIs in NZ, particularly involving VRUs, the development of a good practice guide for treating VRUs in TTM is not just timely but critical. If there is to be a meaningful reduction in those killed and seriously injured in TTM environments in New Zealand – a concerted and unrelenting effort must be made focused on those who are vulnerable, most prominently those on foot.

VRU Risk Factors in TTM Environments

In the TTM domain, VRUs encounter amplified risks, which is supported by evidence that even though cyclists represent a small minority in comparison with motorised vehicles (Prati et al., 2017), they account for a relatively large proportion of fatalities (European Road Safety Organisation, 2016). They lack the protective encasement vehicles provide, making them especially prone to injuries in even low-speed environments (Moudon et al., 2011). Figure 3 shows that even in a 50km/h environment – pedestrians face a roughly 80% chance of fatal injuries.

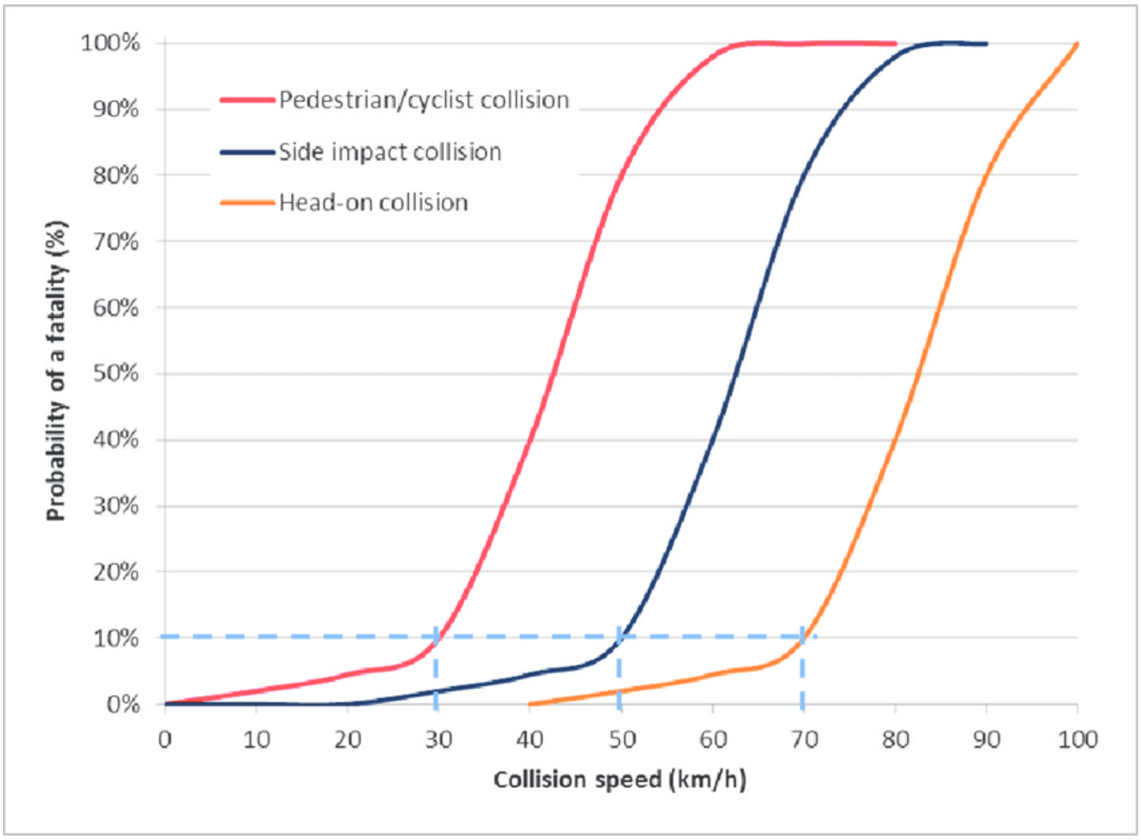

Figure 3 - Wramborg's model for fatality probability vs. vehicle collision speeds (Jurewicz et al., 2016)

The absence of defined pathways in TTM contexts can expose pedestrians to sudden obstructions. Cyclists might grapple with confined spaces or shared zones, escalating conflict potential (Schepers et al., 2014). Sensory interferences, coupled with varying road surfaces, can enhance VRU vulnerabilities.

In contrast, motor vehicle users benefit from a protective shield, reducing their immediate risks (Elvik et al., 2009b; Xin et al., 2017). However, they, too, navigate altered patterns and potential congestion in TTM zones. The inherent risks for VRUs in these dynamic environments highlight the urgency for a more VRU-centric approach in TTM protocols.

TTM spaces invariably restrict movement, often thrusting VRUs into tight confines adjacent to vehicular traffic or construction activities, elevating the risk (Zito et al., 2015). Additionally, temporary road surfaces might not always offer the necessary traction for cyclists, leading to slips or falls (Moller & Hels, 2008). The transient nature of TTM necessitates adaptive and flexible strategies that offer protection to VRUs, especially given the fluidity of hazards in these spaces (Martens, 2016). The variability of signage in TTM zones further compounds this unpredictability (Shaw et al., 2023).

The Need for a VRU Treatment Mechanism in TTM

The evolution of traffic management necessitates a shift towards a more inclusive perspective. Historically, the emphasis has predominantly centred on motor vehicles, often sidelining VRUs (Morelli et al., 2005).

This narrow focus has been evident in roadway projects, utility and public works projects, and construction sites (Shaw & Oneyear, 2021). Many officials, particularly at the local government level, have operated under the misconception that pedestrians are rare in their work zones. However, field observations have consistently shown the opposite: pedestrians are present at almost every site, underscoring a significant lack of awareness and empathy for pedestrian needs (Shaw & Oneyear, 2021).

TTM auditing data from Auckland Transport[5] from 2015 to 2022 reveals a concerning trend with a generally increasing proportion of sites with inadequate provision for pedestrians or cyclists. Specifically, the percentage of sites with inadequately managed VRUs rose from 15.42% in 2015 to 27.94% in 2021 (Kiddle, 2023)[6]. The linear trend analysis of this data reveals a 1.25% year-on-year increase (r=0.608). This upward trend in audited inadequacies aligns with the international literature that underscores the plight of VRUs in TTM environments. It further emphasises that VRU treatment in TTM environments in NZ is worsening, evidenced by the earlier DSI data and this exploration of TTM sites having a higher prevalence of inadequate safety measures that can effectively protect VRUs.

[5] Data from audits conducted by Auckland Transport staff who specialise in TTM, and undertake site audits on behalf of the Road Controlling Authority.
[6] This data is also housed within Appendix A.

To truly cater to these vulnerable users, TTM measures need to be tailored to their specific requirements. A more integrated approach is essential, where VRU-centric strategies become integral to the broader TTM framework, ensuring a more encompassing traffic management system (Hague, 2015) catering to the future transport network landscape.

Defining and Establishing Good Practice

Defining Good Practice

The importance of terminology in research, especially when developing or updating guidelines or standards, cannot be overstated. Central to this review is the term *good practice*. While *best practice* connotes an ultimate standard, its applicability is context-dependent, and what is best in one situation might not be in another (Druery et al., 2013). Conversely, *effective practice* is based on predetermined criteria. For instance, a practice in TTM might be *effective* if it reliably prevents harm, but this does not guarantee its broad endorsement.

Good practice offers a nuanced middle ground. Adopted by entities such as WorkSafe NZ (WorkSafe NZ, 2019), it mandates practices to be above a certain value threshold. A *good practice* must achieve the intended outcome, indicate a higher probability of repeated success, and be applicable across different scenarios and territories (Alli, 2001; FAO, 2013; Sorensen et al., 2018). It is characterised by adaptability and iterative evolution. For this research, I have defined good practice as *a method or technique aligned with a specific objective and validated by solid evidence to yield consistently better results than other approaches. It is designed to be iterative, adapting and improving over time. It can be reliably used and adjusted to fit different settings.*

Both grey and academic literature play vital roles in documenting these practices.

Good Practice in the context of TTM in New Zealand

TTM in New Zealand is experiencing pivotal change with the replacement of the longstanding CoPTTM by the NZGTTM (Waka Kotahi, 2022). Although the NZGTTM introduces 'practice notes' as a central repository for good practice, the onus is on the TTM sector to develop them. This shift is significant for an industry accustomed to prescriptive rules. The evolving nature of these 'practice notes' remains ambiguous. The decentralisation of their creation raises concerns about their authenticity under the NZGTTM framework. Recognising this, the recently established TTM Industry Steering Group (TTM ISG) strives to ensure the integrity and robustness of good practice within the NZGTTM context (E. Mitrova, personal communication, 21 August, 2023).

This research makes two main contributions:

1. To provide a foundation for the subsequent good practice guide.
2. Offer a comprehensive approach for researching and establishing good practices for TTM in New Zealand, which can be a reference for other TTM disciplines.

The new TTM ISG should leverage this research to avoid the risk of fragmentation in managing the NZGTTM transition. A noticeable gap exists in New Zealand's VRU treatment in TTM, and this deficit will likely grow with the shift to NZGTTM's philosophy.

International Good Practice

As New Zealand restructures its TTM framework, international benchmarks offer valuable insights. Practices from diverse regions, tested across contexts, offer data-rich solutions (Steers et al., 2018). By examining these practices, especially from nations with a successful history of VRU integration in TTM, this research can help address the current gap in VRU treatment. Furthermore, studying these practices lays a robust foundation for New Zealand's TTM future.

What constitutes good practice?

Of critical importance in this research is the evaluation of whether something is good practice. As explored in the *Defining Good Practice* section, the ambiguity associated with this terminology and the potential subjectivity of the threshold of 'good' warrant more stringent conditions on what should be included in a good practice guide. As put by Althaus (2005), "there is no independent arbiter of what is risky" (p. 575) – which means the inherent subjectivity of risk assessment results in further variation in what *good practice* would be. This is due to individuals having a different interpretation of what good treatment of risk would look like (conditional on their assertion of what needs treatment in the first place).

A critical challenge with such a determination is that which has befallen the existing CoPTTM, which for some time has had a discrepancy between the perception of its users (that it defines 'good practice') and the reality (that it represents, in many cases, *minimum* practice). Based on the current cultural approach to TTM in New Zealand, the risk is that any new good practice becomes similarly reflective of not what is *good* but what is the *least acceptable practice*, which would conflict with the philosophy of the Health and Safety at Work Act 2015.

As the analysis of international good practice (both grey and traditional academic literature) continues, this research must provide a conglomeration of international practices and criteria with which it can be assessed to show that it represents *good practice*, warranting its inclusion in a future New Zealand-based guide.

Literature Review Conclusion

The terrain of TTM, particularly in New Zealand, is undergoing transformative shifts. This transformation is underpinned by a nuanced understanding of evolving road user profiles, policy imperatives, and an inclusive urban vision. While roads were historically designed as conduits for motor vehicles, contemporary urbanisation trajectories and societal shifts are redefining these spaces as shared, multi-modal, and inclusive. As New Zealand steadily moves towards this inclusive paradigm, concern for the safety of VRUs in TTM is coming to the fore.

The framework of the NZGTTM has emerged as a viable anchor for the country's TTM practices to an adaptive, responsive, and future-oriented structure. However, its dynamism mandates industry-wide collaboration, knowledge co-production, and a commitment to continuous learning. Central to this are the concepts of *good practice*, which stand apart from their more absolute counterparts, such as *best* or *effective* practice. This conceptual clarity is pivotal to ensure that as the TTM field evolves, it does so with grounded precision, informed adaptability, and a commitment to safety.

It is evident that VRUs, in their diverse profiles, present both a challenge and an opportunity. The challenge lies in safeguarding their well-being in transient and dynamic TTM environments. However, the opportunity is twofold: reimagining New Zealand’s Road environments as inclusive spaces and innovating TTM practices to achieve this vision.

The international perspective is indispensable in this journey. Diverse global practices, distilled from varied socio-cultural and infrastructural contexts, offer a repository of evidence-backed strategies that New Zealand can critically engage with. Doing so ensures that the country's TTM practices are not insular but are, instead, enriched by global best practices that are tailored to New Zealand's unique context.

The path ahead for New Zealand's TTM is informed evolution. It balances the fine line between embracing change, safeguarding the vulnerable, and staying rooted in evidence and adaptability. This dynamic balance, when struck, can redefine the country's TTM paradigm, positioning it as a global leader in inclusive, safe, and adaptive traffic management practices.

CHAPTER 3: METHODOLOGY

Utilising an Integrative Review

Addressing the issue requires a robust, holistic, and adaptable approach, given the complexities and evolving dynamics of accommodating vulnerable road users within TTM environments. In this context, an integrative review offers an appropriate strategy. The integrative review synthesises data from both empirical and theoretical literature, thus offering a comprehensive understanding of complex phenomena. By incorporating diverse data types like quantitative, qualitative, and grey literature, this approach includes solutions from various disciplines, including traffic engineering, urban planning, and public health (Souza et al., 2010; Whittemore & Knafl, 2005). It involves thematic analysis to pinpoint themes and variations across research outputs (Thomas & Harden, 2008). An integrative review allows for blending empirical results with theoretical viewpoints to craft guidelines tailored to New Zealand's unique landscape (Torraco, 2016). It also allows for the development of evidence-based guidelines (Cronin & George, 2020), matching the aim of this research to bridge the guidance gap for vulnerable road users in New Zealand's TTM contexts, especially in light of the NZGTTM replacing the CoPTTM.

Types of Literature

Figure 4 represents the component literature utilised as part of this integrative review. Each is explored briefly below.

Grey Literature

In the TTM realm, grey literature stands out due to its prominence in the current practice framework in New Zealand and abroad. Such literature primarily consists of government or institutional guidelines and standards that standardise practices while aligning with legislative duties, such as the Health and Safety at Work Act (Bickley et al., 2020). Other categories include government reports, working papers, theses and dissertations, conference proceedings, technical standards, and policy documents (Lawrence et al., 2014). Additionally, research commissioned by authorities, like the research programme of Waka Kotahi (NZ Transport Agency), offers niche insights (Te Manatu Waka (Ministry of Transport), 2023; Waka Kotahi, 2023g). This study's methodology prioritises grey literature for its territorial specificity on TTM standards. Initial grey literature exploration sets the path for academic literature search, focusing on documents meeting specific inclusion criteria: credibility, relevance, recency, and accessibility (Adams et al., 2017; Schöpfel, 2011). The applied criteria amplify the research's practical applicability within TTM frameworks by utilising a broad range of evidence (Auger, 1998). Table 3 takes this array of grey literature types, applies the layering provided by Garousi et al. (2019), and categorises the grey literature avenues used in this research to this framework.

Grey Literature Tier	Examples	Examples used in this research
Tier 1 (high outlet control / high credibility)	Books, magazines, government reports, white papers	Government or institutional TTM standards Commissioned reports by research entities or institutions Government reports and or research
Tier 2 (moderate outlet control / moderate credibility)	Annual reports, news articles, presentations, videos, Wiki articles	News articles Presentations from institutions or agencies Government website content
Tier 3 (low outlet control / low credibility)	Blogs, emails, tweets	Some personal communication with experts

Table 3 - Grey literature types utilised in this research matched to Garousi et al. (2019)'s framework

Academic Literature

Traditional academic sources, manifested in journals or conference publications, offer a structured and comprehensive dimension to the research. They bolster the practical insights from grey literature and contribute significantly to establishing good practice.

New Zealand Legislation

Lastly, understanding New Zealand's legal context is paramount. Relevant legislative provisions, essential to the good practice framework, ensure its legal robustness. Post-research, these provisions might serve as a checklist to ascertain the validity of the ensuing good practice guidance.

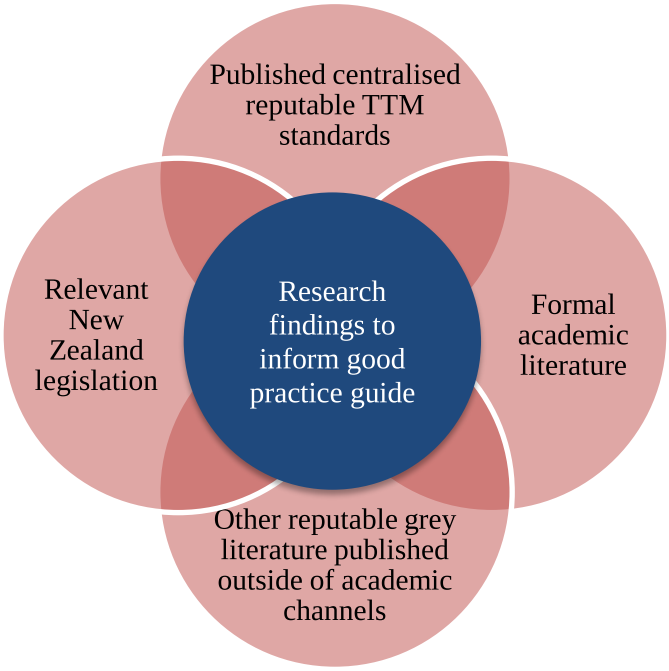

Figure 4 - Model of literature avenues as part of this integrative review

TTM Standards - Establishing the Geographical Catchment

To effectively integrate grey literature from established TTM standards, it is pivotal to designate an appropriate geographical catchment. Given NZ's membership of the Organisation for Economic Co-operation and Development (OECD), I use member countries as the benchmark, and several factors substantiate my choice.

First, OECD countries, including New Zealand, present a viable road safety performance comparison framework. It has been observed that road fatality rates in these nations tend to be influenced by economic dynamics, resulting in fatality rate convergence among member countries (Nghiem et al., 2013). Such observations are pivotal when analysing New Zealand's TTM and road safety trajectory.

Methodological innovations in road safety benchmarking have prominently featured OECD countries (Chen et al., 2020). Grey literature, particularly government reports and guidelines, offer instrumental methods for monitoring, thus granting New Zealand actionable insights from varied road safety journeys (Elvik et al., 2009a).

Emphasising technological advancements in road safety, the commitment of OECD countries has been evident over the past decades (Nghiem & Connelly, 2015). Furthermore, examining the efficacy of road safety campaigns within these countries yields valuable best practices (Hoekstra & Wegman, 2011). The International Transport Forum's annual road safety reports reinforce the significance of OECD countries in global road safety (International Transport Forum, 2022).

As of July 2023, the OECD's roster comprises 38 nations[7] (OECD, 2023). However, to align with the research objectives, further refinement is imperative. This entails concentrating on political dynamics and the underpinnings of health and safety legislation, which are essential in shaping TTM risk perception and management. Such targeted refinement ensures that the derived insights are apt for the integrative review.

The importance of the democratic climate

Political constructs invariably affect the establishment and execution of health and safety standards, including TTM. Differentiating countries based on their democratic structures becomes

[7] Refer to Table 3

crucial, as variances in political paradigms result in distinct risk management strategies for health and safety matters. Democratic regimes differ in participation, deliberation, and equity considerations, which shape risk responses, especially in traffic management (Peters & Pierre, 2016).

The 2023 Democracy Report from the Varieties of Democracy (V-Dem) project offers a comprehensive perspective on nations' democratic climates, ranking them on a 0-1 scale (Papada et al., 2023). A superior V-Dem score denotes pronounced democratic values, potentially mirroring the climate underpinning health and safety norms. A representation of the 2023 V-Dem scores for OECD countries is available in Figure 5.

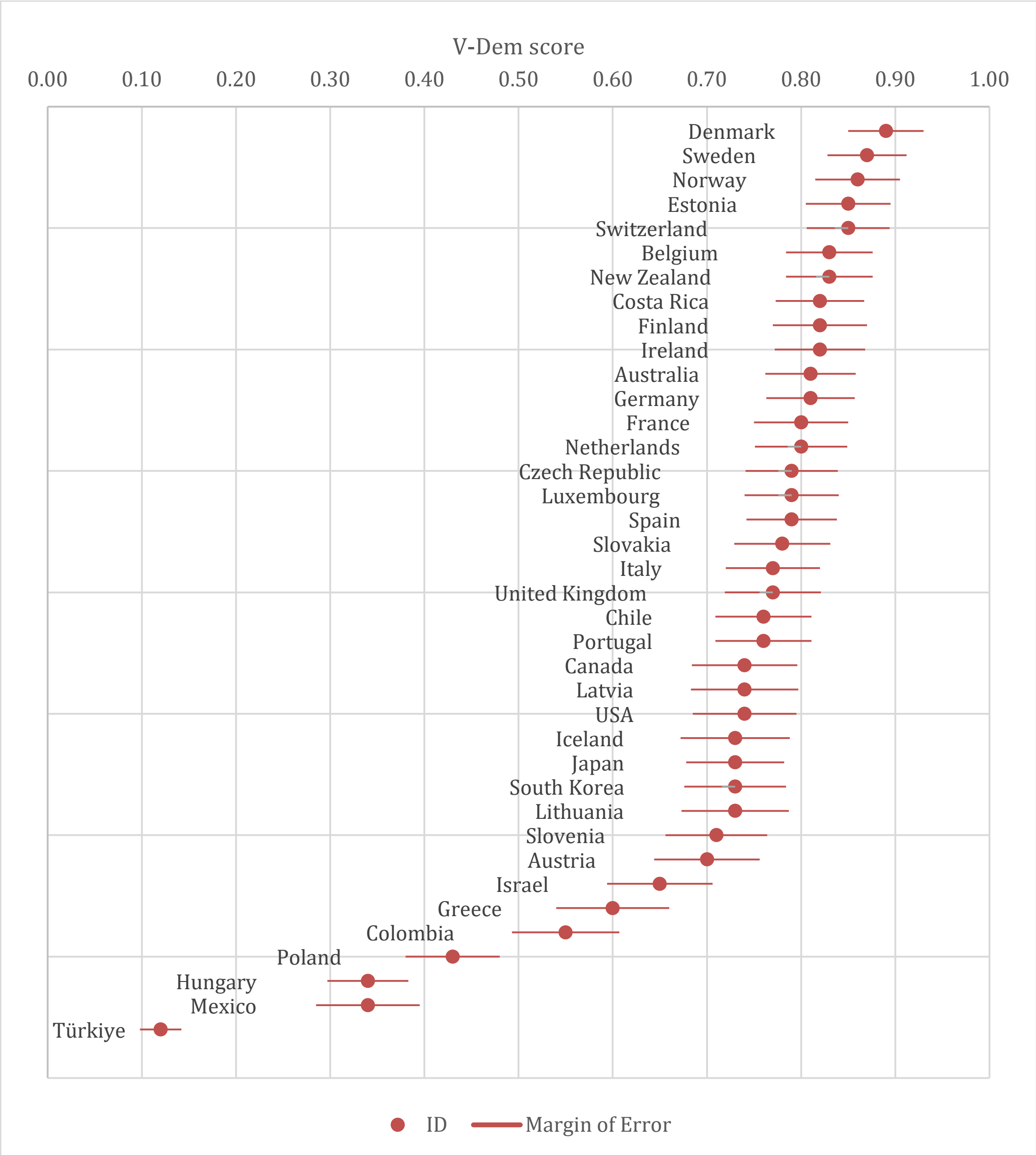

Figure 5 - OECD country V-Dem scores 2022 (Papada et al., 2023)

Using New Zealand's score of 0.83 as a benchmark and factoring in a standard deviation of 0.164 from collective scores, a range was deduced, spanning 0.71 to 0.95. Nations with V-Dem scores within this spectrum reflect democratic climates like New Zealand. Those falling outside this bracket exhibit a disparity that could lead to inconsistencies when paralleling TTM standards. The 30 remaining countries falling within the established range are listed in Table 4.

Countries with a V-Dem score within 0.75 SD of New Zealand on the V-Dem range		
Australia	Germany	Norway
Belgium	Iceland	Portugal
Canada	Ireland	Slovakia
Chile	Italy	Slovenia
Costa Rica	Japan	South Korea
Czech Republic	Latvia	Spain
Denmark	Lithuania	Sweden
Estonia	Luxembourg	Switzerland
Finland	Netherlands	United Kingdom
France	New Zealand	USA

Table 4 - OECD Countries categories by 2023 v-Dem Democracy Project score

Occupational Health and Safety (OHS) legislative context

For integrating international best practices into New Zealand's TTM domain, focusing on nations with a health and safety legislative foundation analogous to New Zealand is imperative. This ensures the feasibility of implementation within the New Zealand context. The Health and Safety at Work Act (2015), inspired by the Robens-style legislation, is central to New Zealand's OHS. Emphasising a general duty of care over prescriptive regulations, the Robens model operates on the principle that those creating risks are optimally positioned to manage them (Johnstone et al., 2012). Countries adopting this model, like Australia and the UK, align closely with New Zealand's OHS philosophy.

Territories included due to Robens-style legislative foundation		
Australia	New Zealand	United Kingdom (UK)

Table 5 - Robens-style OHS legislative territories for ongoing inclusion in the review

The European Union (EU) has a directive on OHS mandating its member countries to abide by a shared framework to align national policies (European Agency for Safety and Health at Work, 2021). Mirroring the Robens-style legislation, it mandates risk management by the risk creators. The EU framework for TTM standards is explored more in the *TTM in Europe* section. Table 6 outlines the countries from the already-narrowed list that fall into this jurisdiction.

Territories included due to EU OHS directive adherence		
Belgium	Germany	Netherlands
Czech Republic	Ireland	Portugal
Denmark	Italy	Slovakia
Estonia	Latvia	Slovenia
Finland	Lithuania	Spain
France	Luxembourg	Sweden

Table 6 - EU OHS directive territories for ongoing inclusion in the review

While the United States Occupational Safety and Health Act (OSHA) is more prescriptive, it holds to the core tenet of fostering a safe working environment, thus sharing an alignment with

New Zealand's legislative principle (Takala et al., 2009). Similarly, Canada, albeit lacking a federal OSHA equivalent[8], follows an approach parallel to that of the US (Eakin et al., 2016). Japan's Industrial Safety and Health Act also resonates with OSHA's philosophy. (Nordin & Ahin, 2016).

Territories included due to OSHA-style legislative foundation	
Canada	Japan
United States	South Korea

Table 7 - OSHA-style legislative territories for ongoing inclusion in the review

Several countries, including Chile, Costa Rica, Iceland, Norway, and Switzerland, were excluded due to their distinctive OHS legislative approaches. Chile and Costa Rica follow a more prescriptive approach, deviating from the Robens-style, EU Directive, and OSHA-style laws (Eakin et al., 2016). Iceland combines prescriptive and performance-based aspects (Sargeant & Tucker, 2016). Norway's legislation aligns with the EU Directive but also integrates facets of the Nordic model, emphasising tripartite cooperation (Gustavsen, 2011). Switzerland's federal system sees each province responsible for OHS law implementation, leading to varied enforcement, a deviation from New Zealand's unified approach (Hämäläinen et al., 2006).

The Resultant International Territories

A consolidated list of OECD countries is presented after factoring in democratic climate and OHS legislative congruence in Table 8.

Final list of territorial inclusions for grey literature review		
Australia	Germany	New Zealand
Belgium	Ireland	Portugal
Canada	Italy	Slovakia
Czech Republic	Japan	Slovenia
Denmark	Latvia	South Korea

[8] Canada does not have a single unified federal Occupational Safety and Health Act. However, occupational safety and health regulations are covered under the Canada Labour Code, specifically Part II - Occupational Health and Safety.

Estonia	Lithuania	Spain
Finland	Luxembourg	Sweden
France	Netherlands	United Kingdom
		United States

Table 8 - Final list of 25 country inclusions for grey literature in TTM

Gathering of Territorial TTM Standards

Collecting TTM standards from selected territories serves multiple purposes. It fine-tunes the subsequent academic literature search by acknowledging regional terminology differences (Adams et al., 2017), and it informs a relevant timeframe for the search. Moreover, these standards enrich the integrative review, revealing prevailing standards and practices across diverse territories (Auger, 1998).

To collect TTM standards, appropriate governmental bodies were identified, with their latest guidelines procured and analysed in line with the research aims. This process entailed online searches, accessing the guidelines via official websites or direct communication, and thorough reviews to ascertain their depth on TTM standards, particularly vulnerable road user safety.

For Canada and the United States, standards primarily emerged at state or provincial levels, requiring further categorisation for relevance and applicability.

National-level standards

Aside from Canada, the countries listed in Table 6 maintain at least one (and in some cases multiple[9]) overarching national TTM standard/s. Each of those standards has been reviewed for meaningful content regarding VRUs, leaving 21 unique pieces of grey literature for inclusion, as catalogued in Appendix C.

[9] Multiple national standards materialise where TTM expectations are spread across multiple documents – such as an overarching wholesome TTM standard supplemented by a VRU-specific one, or in the case of New Zealand where there is an outgoing and incoming national standard which are currently both active.

Luxembourg and the Czech Republic have no easily accessible national TTM standards; however, they are parties to several EU standards covered in the *TTM in Europe* section. Australia primarily conforms to state-level standards; however, it has a centralised national standard that is in the process of adoption, and therefore, this has been included (but not the state-level standards as these are deemed to be superseded).

TTM in Europe

The European Union (EU) governance framework results in several countries conforming legislatively or voluntarily to trans-national directives and standards. The intersectionality of these layers across the EU becomes increasingly intricate, ranging from EU parliamentary directives to research reports to voluntary privatised standards.

This includes the European Parliamentary Directive, which mandates road safety procedures that member states must legislatively address (European Parliament and of the Council, 2019; European Union, 2023). The European Union Road Federation (ERF) Working Group on Road Work Safety, originating from a European Parliament directive, has integrated analyses from 16 EU nations in its 2019 report *Towards Safer Work Zones* (ERF Working Group Work Zone Safety, 2019; World Highways, 2015). Other initiatives like the Incursion Reduction to Increase Safety in Road Work Zones (IRIS) project and the Trans-European North-South Motorway (TEM) Project aim to disseminate best practices and unify TTM standards across multiple countries (Strnad et al., 2019; UNECE, 1997, 2021). Additional EU-wide efforts include the Preventing Road Accidents and Injuries for the Safety of Employees (PRAISE) project and the Scoring Traffic at Roadworks (STARs) project, which guide work-related road safety policy and offer holistic methods to assess road work schemes, respectively (ETSC, 2011; Weekley et al., 2013). Alongside these EU-wide initiatives, individual member countries have also developed their own TTM standards, as detailed in Appendix C. Several additional literature items originating in Europe are also captured in the *Other grey literature* section.

Table 9 consolidates the above standards and provides a matrix of applicable TTM standards across EU countries.

Included EU countries and corresponding applicable standards																		
Standard	**Country**																	
	BE	**CZ**	**DK**	**EE**	**FI**	**FR**	**DE**	**IE**	**IT**	**LV**	**LT**	**LU**	**NL**	**PT**	**SK**	**SI**	**ES**	**SE**
ERF Towards Safer Works Zones (ERF Working Group Work Zone Safety, 2019)		Y		Y	Y	Y	Y	Y	Y	Y	Y			Y	Y		Y	Y
IRIS Guidance Document on Temporary Traffic Management (Strnad et al., 2019)	Y						Y	Y								Y		Y
Trans-European Network for Motorways (TEM) Guidelines on Work Zone Safety (UNECE, 2021)									Y			Y			Y	Y		Y
Preventing Road Accidents and Injuries for the Safety of Employees (PRAISE): Road Safety at Work Zones (ETSC, 2011)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Scoring Traffic at Roadworks (STARs) project (Weekley et al., 2013)			Y		Y		Y						Y			Y		Y

Table 9 - European Countries - TTM frameworks and standards

TTM standards in Canada and the United States

Canada lacks a singular national TTM standard, requiring examination at the provincial level. Selection criteria excluded territories based on size (e.g., Northwest Territories, Nunavut, Yukon, Prince Edward Island) or accessibility to English-language standards (e.g., Quebec). City-level standards, such as Calgary, are omitted due to the suitability of provincial standards for this study. The complement of reviewed Canadian provincial standards are outlined in Appendix D, with those included in the review catalogued in Appendix E.

In contrast, the United States offers some federal TTM guidance (catalogued already in Appendix C). However, state legislatures predominantly provide substantive TTM guidance. The comprehensive nature of available U.S. resources necessitates further inclusion and exclusion criteria. An initial examination encompassed 53 U.S. jurisdictions (50 states, the District of Columbia, Puerto Rico, and Guam) concerning TTM. This was facilitated by the repository from the US National Workzone Safety Clearing House (American Road and Transport Builders Association (ARTBA), 2023).

Beyond the state-level general TTM guidance influenced by Americans with Disabilities Act (ADA) stipulations, select states offer specialised TTM guidance for VRUs. Given their pertinence to this study, the general and VRU-specific guidelines are incorporated. Eight jurisdictions, including California, Minnesota, Missouri, North Carolina, Oregon, Vermont, and the District of Columbia, possess dedicated VRU guidelines for work zones.

A preliminary scan of the 53 jurisdictions revealed 30 possessing easily accessible TTM standards or guidelines. Within these 30:

- Sixteen sparsely reference pedestrians or cyclists, offering limited value to this research.
- Five have a publication date preceding 2015, reducing their relevance in capturing current best practices.

After filtering, nine U.S. territories remain for general TTM standards, complemented by the previously identified eight states with VRU-specific guidelines. In total, nineteen distinctive U.S. standards have been considered, with comprehensive exploration in Appendix D. Those subsequently included in the review are catalogued in Appendix E.

,,

Other grey literature

Several additional guidelines, reports, and papers not classified as territorial guidelines but still fitting the grey literature definition were uncovered throughout the search and collation of territorial grey literature.

Of valuable note is the contributions to this field by the Australian National Road Safety Partnership Program (ANRSPP) which a number of these other grey literature pieces are featured within. The ANRSPP's collaborative approach uniting industry, research bodies, and government agencies has fostered a more prominent evidence-based approach in the grey literature space, particularly in emergent disciplines like TTM which have historically suffered reduced maturity. A total of twenty-six pieces of literature ranging from the *Pedestrian Accommodation in Work Zones Field Guide* published by the American Traffic Safety Services Association (ATSSA) (2021) to WorkSafe NZ's *Keeping health and safe while working on the road or roadside* (WorkSafe NZ, 2022b). Each item is catalogued in Appendix E with a brief description.

Complete catalogue of included grey literature

Figure 8 pictorially represents all territories (countries, states, provinces) with an included TTM standard identified and collated through the grey literature search process. In total, 67 TTM standards that meet the identified criteria and 26 additional grey literature items have been catalogued as outlined earlier.

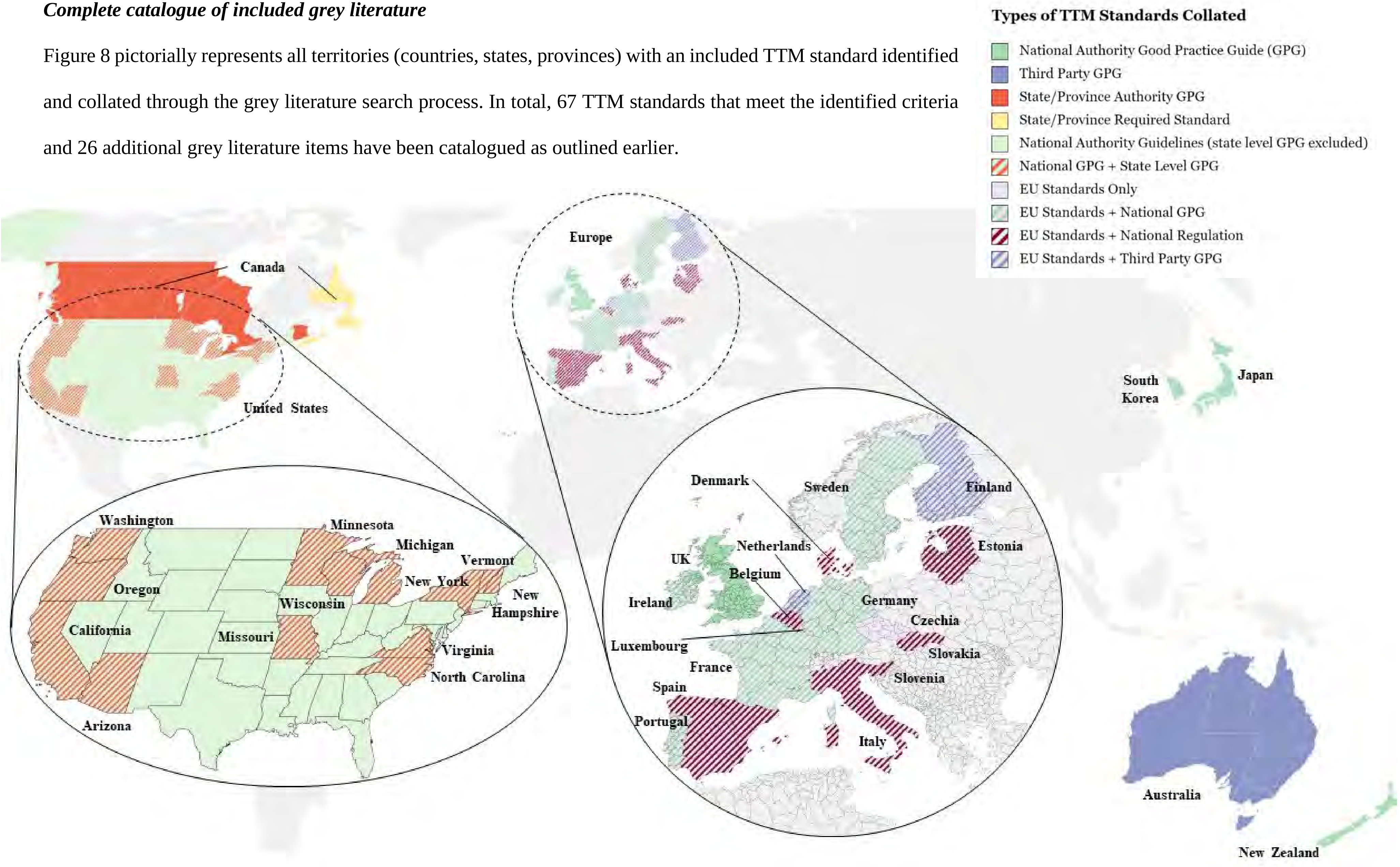

Figure 6 - Included Grey Literature (TTM Standards) from final included territories

Examination of the Gathered TTM Standards

A holistic examination of the standards

Surveying 25 relevant countries, encompassing 67 states, provinces, or municipalities, yielded 92 distinct grey literature items (including those in the *other grey literature* category). After an initial review, 73 possess substantial content on VRUs' treatment within TTM settings.

These 73 unique items, having undergone the preliminary review, will be subjected to a detailed assessment and represent the conclusive catchment for this integrative review. The comprehensive list of these 73 items can be found in Appendix E (segregated into tables of their type).

Accounting for potential terminology variances across regions is vital. Terms such as "Temporary Traffic Management" might be denominated as "Traffic Control" in certain territories. Therefore, standardising the understanding of pivotal terms became imperative. This effort required a meticulous evaluation of each standard, pinpointing terms representing central concepts pertinent to this study - *vulnerable road users*, *worksite*, and *TTM*. The ambition was to develop a terminological correlation enabling effective cross-territorial searching. This approach also facilitates a more focused academic literature exploration, circumventing geographical idiosyncrasies. The original 92 distinct grey literature pieces assisted in discerning terminology differences. The most common variations identified are presented in Table 10. An exhaustive enumeration of terminology variations is accessible in Appendix F.

Common variations of TTM terms across included territories	
Primary Term	**Variations**
Temporary Traffic Management (TTM)	Temporary Traffic Arrangements, Temporary Traffic Control, Temporary Traffic Management, Temporary Traffic Measures, Traffic Accommodation, Traffic Control.
Vulnerable Road User	Bicyclist, Cyclist, Impaired Pedestrians, Mobility Impaired Pedestrians, Non-Motorized Traffic, Pedestrian, Persons With Disabilities, Pushchairs, Scooters, Special Needs Groups, Visually-Impaired Pedestrians, Vulnerable Highway Users, Vulnerable Transport User, Vulnerable Road Users.
Work Site	Road Work, Road Workplaces, Roadside Work, Roadwork Site, Roadwork Zone, Roadworks, Work Activity Area, Work Site, Work Zone, Worksite.

Table 10 – High-use terminology across included territories from grey literature

TTM standard renewal cycles

Identifying the renewal cycle of the collected TTM standards constitutes the final step of this methodological phase. Grasping the update frequency of these standards is essential in designating an apt span for subsequent academic literature exploration. This task required assessing each standard and supplementary data from the associated source websites, pinpointing the latest update date and usual update intervals.

The update cadence of these standards delineates the academic search span, given the established premise in academia that a source's contemporaneity critically underpins its pertinence and trustworthiness (Fink, 2010). Antiquated sources might not mirror prevailing insights, techniques, or accord in effective practice, underscoring this study's requirements. Hence, comprehending the update rhythm of the TTM standards aids in anchoring the literature review in present-day expertise and methodologies.

In defining the renewal cycle, revisions deemed 'major' encompass significant alterations to the guidelines or methods stipulated in the standard, contrasting with trivial textual or layout modifications. This discernment draws from the standard's revision chronicle or change registry if accessible, or supplementary documentation furnished by the sanctioning entity. The ascertained renewal cycles and the current versions consulted are catalogued in Appendices C and D. Of the 74 amalgamated grey literature pieces, 51 are revisable documents with an accessible publication date, depicted in Figure 7.

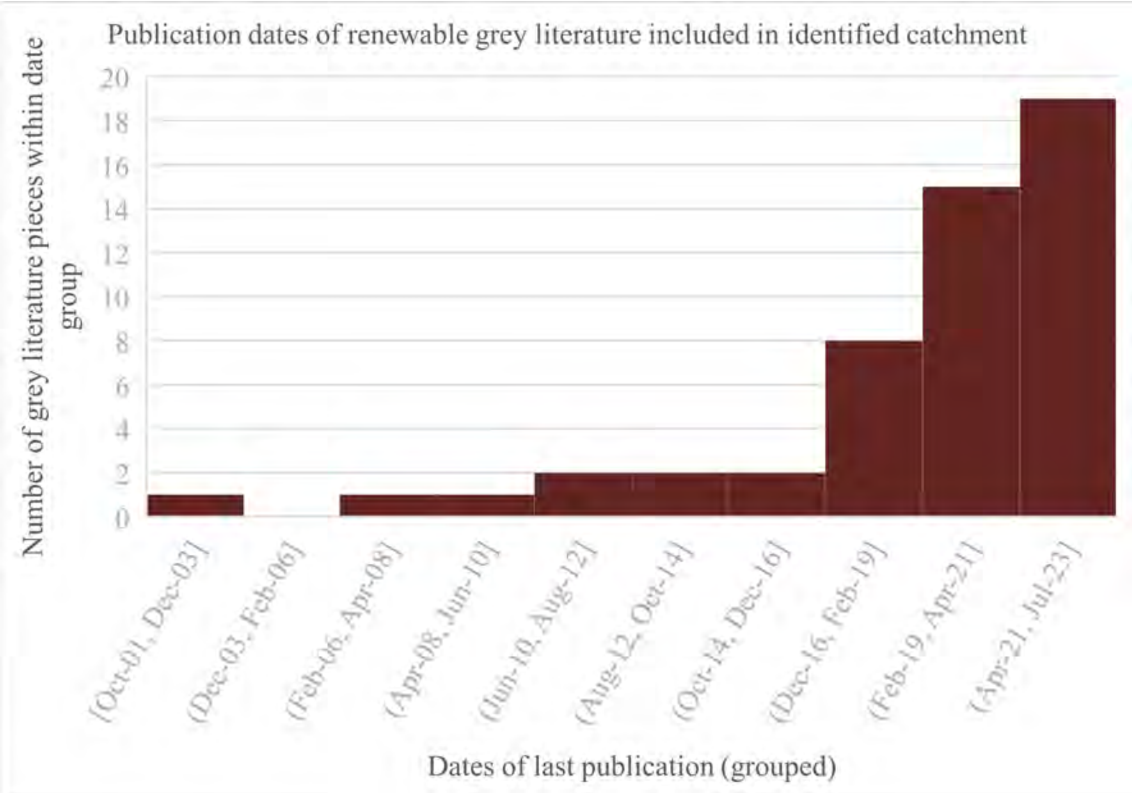

Figure 7 - Publication dates of renewable grey literature included in the identified catchment

Subsequent analysis denotes that 42 standards lie within two standard deviations (SD) and were promulgated post-January 2015, rendering the age span of this literature body at 8.5 years.

A subset of 26 documents have discernible version histories. These 26 serve as the basis for ascertaining an apt renewal rhythm, visually represented in Figure 8.

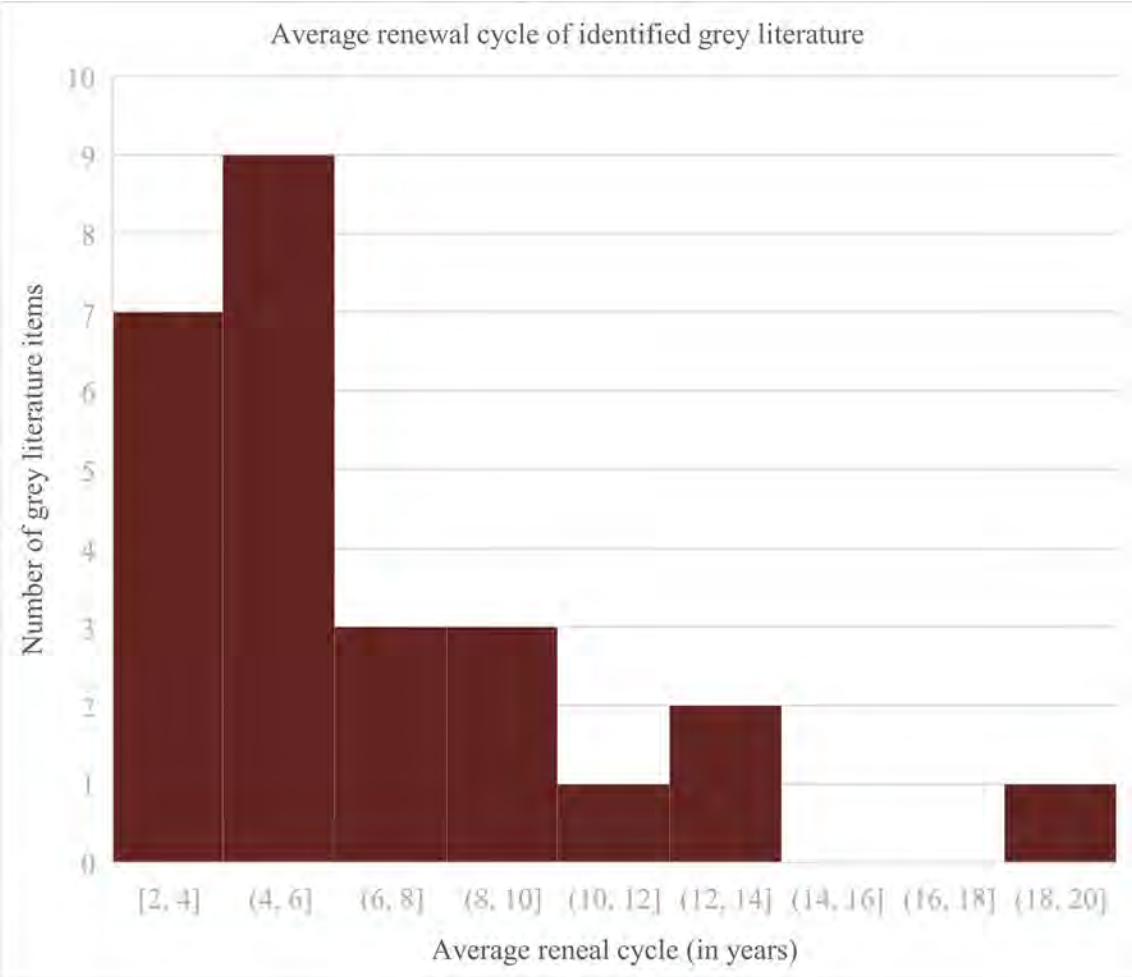

Figure 8 - Average renewal cycle of identified grey literature

Evaluative scrutiny reveals that 19 of these standards are encased within 2 SD and were issued after January 2015, with this literature subset averaging 8.3 years since the preceding renewal. Thus, an academic literature search window spanning nine years is selected, ensuring the incorporation of a pertinent body of literature that mirrors the current understanding regarding this research's focal theme.

New Zealand Legislative Literature

NZ's legislative framework for TTM is complex and polycentric, involving multiple regulators that influence the same duty holders (Black, 2008; Carden et al., 2021). This complexity necessitates a detailed understanding of the overlapping legislative context, directly informing good TTM practice. The New Zealand Parliamentary Counsel Office administers the country's legislation, including first and second-tier legislation and other instruments (New Zealand Parliamentary Counsel Office, 2023).

Three strategies were employed to capture relevant legislative content. First, the recently released New Zealand Guide to Temporary Traffic Management (NZGTTM) and its predecessor, the Code of Practice for Temporary Traffic Management (CoPTTM), identify critical legislative acts and regulations, including the Health and Safety at Work Act 2015 (Waka Kotahi, 2019a). Second, Waka Kotahi's website, in compliance with the Land Transport Management Act 2003, lists legislation relevant to its operations (Land Transport Management Act 2003, s 96A; Waka Kotahi, 2023d, 2023e). Third, a Boolean search on the New Zealand legislation website yielded 147 unique legislative documents reviewed for relevance to TTM or vulnerable road users.

Applying these strategies resulted in identifying 33 distinct legislations with 104 unique provisions relevant to treating vulnerable road users in TTM. These provisions were further scrutinised to eliminate overlaps and highlight their direct relevance to this research. The legislative stipulations affect TTM stakeholders, including asset owners, clients, contractors, and road users. A systematic categorisation of these provisions and their applicability to stakeholders is detailed in Appendices G and H, which will be the primary basis for establishing the legal appropriateness of promising practice findings from this review.

Academic Literature Review

Methodology

A systematic literature review (SLR) method was used to glean the most applicable academic literature. A modified PSALSAR framework[10] is adopted for use, mirroring the approach taken by Mengist et al. (2020).

Steps	*Outcomes*	*Methods*
1. Protocol	Define the study scope	Informing good practice guide for treating vulnerable road users in temporary traffic management.
2. Search	Define the search strategy.	Searching strings
	Search studies	Search databases
	Selecting Studies	Closely define inclusion and exclusion criteria.
3. Appraisal	Quality assessment of studies	Define quality criteria
	Extract Data	Extraction template
4. Synthesis	Categorise the data	Categorise the data based on the areas of the question – VRU, TTM, and Good Practice.
	Data Analysis	Quantitative analysis and narrative analysis on the organised data
5. Analysis[11]	Result and discussion	Show the findings and connections giving rise to the recommendations to feed the development of TTM good practice.
	Conclusion	Derive the recommendations
6. Report[11]	Report writing	Utilising PRISMA methodology (Page et al., 2021) and integrated into this research paper.
	Article production	Distill research for a larger publication.

Table 11 - Application of the PSALSAR framework to this academic SLR

[10] Protocol Search Appraisal Synthesis Analysis and Report - A synthesis of two methodologies - the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and the Search, Appraisal, Synthesis, and Analysis (SALSA)

[11] Steps 5 and 6 are undertaken with the previously collated grey literature as well. Step 5 is still followed; however it is done so in the subsequent Findings and Discussion section of this paper.

Step 1 – Protocol – defining the scope

Rooted in prior findings and discussions, four avenues emerge as paramount in understanding the connection between VRU and TTM. These areas, delineated below, reflect the tangible strategies employed in the field and the underlying principles and behaviours that inform them. The choice of these specific areas emerges from the necessity to merge practical TTM applications, theoretical underpinnings, and the unique considerations of VRU.

1. *Vulnerable Road Users (VRU) Treatment in Temporary Traffic Management (TTM).* The crux of the research lies in the intersection of VRU and TTM. Therefore, it is imperative to delve into how VRUs have historically been treated in TTM scenarios. This provides a platform to identify gaps, leverage best practices, and cultivate an in-depth guide (Zegeer & Bushell, 2012)
2. *TTM Principles and Philosophies for VRU.* Certain principles or philosophies underpin the practical application of TTM. Grasping these foundations not only aids in understanding the evolution of TTM practices but also guides how these can be tailored for VRU (Elvik et al., 2009a).
3. *VRU Psychology, Compliance, Behaviour, or Needs Relevant to TTM.* A user-centric TTM system necessitates comprehension of VRU's psychology and behaviours. Recognising how VRU interact with traffic scenarios ensures the development of strategies that foster safety and compliance (Papadimitriou et al., 2013).
4. *Compilation and Presentation of Good Practice Guides in TTM and Comparable Disciplines.* Methodologies underpinning the creation of good practice guides, especially within comparable legislative frameworks, are invaluable. They offer a structural roadmap to achieve the research objective, ensuring legal and practical alignment (Sorensen et al., 2018).

Each of these four areas will receive a structured academic literature search undertaken methodically following the parameters outlined below.

Step 2a – Search – Establishing the search strategy

An appropriate search string for the four search avenues can be crafted based on the terminology exploration done as part of the grey literature compilation process.

Due to the restrictive (number of operators) nature of some databases and the desire to approach this search more methodically – the search strings are broken into main and then secondary searching terms to cover the spectrum of terminology similar to the approach explained by Mengist et al. (2020) and Fernández del Amo et al. (2018)

Vulnerable Road Users (VRU) Treatment in Temporary Traffic Management (TTM)

<table>
<tr><th>Intent of Search Term</th><th>Variations of Search Terms</th></tr>
<tr><td rowspan="3">Vulnerable Road Users (and variations)
AND
Temporary Traffic Management (and variations)
NOT[14] (air OR rail OR LAN) [12]</td><td>(pedestrian* OR *ycl* [13] OR wheelchair* OR disabilit* OR vulnerab*) AND “Traffic Management”</td></tr>
<tr><td>(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND “Traffic Control*”</td></tr>
<tr><td>(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND “Traffic Guid*”</td></tr>
</table>

Table 12 - Search terms relating to VRU and TTM together

TTM Principles and Philosophies

Intent of Search Term	Search Term
Temporary Traffic Management (and variations) **OR Work Zone (and variations)** **AND** **Documentation or standards variations (i.e., methods, principles, etc.)** **NOT [14] (air OR rail OR LAN) [15]**	("Traffic Management" OR "Traffic Guid*" OR "Traffic Control*" OR "Work Zone" OR "Road Work") AND (method* OR approach* OR guide* OR principl* OR philosoph* OR strateg*)

Table 13 - Search term relating to TTM guidance

[12] This NOT term is included deliberately to ensure the focus remains on road-based temporary traffic management, omitting any references to air traffic control, railway systems, or information technology.
[13] Accounts for cycling, cyclist, cyclists, bicyling, bicyle, bicyclist
[14] Scopus requires the exclusion term ‘AND NOT’
[15] This NOT term is included deliberately to ensure the focus remains on road-based temporary traffic management, omitting any references to air traffic control, railway systems, or information technology.

VRU Psychology, Compliance, Behaviour, or Needs Relevant to TTM.

Intent of Search Term	Variations of Search Terms
Vulnerable Road Users (and variations) **AND** **Behavioural or psychological terms**	(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND (behavio* [16] OR respon* OR attitude* OR perception* OR psycholog*)

Table 14 - Search term relating to VRU behaviour

Compilation and Presentation of Good Practice Guides in TTM and Comparable Disciplines.

Intent of Search Term	Variations of Search Term
Work Zone Safety **AND** **Guidance (and variations)**	“safety” AND ("Work Zone" OR "Road Work") AND (guide* OR protocol* OR practice* OR standard*)

Table 15 - Search term relating to the generation of Health and Safety good practice

These tables represent six search strings to be searched across databases to generate suitable academic literature concerning VRU in TTM, TTM principles, VRU behaviour, and the generation of good practice.

Step 2b – Search – Search Studies

The selection of academic databases is critical to ensure the comprehensiveness and relevance of the literature review (Bramer et al., 2017). Accordingly, I have selected three larger databases with general and technical orientations for this academic search.

Firstly, Scopus, a multidisciplinary abstract and citation database, provides a broad lens into diverse academic disciplines, which for this review is valuable due to the potential cross-pollination of research surrounding TTM into the likes of psychology and engineering.

Secondly, the Transport Research International Documentation (TRID) database offers a specialised view tailored to transportation research. As a globally recognised transportation

[16] Accounts for English spelling variations (behavior and behaviour)

database, TRID provides insights into the latest methodologies, findings, and trends, grounding the review in current and pertinent research.

Lastly, the IEEE[17] Xplore digital library, renowned for its high-quality literature in various engineering and related fields, proves invaluable. The choice of these databases seeks a balanced exploration of the literature, capturing diverse nuances and intricacies relevant to the study. The six identified search strings were used across the three identified databases – resulting in eighteen different search results. In many cases, additional exclusion terms were added to the search strings to remove noticeable out-of-scope results during the search process. The catalogue of these eighteen searches and their results and the utilised search terms (including amendments from the above tables) is held in Appendix I.

A total of 1122 results were returned across the eighteen searches. These results were compiled into a master list, and duplicates were removed, resulting in 811 unique results.

Step 2c – Search – Select Studies

Utilising Microsoft Excel, all keywords from the 811 results were extracted, listed, de-duplicated, and evaluated for relevance. Of the 674 unique keywords from all 811 results – 158 were selected as relevant, with 516 excluded. Subsequently, excluding articles with these 516 keywords resulted in a final catchment of 46 academic literature items for further forensic examination. The 158 keywords that were retained are included in Appendix J.

These 46 articles underwent a one-by-one analysis of their abstracts to derive more precise relevance to this research. Sixteen were *included* due to clear relevance, 16 were *included* due to moderate or potential relevance, and the remaining 19 were *excluded* due to lack of relevance.

The consolidated catalogue of these 46 articles and their relevance classification (and justification) is provided in Appendix K. The 32 articles of either moderate or clear relevance are carried forward for full exploration and utilisation within this research.

[17] Institute of Electrical and Electronics Engineers

Step 3a – Appraisal – Quality Assessment

An evaluation was conducted on the 32 incorporated articles to ascertain their quality and relevance towards this research. This appraisal encompassed a review of the journal's quality and the article's standing. Utilising the Australian Business Deans Council (ABDC) rankings, the quality of the journals was assessed, and Scopus standings were employed to examine the impact factor and the citation count for each article. The relevance of each article to this research was gauged through a preliminary review of their abstracts. A summary table was constructed, encapsulating each article's essential information and quality metrics, and is documented in Appendix L. This table was a reference during the data extraction, particularly when encountering conflicting findings or data.

Step 3b – Appraisal – Data Extraction

The data extraction phase was initiated with a review of all 32 included academic articles, where the content was systematically coded using NVivo software, facilitating subsequent synthesis alongside the grey literature. A prioritised examination was conducted, starting with the most pertinent academic literature, facilitating the establishment of an initial set of NVivo codes to guide the subsequent coding process. Codes were selected based on two criteria: emergent themes discerned during the review and core research components, encompassing TTM, VRU, and good practice, alongside overarching disciplines such as risk management and regulatory frameworks. The culmination of this data extraction process was coding all 32 articles across 62 distinct codes, encapsulating 1141 uniquely identified relevant findings or entries. The resultant NVivo codebook is provided as Appendix M.

Step 4 – Synthesis

The synthesis of academic literature findings now rejoins the grey literature identified earlier to formulate the full integrative review. Synthesis of all 73 included grey literature pieces and 104 legislative provisions (found with 33 pieces of legislation) were undertaken to arrive at the distilled findings and discussion in the next section. Figure 9 visually shows the extent of included literature from different origins.

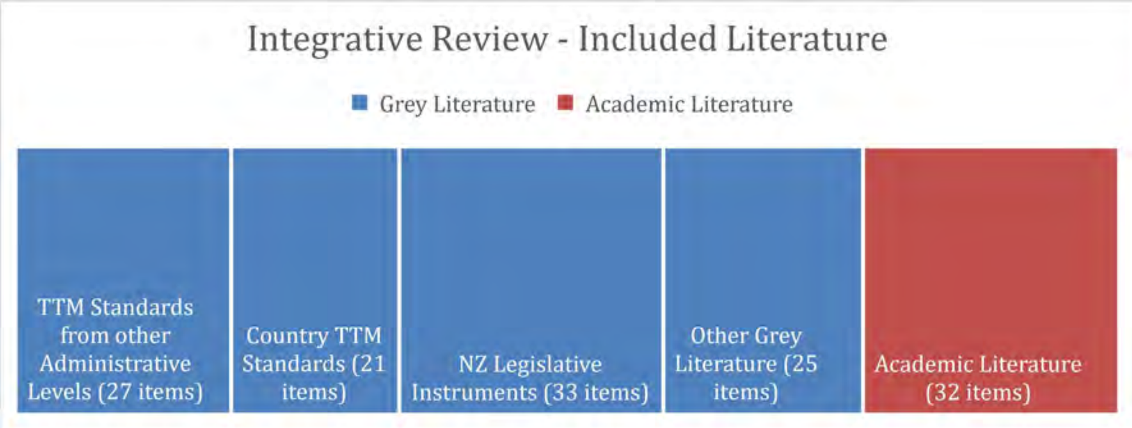

Figure 9 - Treemap of included literature as part of this integrative review

A detailed coding process was undertaken using NVivo software, which allowed for a structured and systematic analysis of the collected data. Initially, preliminary codes were generated based on the recurrent themes observed across the academic literature and grey literature, focusing on areas such as TTM principles, VRU behaviour, and safety practices. This process involved iterative refinement, where codes were continuously merged, divided, or redefined to more accurately reflect the nuances of the data. For example, initial codes such as 'VRU safety concerns' and 'TTM effectiveness' were combined into a broader theme of ' Overarching TTM Principles or Frameworks' inside the 'VRU Principles or Framework' higher level code, highlighting the intersection between VRU safety and TTM practices. The merging of codes into cohesive themes facilitated a deeper understanding of the literature's collective insights. The complete list of codes and their integration into specific themes (higher level codes) is documented in the NVivo codebook, which is provided in Appendix M.

NVivo software was once again employed to distil findings, mirroring the coding process executed for academic literature, to manage, filter, and categorise the data gleaned from the grey literature and legislative provisions. This exercise facilitated the gradual evolution of the coding framework. As the review progressed, new codes emerged, and existing ones were refined to reflect the nuanced themes and insights that were being uncovered.

A thorough review of all coded content ensued after the comprehensive coding exercise. This step aimed at synthesising the amassed data to unveil layers of codes and their interconnections, subsequently forming a coherent narrative aligned with the research objectives. Additionally, the synthesis process aimed to identify and evaluate existing models unearthed during the review that bore relevance and utility to the research context. These models are explored below and are instrumental in structuring the systematic and meaningful exploration of findings. The models identified to assist with the distillation of the findings are explored first in the next section.

CHAPTER 4: FINDINGS AND DISCUSSION

The findings of this research are multi-layered and transcend multiple domains to inform future good practice in this subject area appropriately. Accordingly, a deliberate, structured approach to presenting these findings has been employed, outlined below in Figure 10. Each block represents a primary heading within these findings.

Figure 10 - Layout of research findings section

Additionally, the following table provides additional summation of finding themes:

Finding Category	Key Insight	Implication(s) for TTM Practice	Suggested Action/Consideration
Risk and it's Treatment	The risk to VRUs in TTM is multifaceted, including physical, psychological, and social dimensions.	Current TTM practices may not fully account for the comprehensive nature of risks to VRUs, potentially leading to inadequate safety measures.	Develop comprehensive, site-specific risk assessment frameworks that consider the full spectrum of VRU risks, incorporating evidence-based controls.
Operationalising Good Practice	Gap between work as imagined vs. work as done highlights challenges in guideline implementation.	The disconnect may result in safety measures that are theoretically sound but not practically feasible, undermining VRU safety in TTM settings.	Ensure TTM guidelines are not only theoretically robust but also practically applicable, with flexibility for field adaptations.
Guidance Presentation	The efficacy of TTM guidelines is significantly influenced by their	Ambiguous or complex guidance may hinder its effective	Utilize clear, concise language and visual aids in TTM guidelines to enhance understanding and

	presentation and comprehensibility.	implementation, affecting VRU safety.	applicability for field practitioners.
Language	The use of directive language (must, should) affects the interpretation and implementation of safety measures.	Inconsistent use of directive language can lead to variability in compliance and safety outcomes for VRUs.	Clearly define and consistently use directive terms in TTM guidance to ensure clarity and enhance compliance with safety measures for VRUs.
Checking and Acting in the PDCA Cycle	The Check and Act phases of the PDCA cycle are underdeveloped in TTM practices, affecting continuous improvement.	Lack of effective monitoring and evaluation mechanisms can prevent the identification and rectification of issues in VRU safety measures.	Integrate robust checking and acting mechanisms within TTM practices to facilitate continuous improvement and adaptation of VRU safety measures.
Design Principles and Process	Existing TTM guidelines often lack a systematic approach to design, relying on prescriptive or overly broad principles.	This can lead to designs that are not optimally tailored to VRU needs, potentially compromising safety.	Advocate for a more structured design process that incorporates specific VRU considerations, balancing flexibility with clear, actionable guidance.

Table 16 - Summarised finding themes

Models and Frameworks identified for use with research findings

Layers of expectations

Hale and Swuste's (1998) rule-layering concept, henceforth referred to as *Layers of Expectations*, provides a framework conducive to this analytical expedition. This framework has three layers - outcome, process, and prescription. These layers are constructed for TTM in Figure 11 (with appropriate reference to the corresponding layers from Hale and Swuste's taxonomy).

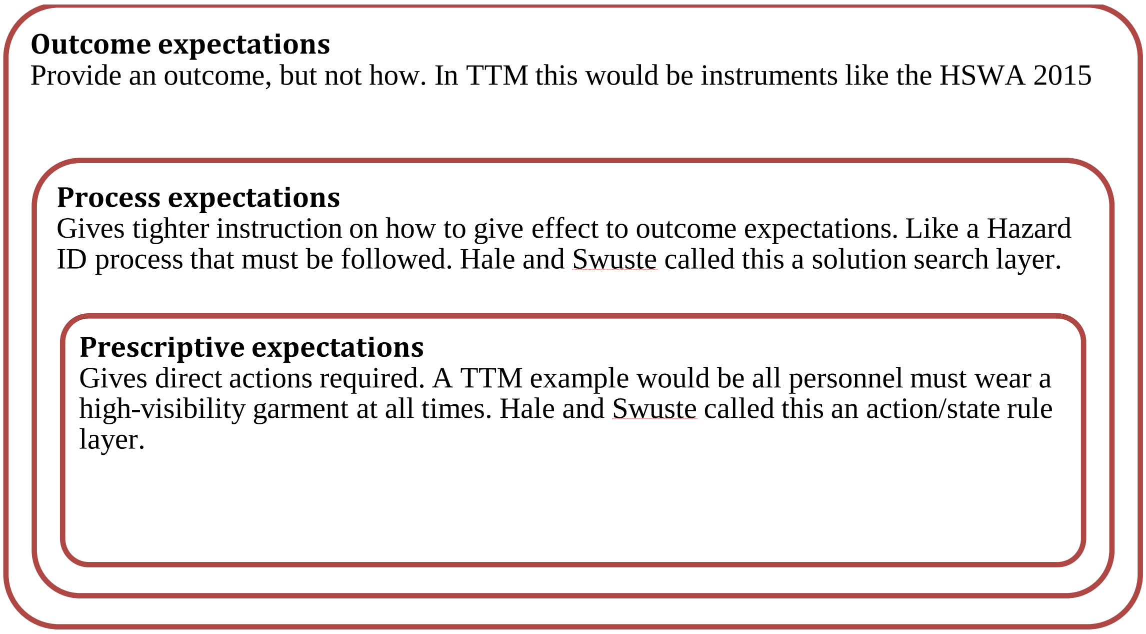

Figure 11 - Hale and Swuste's (1998) taxonomy applied to TTM

The utility of this model is aligned with the concept of good practice – which itself is layered, encompassing legislative, organisational, and operational domains. The most expansive outcome expectations parallel legislative mandates requiring safety without specifying methods. The NZGTTM and WorkSafe NZ underscore the significance of outcome rules within NZ legislation (Waka Kotahi, 2023c; WorkSafe NZ, 2022b). These high-level outcomes, while pivotal, often lack the specificity necessary for practical implementation (Coglianese, 2012; Kagan et al., 2019). Legislation, often directed at organisations and responsible individuals, primarily encompasses outcome expectations to ensure alignment with societal safety goals without stifling innovation (Carden et al., 2021).

Process expectations provide explicit procedures, guiding decision-making and reducing uncertainty, which parallels Hale and Swuste's (1998) "solution search rules" (p. 166). These expectations serve as a heuristic for stakeholders, such as aiding in hazard identification to decrease the possibility of harm (Viegas et al., 2020). Within the NZ TTM context, process-centric expectations are mirrored in legislative and regulatory guidance, such as the hierarchy of controls and WorkSafe NZ's risk management expectations ("Health and Safety at Work (General Risk and Workplace Management) Regulations," 2016; WorkSafe NZ, 2022b).

Prescriptive expectations, the third tier, delineate specific actions. These expectations may be problematic due to their assumption of universally effective outcomes, mirroring Hale and Swuste's (1998) "action/state rules." (p. 167) (Black, 2008; Carden et al., 2021). For instance, a Transport for London directive underscores the risk of over-reliance on standardised traffic management arrangements without considering the unique characteristics of specific road networks (Transport for London (TfL), 2018). However, Hopkins (2011) posits that prescriptive rules are indispensable for fostering optimal safety behaviours among front-line workers. This dichotomy underscores the necessity for a balanced and layered approach to good practice.

The utility of Hale and Swuste's model in this context is twofold:

- The utilisation of these layers to segregate aspects of modular guidance can assist with ensuring the digestibility of content for different audiences and
- The three layers of expectations themselves can be applied across different parts of the TTM system. For example, regulations themselves have expectations that apply across these layers.

To this second point, take the example of a pedestrian fence. Table 16 below explains how guidance might manifest concerning a pedestrian fence across different layers of expectations.

Example application of layers of expectations across TTM good practice		
Outcome Expectation	**Process Expectation**	**Prescriptive Expectation**
Vulnerable road users must be protected from hazards at all times	When considering vulnerable road users' protection mechanisms, elimination of the hazard must be considered first, followed by an isolation control, followed by a control that relies on instructions being followed.	Any fencing utilised to prevent vulnerable road users' access to hazardous areas must be no less than 1.2m high.

Table 17 - Example application of layers of expectations across TTM good practice

These layers of expectations are utilised through these findings to differentiate between the type of findings extracted from the literature and how those extractions would translate to a sound practice system.

A further consideration concerning the utility of these layers of expectations for TTM in New Zealand is, as alluded to in the *Background and Context* section, the impending retirement of CoPTTM (which includes a high volume of prescriptive content). The NZGTTM, with its reduced prescriptive guidance, will see a greater dependency on process and outcome expectations, highlighting a capability gap. The TTM industry's historical reliance on prescriptive expectations requires a reconfiguration of how layers of expectations are represented in available TTM good practices; hence, the utilisation of this model as part of this research as a way to convey the different types of expectations (not just prescriptive ones) to enhance the utility of this research in the development of good practice, and its applicability in the context of a more risk-based approach.

The words used in different layers of expectations, such as *must*, *should*, *could*, *may*, and *optional*, significantly impact how guidelines are understood and followed in TTM. This subtle use of language will be examined later in this research to understand its effect on the successful use of good practice guides.

The Plan-Do-Check-Act (PDCA) Cycle

The Plan-Do-Check-Act model serves as a continuous improvement loop and is widely recognised for its effectiveness in quality management and process optimisation (Gidey et al., 2014).

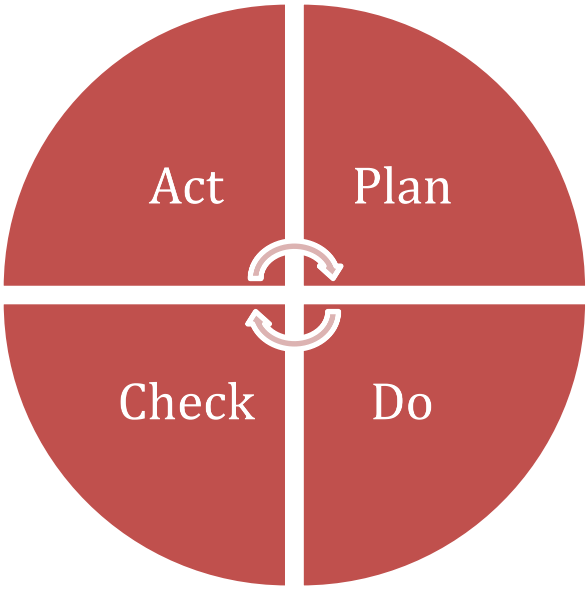

Figure 12 - The Demming (PDCA) cycle

Integrating the PDCA Cycle in TTM, especially concerning Vulnerable Road Users, reflects a synergy between iterative improvement and strategic operational workflow. The PDCA cycle features prominently in relevant NZ TTM literature in WorkSafe NZ's (2022b) *Keeping healthy and safe while working on the road or roadside* guidance and Waka Kotahi's (2023c) NZGTTM. It also resonates with the risk management framework foundational to ISO 31000 (ISO, 2009).

The planning phase in TTM, emblematic of the selection of controls and discerning understanding of risks, mirrors the planning stage of the PDCA cycle. Similarly, the subsequent doing, checking, and acting phases correlate with the execution, evaluation, and refinement stages within TTM. This alignment materialises in the workflow of TTM (plan, execute, check, repeat) but also in the necessity for iterative progress – which has critical implications for the definition of good practice. The iterative ethos of the PDCA cycle aligns well with some TTM good practice shortfalls identified by Shaw and Oneyear (2021) and Mazumder et al. (2017), who point out a gap in the detailed evaluation of safety measures for VRUs in TTM. This lack of evaluation highlights a critical opportunity for applying the PDCA cycle in this field.

The regulatory prominence of the PDCA cycle, its alignment with the established workflow of the TTM system and the identified historical shortfall of iterative good practice in this space provides reasonable justification for the ongoing utilisation of this cycle in these findings.

The State of Existing Guidance

Shortfalls of existing guidance

The landscape of existing guidance presents a picture marked more by its deficiencies than its strengths. The evolution of these guidelines has been somewhat stunted, lacking the rigour and breadth necessary to effectively address the complex dynamics between VRUs and TTM setups and the risks involved. This section delves into the shortfalls inherent in the current guidance. These shortfalls shed light on areas of improvement, providing a roadmap for future NZ guidance.

Sufficiency and Prominence of Vulnerable Road User Guidance.

The examination of U.S. TTM standards reveals a significant limitation: a high degree of uniformity traced back to foundational guidelines from the Minnesota Department of Transportation (MnDOT) (Shaw et al., 2016). A cluster analysis of 49 U.S. standards shows a Pearson correlation coefficient of >0.5 [18] for over 500 of the 2352 relationships between standards, indicating high similarity. This uniformity limits the contextual consideration of good practice for VRU treatment (Shaw et al., 2016). In contrast, Sweden lacks a national standard, offering only localised literature with a limited focus on VRUs (Swedish Transport Authority (TRVK), 2019).

Academic literature also reflects this inadequacy, with a 17½-year systematic review yielding only nine studies on work zone pedestrian safety (Shaw & Oneyear, 2021). Regional discrepancies in treatment controls further highlight the lack of a comprehensive approach (Austroads, 2021; MNDOT, 2018; Waka Kotahi, 2019a). Even the Waka Kotahi cycling panel's final report overlooks TTM, reflecting a siloed approach that neglects integrated discourse (Cycling Safety Panel, 2014).

Carden et al. (2021) advocates for regulatory standards that are efficient, effective, and user-friendly, while Bruder et al. (2009) suggest a modular design to reduce complexity. Black (2008) and Parker and Nielsen (2011) highlight the need for flexible regulations, particularly relevant where VRU standards for TTM apply to diverse organisations.

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[18] A perfectly correlated relationship (i.e. the documents are a perfect match) would return a result of 1.

VRU treatment guidance is often embedded within TTM standards (ADOT, 2019; Government of Ireland, 2009; Helsingin Kaupunki, 2022; Junta Autónoma de Estradas, 1997; Manitoba Infrastructure and Transportation, 2015; Ministerstvo dopravy a výstavby, 2022; Ministrstvo za promet, 2007; Ministru kabineta, 2001; Ministry of Highways, 2023; MITMA, 1997), or referred toward permanent guidance (U.S. Access Board, 2023; Americans with Disabilities Act, 1990), or in some cases standalone (MNDOT, 2021a, 2021b; NCDOT, 2018; TfL, 2019; VTrans, 2018), resulting in a lack of focused, prominent guidelines for VRU TTM treatment

The effect of this smattering approach across geographies is homelessness for VRU TTM treatment, which is evident through a lack of guidance (in terms of volume) or a lack of prominence (in terms of its substance or promotion in other guidance). The current TTM standards for VRUs lack uniform evidence-based guidelines. While the U.S shows some structure, state-level guidance often suffers from unoriginality. Regulatory design principles offer a pathway to more evidence-based, straightforward, and adaptable VRU TTM standards with apparent authority.

Ambiguity and Abstractness of Guidance

The ambiguity and abstractness in TTM guidance compromise the effective implementation of safety measures for VRUs. For instance, Caltrans' (2010) guidance advises *regular inspections* without defining the term regular, while ODOT's (2023) and MDOT's (2022) guidelines lack specificity in describing changes in alignment and facilities for non-motorised users. Such vagueness often reflects an outcome-based focus, as seen in guidelines from the National Technical University of Athens (1998) and Waka Kotahi (2023c), which emphasise the end goal of safety without detailing the means to achieve it. This abstractness can result in misinterpretation among implementers (Demirkesen, 2020) and may indicate a lack of consensus among guideline developers due to insufficient VRU-focused TTM research (Uzondu et al., 2022).

However, a trend toward precision is evident in more recent standards, such as those from Transport for London (TfL) (2019) and recent U.S. publications (ODOT, 2023b;

WSDOT, 2022), which offer more detailed guidance. The consequences of ambiguous guidelines include ineffective VRU safety management, a lack of substantive decision-making processes, and a potential under-prioritisation of VRU safety in TTM.

A shift toward more precise and actionable language is essential to address these issues. This involves moving from more outcome-based to more process-based guidance, providing specific criteria for effective safety measure implementation. Additionally, feedback from VRUs and frontline personnel can offer critical insights for enhancing the clarity and effectiveness of TTM guidance.

Lack of Iteration

The absence of iterative evolution in VRU guidance for TTM poses a significant challenge to its adaptability and effectiveness. The Plan-Do-Check-Act cycle emphasises incorporating past experiences' learning to refine future practices (Gidey et al., 2014). While MnDOT has proactively adopted early guidance on Temporary Pedestrian Access Routes (TPAR) (FHWA, 2017), many guidelines remain static. In contrast, regions like Michigan, Nova Scotia, and Oregon demonstrate iterative improvements through regular updates (Department of Public Works, 2023; MDOT, 2022; ODOT, 2023a). The lack of evaluation and iteration leaves the effectiveness of various design solutions unverified, as noted by Shaw and Oneyear (2021).

To maintain its status as 'good practice,' continual evaluation and improvement are essential (Demirkesen, 2020). The envisioned good practice guide should include a mechanism for capturing real-world learnings and evolving best practices. Feedback from end-users like cyclists and pedestrians can be invaluable for iterative improvements (Niska & Eriksson, 2014). Academic evaluations and a culture of continuous learning among TTM practitioners can further enhance the iterative evolution of VRU guidance. Dissemination of updated guidelines is equally critical to adopting the most recent and effective practices.

Lack of Utility

A dissonance exists between the conceptualisation and practical implementation of VRU guidelines, often formulated by administrative hierarchies but intended for grassroots application (Carden et al., 2021). This lack of utility manifests in several ways. For instance, standardisation attempts using diagrams, such as those by the Department of Public Works (2023, pp. 8-11), present a paradox. They offer a model for good practice but also demand contextual alterations, creating the potential for confusion or misapplication.

The MDOT Work Zone Safety and Mobility Manual (2022) ambiguously refers to providing "adequate" facilities for non-motorised users, leaving room for varied interpretations. Similarly, Germany's Research Society for Road and Transport Engineering (FSGV, 2021) mandates *immediate remedial actions* for traffic safety issues but fails to define what these terms entail.

Shaw et al. (2023) critique the United States' practice of leaving temporary pedestrian accommodations to field personnel's discretion, citing issues like inconsistency, unforeseen expenses, and communication gaps. Koorey et al. (2017) advocate for a more structured yet non-prescriptive approach, as seen in Kiwirail guidance, which outlines fundamental solutions, usage scenarios, and pros and cons, offering a more practical model.

Existing literature and standards reveal a lack of utility due to vague terminology, incongruent models, and the absence of actionable directives. This undermines the goal of enhancing VRU safety within TTM frameworks. Utility in TTM guidance must extend beyond documenting good practice to ensuring it is comprehensible, actionable, and effectively translatable to end users responsible for VRU safety.

Foundational Principles for TTM and Vulnerable Road Users

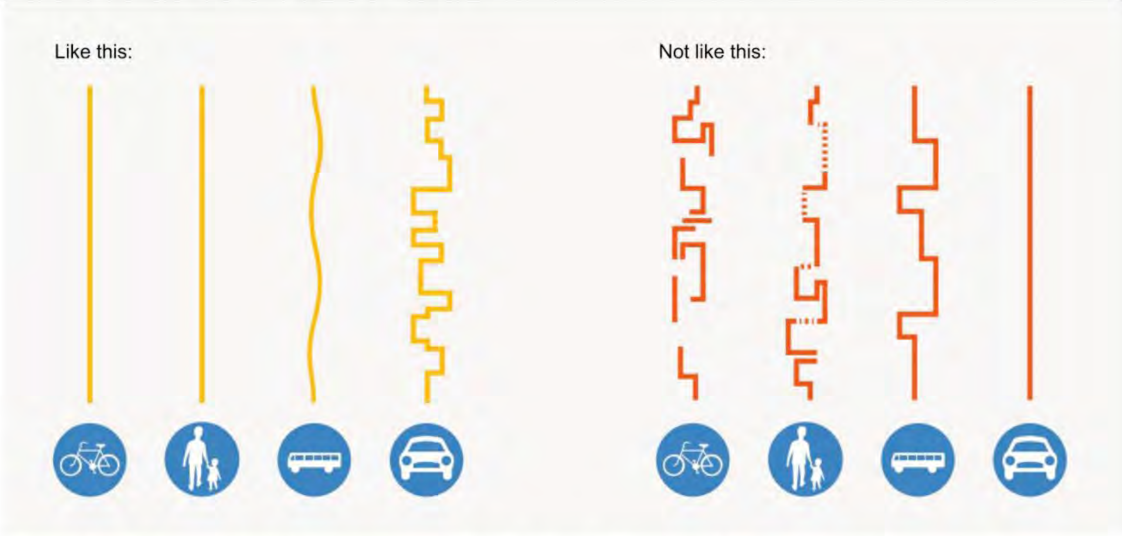
Principles underpin TTM guidance, and their variations across guidelines have tangible implications for interpretation and subsequent guidance (Shaw & Oneyear, 2021). Scrutinising these principles is vital for refining NZ-specific TTM guidance and assessing the philosophies that inform them. Moreover, aligning these principles with legislation is not merely a compliance exercise; it is crucial for ensuring that the ensuing detailed guidance is both legally sound and effective. This alignment is indispensable for crafting robust TTM practices in NZ that adequately address the safety of vulnerable road users.

Principles for TTM

The core of TTM principles aims to balance safety, mobility, and comprehensibility for all road users, including VRUs, while facilitating a safe work environment. The Permanent International Association of Road Congresses (PIARC) (2012) encapsulates this as being "conspicuous, clear, consistent, and credible" (p. 20), a principle echoed globally. However, the challenge lies in the principles' practical application and adaptability, particularly for VRUs.

New York's Department of Transport (2023) and ODOT (2023) underscore the dual focus on safety and mobility, a recurring theme in global TTM principles. Ontario Ministry of Transportation (MTO) (2022) and New Brunswick Transportation and Infrastructure (2021) stress the importance of clear communication and accessibility. Efficient planning and execution are also emphasized to minimise work duration and potential hazards (Majandus- ja Taristuminister, 2018; National Technical University of Athens, 1998). Waka Kotahi (2023c) and Strnad et al. (2019) advocate for the inclusion of diverse road users, including VRUs, while the Swedish Association of Local Authorities and Regions (SALAR) (2019) provides a pictorial representation of this philosophy, as shown in Figure 13.

Figure 3. Example of traffic management principles



Detours must include an entire journey perspective. Walkway, crossing points and destination points such as entrances and stops must be taken into account.

Figure 13 - TTM Principles presented in Sweden TTM guidelines (SALAR, 2019)

Austroads (2021) and FSGV (2021) highlight the need for risk management and adaptability, aligning with foundational TTM principles. However, the balance between safety and disruption is not universally agreed upon, suggesting a lack of a unified approach. This divergence indicates an underexplored opportunity for mutually beneficial safety and efficiency measures.

A common shortfall is the superficial treatment of well-articulated principles like the 4C's(Strnad et al., 2019). While eloquently stated, these principles are often not reflected in actionable aspects of the guidelines. Thus, there is an urgent need for TTM guidelines to evolve from merely stating principles to consistently applying them, addressing existing deficiencies and ensuring a more comprehensive approach, especially concerning VRUs.

The Safe System

The Safe System approach, originating as Vision Zero in Sweden, has become a global road safety model, adopted in New Zealand as Safer Journeys (Te Manatu Waka (Ministry of Transport), 2021). It aims to mitigate severe outcomes from inevitable human errors and is structured around four pillars: safe roads, safe speeds, safe vehicles, and safe road use (Jurewicz et al., 2016). Its effectiveness is empirically supported;

Sweden saw road deaths halve post-1997 (Skyving, 2015), and Victoria, Australia, reported a 30% fatality reduction within a decade (Mahrt, 2022).

In the New Zealand TTM context, the Safe System's principles are particularly relevant for VRUs. TTM environments inherently alter permanent road safety features and introduce dynamic hazards. However, a review of the 106 pieces of included literature in this review found minimal Safe System integration, with only 17 references and three instances in actual TTM standards. Corben’s (2020) Austroads analysis offers a notable exception, exploring Safe System integration with VRU movement. Austroads' (2021) Guide to TTM has also begun incorporating Safe System references, suggesting a pathway for its broader inclusion in NZ.

Given the Safe System's proven efficacy and its emerging recognition in TTM standards, there is significant potential for its principles to enrich New Zealand's TTM guidelines, particularly in areas like safe roads and speeds, which could benefit both vehicle flow and VRU safety.

The Hierarchy of Controls

The Hierarchy of Controls (HoC) finds its legislative foundation in New Zealand within the Health and Safety at Work (General Risk and Workplace Management) Regulations 2016. This framework is not exclusive to New Zealand, as it forms a foundational pillar across various global territories in health and safety (H&S) literature, encompassing Robens’ style H&S legislation, EU directive style, and OHS style frameworks. Despite its pivotal role, the HoC utilisation within the TTM sector in New Zealand and abroad seemingly lacks the due diligence it demands.

The HoC is an extension of the Health and Safety at Work Act 2015 itself, where elimination of health and safety risks is required unless not reasonably practicable. If elimination is deemed not reasonably practicable, then minimisation is required through a series of layers of controls, hierarchically preferred based on their effectiveness (WorkSafe NZ, 2022b) (Figure 14).

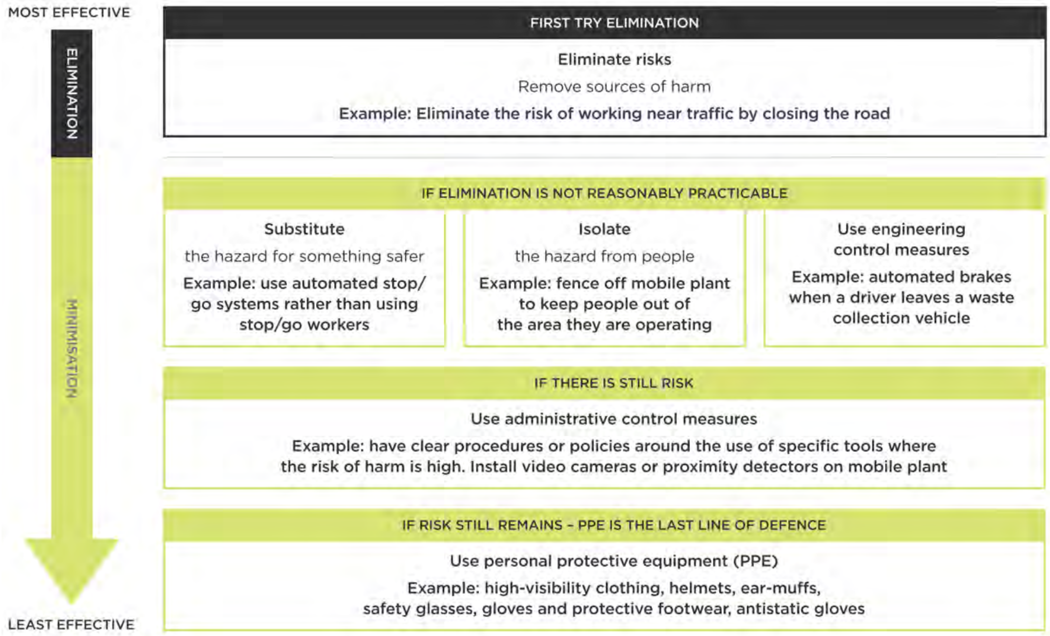


Figure 14 - WorkSafe depiction of Hierarchy of Controls (WorkSafe NZ, 2022b)

The challenge lies in contextualising the HoC to TTM and VRU considerations. The effectiveness of certain controls may be contingent on other measures or specific deployment contexts. For instance, the decision to employ an isolation control, although categorised under engineering controls, hinges on administrative decisions, thus blurring the categorisation.

Recent guidance, like that published by Transport for London (2019), amplifies the HoC's prevalence, emphasising process expectations over prescriptive measures. This shift addresses the challenge where prescription, like the instruction from MNDOT (2018) to select a diagram, undermines the HoC by enticing practitioners towards pre-determined risk assessment processes rather than a thorough evaluation aligned with HoC principles. Prescriptive measures, like standard plans and diagrams, can absolve practitioners from rigorous risk assessments, potentially undermining higher-level controls.

Across many international TTM standards, the provision of highly detailed prescriptive diagrams is widespread, which further increased the prevalence of a prescriptive mindset and overly simplified solutions that underrepresent the complexity of most TTM environments and insufficiently represent the risks that must be managed. An array of such diagrams are shown in Figure 15, Figure 16, and Figure 17.

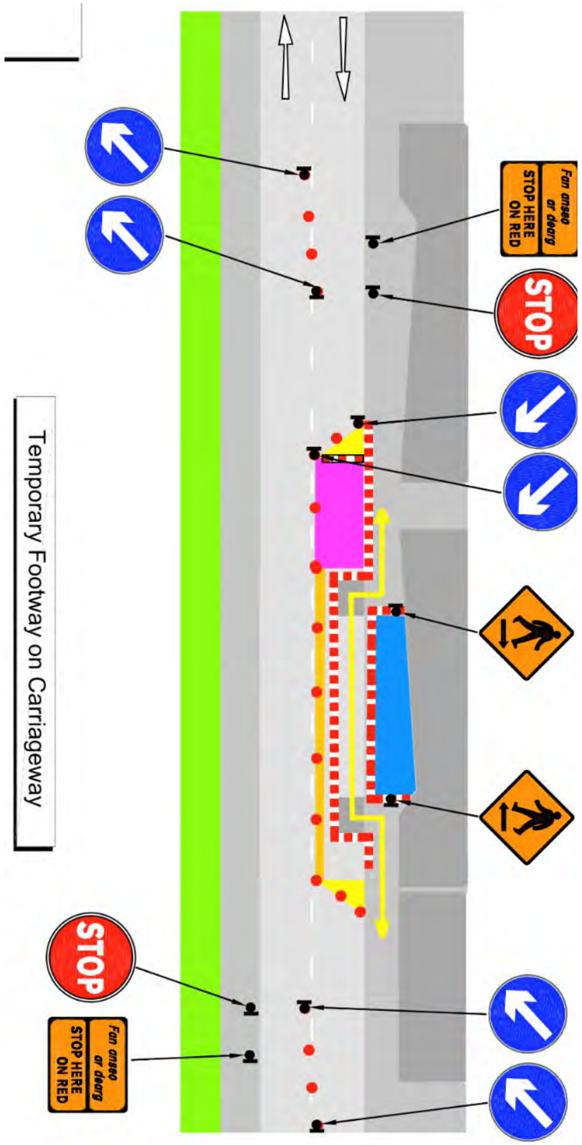


Figure 15 - Pedestrian Diversion Diagram Example (Government of Ireland, 2009)

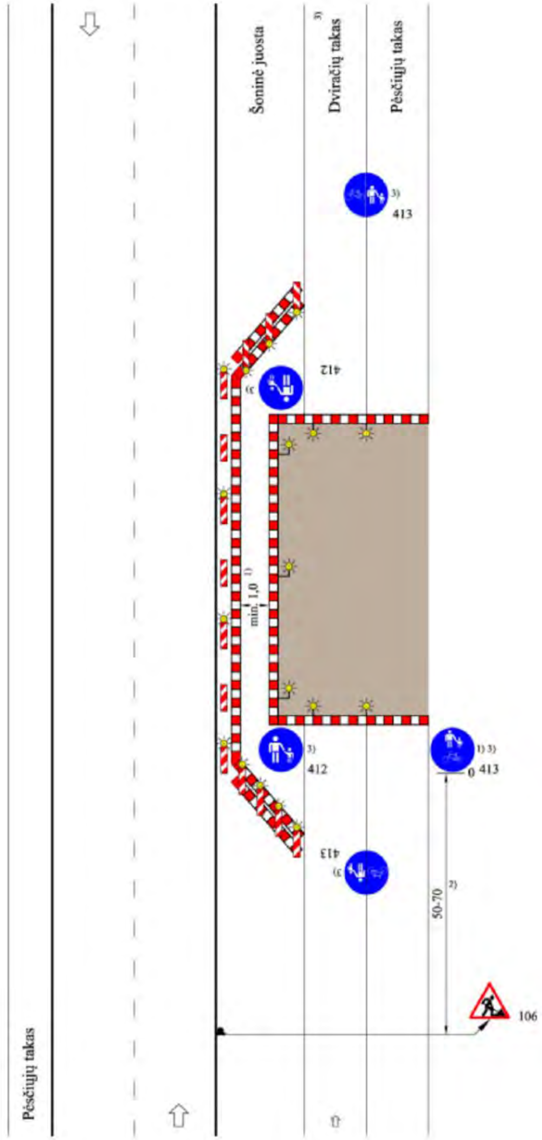


Figure 16 - Pedestrian Diversion Diagram Example (LRA, 2012)

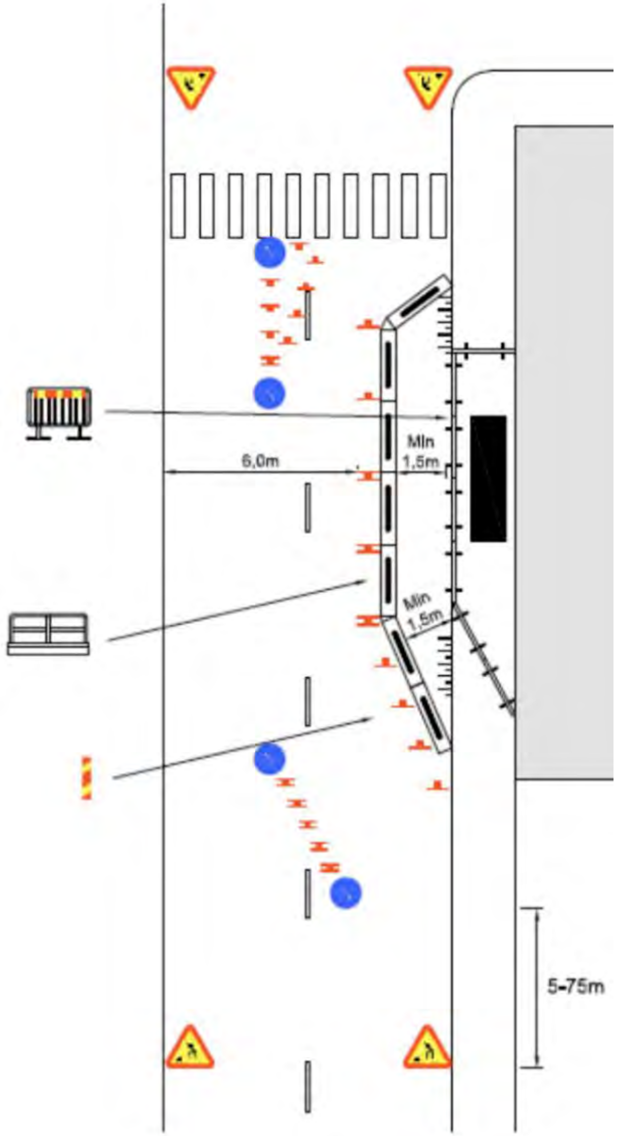


Figure 17 - Pedestrian Diversion Diagram Example (TRVK, 2019)

The discrepancy between such detailed diagrams and the HoC is the predetermination that each of these controls is the most optimal that can be used in any context, and no more reasonably practicable control that is higher in the HoC is available.

The consequence of such prescription at the process level violates the legal obligation of the hierarchy of controls. By prescribing a requirement early in the planning process, a more robust control selection process may be bypassed in favour of design expediency. As part of good practice, planning process expectations should be centred on the robust application of the hierarchy of controls and resistance to the application of prescription at a standards level.

Process or outcome expectations, as more prevalent in newer guidance (Austroads, 2021; TfL, 2018; Waka Kotahi, 2023c), provide a more flexible framework that encourages adherence to the HoC while allowing for site-specific considerations and thorough risk assessments. Flexibility, however, invites ambiguity – and the use of process (HoC style) structures, without prescription, creates a quagmire for practitioners wanting to construct the best TTM solution for VRUs but being hamstrung by a difficult-to-operationalise general system (i.e., HoC) and their existing level of capability being geared towards following prescriptive rules. HoC principles should be interwoven into TTM practices and VRU standards to foster a safety-centric culture. This is already epitomised in the MNDOT (2018) Temporary Traffic Control Field Manual and Construction Logistics and Community Safety (CLOCS) Standard (UK) (2022), which feature the HoC prominently in expectations, even in the expression of prescriptive measures.

Lowest Total Risk

The concept of lowest total risk is pivotal in mitigating inherent risks without escalating other risks within the system, encompassing workers, road users, and VRUs (Kabir & Papadopoulos, 2019). For instance, a fence intended to prevent access to a hazard may introduce new risks, such as tripping or roll-over potential for cyclists. This underscores the need for a net reduction in risk across all components.

NZGTTM provides case studies to illustrate the lowest total risk concept, while other literature, such as the German standard and the Trans European Motorway (TEM) standard, implicitly address the concept through proportionality and structured risk assessments (UNECE, 2021), they do not label it as the lowest total risk. Shaw et al. (2016) and Shaw & Oneyear (2021) emphasise the importance of net risk in evaluating VRU standards in the U.S., highlighting the lag in governmental standards in incorporating this concept.

Current guidance often outlines linear design processes for risk assessment and control selection. However, the lowest total risk concept calls for an iterative approach, where each control measure resets the risk assessment under new conditions (Aven, 2016; Elms, 2019; Peace, 2021; Thomas et al., 2023). Despite its importance, this concept is not adequately conceptualised in existing TTM standards, including NZGTTM and the Austroads Guide to TTM.

Including the lowest total risk concept in NZGTTM aligns with New Zealand's legislative frameworks, contrasting with its predecessor, CoPTTM, which did not incorporate this principle (Waka Kotahi, 2019a). Future TTM standards must reference this concept and integrate it comprehensively, detailing the consequences of specific control selections.

Principles for Vulnerable Road User Treatment

General principles

The function of principles in guiding vulnerable road user (VRU) treatment within temporary traffic management (TTM) is to establish a foundational framework. This framework is intended to inform the planning, design, and implementation of traffic management strategies tailored to VRUs. However, existing literature often falls short of providing concrete, actionable guidance, leaving room for ambiguity and vagueness (Kuhn, 1962; Mctiernan et al., 2015; Shaw & Oneyear, 2021; Theeuwes et al., 2012). For example, the Minnesota Department of Transportation (MnDOT) provides checklists that include considerations for VRUs, but these are often abstract and lack specific, actionable directives (MNDOT, 2018, pp. 6K-p). This lack of specificity undermines the utility of such checklists and leaves practitioners without clear guidance.

Different jurisdictions have approached the issue of principles with varying degrees of specificity. For instance, Sweden and Australia advocate for *facility parity*, which is a positive step but presents challenges in its operationalisation (Austroads, 2021; TRVK, 2020). In the United States, some standards refer to permanent guidelines, such as the PROWAG, and call for maintaining existing facilities as much as possible. However, terms like *technically or fiscally infeasible* are used without clear criteria, making it challenging to establish evidence-based practices (ODOT, 2018).

The concept of spatial and duration impact is another critical consideration. For example, maintaining existing facilities may impose restrictions on construction that could extend work duration, thereby increasing the net impact on VRUs. This intersection of spatial and duration considerations is crucial in construction and TTM methodologies and will be further explored in subsequent sections of this research.

The principle of "reasonable accommodation," as discussed in the Americans with Disabilities Act (ADA) 1990 (p. 9), aims to balance conflicting requirements but often falls short in addressing the specific needs of various categories of pedestrians (Jimenez et al., 2018; Shaw & Oneyear, 2021). Waka Kotahi's NZGTTM (2023c) discusses safety hierarchy but is disconnected from its other pedestrian and cyclist guidance, creating a fragmented standards framework.

Based on the analysis of existing standards and guidance, several themes emerge as essential for the development of future good practice in this area:

- Clarity and Specificity: Future guidelines should move beyond abstract principles to provide actionable guidance.
- Operationalisation: Principles should be accompanied by clear criteria for their operationalisation, including when deviations from these principles are permissible.
- Critical Evaluation: An evaluation component should be integrated into the guidelines to assess their effectiveness in practice.
- Inclusion of Diverse Needs: Guidelines should be inclusive, addressing the specific needs of various categories of VRUs.

- Situational Adaptation: Good practices should be adapted to fit the specific context in which they are applied.

While the role of principles in guiding the treatment of VRUs in TTM is acknowledged, there is a pressing need for guidelines that are both specific and critically evaluated for their effectiveness, not just principle-based.

Vulnerable Road User Treatment is part of a system

Treating Vulnerable Road Users (VRUs) in Temporary Traffic Management (TTM) is intrinsically a systemic endeavour, necessitating an integrated approach encompassing legislative frameworks, risk management, construction planning, and training. In NZ, the legislative cornerstone is the Health and Safety at Work Act 2015 (HSWA), further supported by foundational guidelines such as those from WorkSafe NZ (WorkSafe NZ, 2022b). Legislative frameworks across various jurisdictions generally share a similar structure, where primary legislation is outcome-based, and guidelines, although often voluntary, are deeply entrenched in practice. However, exceptions to this trend exist, such as in Nova Scotia, where the code of practice is legally binding, thereby adding a layer of mandatory compliance (Department of Public Works, 2023).

David Elms' work on risk management underscores the necessity of a systemic approach, one that is adaptable to various factors, including experience and personal bias (Elms, 2019). Often, the planning of TTM, including considerations for VRUs, is a subsequent step that follows the determination of construction methodology. This sequencing can inadvertently limit the scope for mitigating risks to VRUs, as many of these risks are often predetermined by the design of the work itself (Shaw et al., 2016; Arizona Department of Transportation (ADOT), 2021). For instance, the Maryland Department of Transportation (MDOT) explicitly calls for multi-modal considerations to be integrated into all planning phases, including construction (MDOT, 2022). Transport for London (TfL) offers a purpose-built framework for safer pedestrian design, emphasizing the need for a unified approach to conflicting requirements (TfL, 2019) (Figure 18).

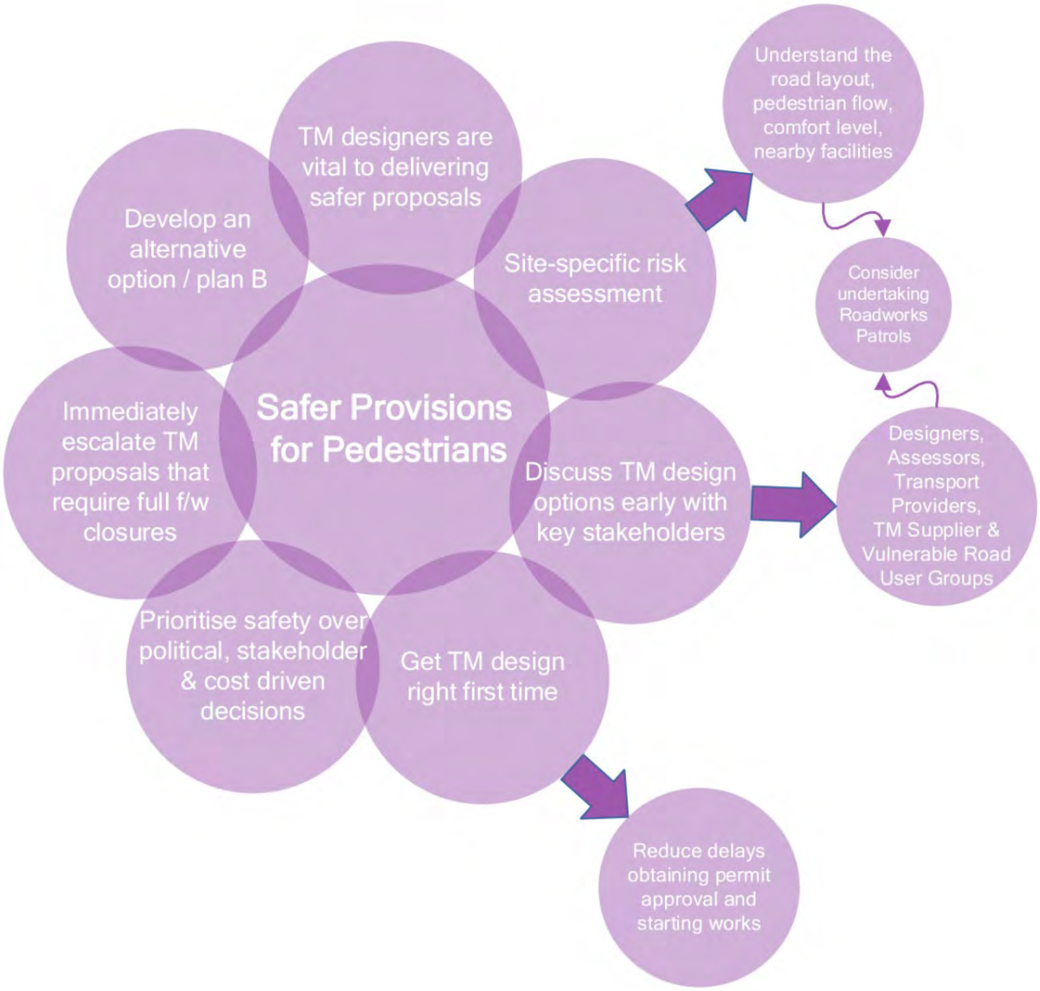


Figure 18 - Transport for London Safer Provisions for Pedestrians Design Framework (TfL, 2019)

Integrating construction considerations into TTM planning is procedural and a safety imperative. This aligns with a comprehensive risk management strategy for VRUs, addressing the challenges that designers face in balancing the needs of road users within the constraints of physical space and budget (Shaw & Oneyear, 2021; Vtrans, 2021; Mazumder et al., 2017). The Health and Safety at Work Act 2015 further mandates this integration, requiring Persons Conducting a Business or Undertaking (PCBUs) to consult, coordinate, and cooperate when they have overlapping duties of care (HSWA, 2015).

Training and competency are also pivotal in this systemic approach to VRU treatment. Effective training enables practitioners to adapt guidelines to various scenarios, a concept called transferrable problem-solving (Al-Zoubi et al., 2022). The European AROWS project emphasises that training should be ongoing and encompass all personnel involved in road works(National Technical University of Athens, 1998). Strnad et al. (2019) further highlight the need for ongoing training to counteract the habituation effect among workers, which can lead to less careful behaviour over time.

The treatment of VRUs in TTM is a complex, systemic issue that requires an integrated approach. This approach must respect the interdependencies among legislative frameworks, risk management strategies, construction planning, and training programs. Any attempt to isolate these elements will likely result in ineffective and incongruent solutions. Therefore, a systemic approach is not just advisable but essential for effectively managing VRU safety in TTM.

The prevalence of impaired persons

The term *impaired persons* refer to individuals with physical, sensory, or cognitive disabilities affecting their ability to navigate TTM settings (Shaw & Oneyear, 2021). The term *disabled* is often floated and could imply stigma (DeFleur, 1964); however, it is still used and justified in road safety, as Doran et al. (2022) explained. In NZ, approximately one-quarter of the population identifies as disabled (this mirrors data from the US indicating 25% for that population (Okoro et al., 2016)), with higher rates among older, Māori, and Pacific peoples (Doran et al., 2022). This demographic information is crucial for TTM planning, especially in areas with higher concentrations of these groups. The prevalence of impaired persons is more significant than most contractors realise, and their impairments are more debilitating than what is often assumed or observed (Koorey et al., 2017; MNDOT, 2021b).

Many existing TTM guidelines inadequately address the needs of impaired persons. For instance, Waka Kotahi's (2019a) CoPTTM dedicates only one clause to provisions for footpath users with sight, hearing, or mobility issues (Section C13.2.1).

Despite past efforts, there has been no measurable improvement in disabled people's access to transport, indicating that existing TTM measures are insufficient (Doran et al., 2022). The needs of impaired persons often appear as the last bullet point in a suite of expectations, indicating a lack of prioritisation (including within the newly published NZ Guide to TTM) (ODOT, 2018; Waka Kotahi, 2023c).

To effectively accommodate impaired persons, TTM must be designed with a deep understanding of their specific needs. The most common everyday difficulty for disabled individuals is walking, directly implicating the design and management of pedestrian pathways in TTM (Doran et al., 2022). For example, visually impaired individuals require detectable edgings to navigate safely (Caltrans, 2020; NHDOT, 2022), a prominent standard repeated throughout US standards but not evident in NZ or Australian standards. Those with mobility impairments may require ramps and smooth surfaces to move unobstructed (Koorey et al., 2017; MNDOT, 2021b). Moreover, tactile and audible information can aid those with sensory impairments (MNDOT, 2021b).

Designing TTM for impaired persons is not without challenges. Conflicting requirements often arise, such as flush curbs for wheelchair users versus tactile paving for the visually impaired (MNDOT, 2021b). Such conflicts necessitate a balanced approach, requiring designers to make *reasonable accommodations* (Shaw et al., 2023). The challenge with expecting *reasonable accommodations* is, once again, the abstract nature of such expectations and the subjective determination of whether an even more reasonable accommodation might have been available but was not selected.

The concept of intersectionality, highlighting that disabled individuals who are also part of other marginalised groups face unique challenges, should be integrated into developing VRU standards for TTM (Doran et al., 2022; Shaw et al., 2023). Intersectionality is crucial to ensure that disabilities are not viewed as siloed categories. A conceptual model of intersectionality, as it might relate to VRUs in TTM, is depicted in Figure 19.

Other intersecting factors:

- Mode of transport
- Age
- The state and nature of TTM present
- Cultural, ethnic, sexual, gender or other demographic factors
- Many others

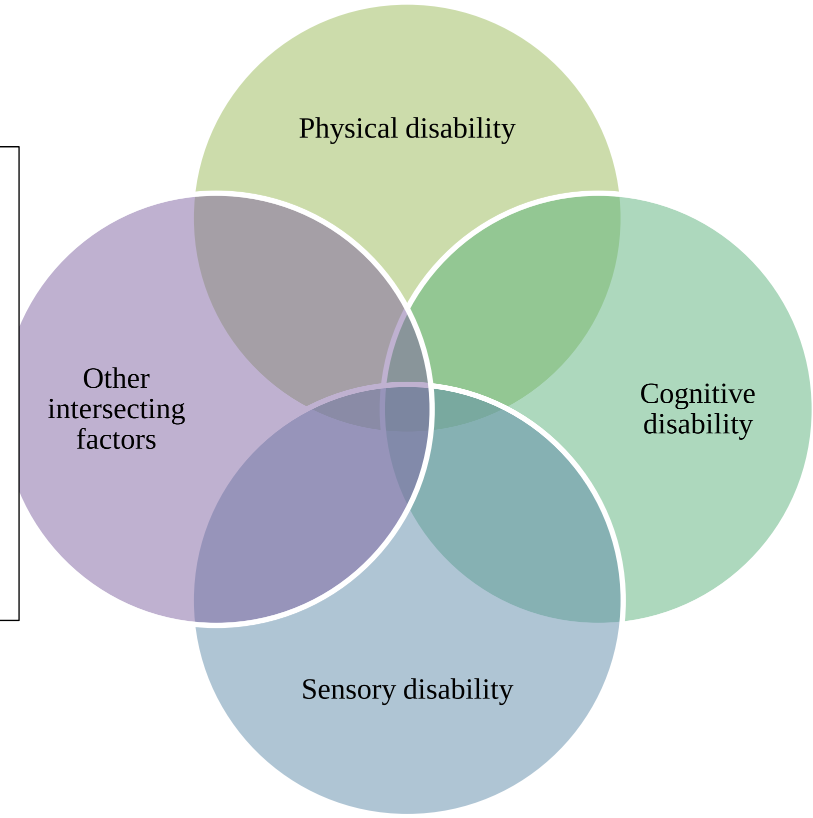


Figure 19 - Model of intersectionality for disabled people in TTM

The effective treatment of impaired/disabled persons in TTM environments requires improvement at every level. Existing guidelines are insufficient, necessitating an improved understanding of the needs of marginalised groups and an increase in tools for practitioners to treat them. A fundamental philosophy explored later in this research is treating *the most restricted, and the rest will be fine.* This philosophy purports that if facilities and TTM are capable of safely and efficiently accommodating the most disabled of users, then all users will have a safe and efficient experience.

Design Principles and Process

The absence of evidence-based guidance in many cases across territories often leaves designers and builders to rely on conjecture to meet the diverse needs of road users (Shaw & Oneyear, 2021). This lack of uniformity in design philosophy is problematic. For instance, the mindset that picking any traffic management arrangement from national standards suffices is indefensible and legally precarious (TfL, 2019). Therefore, there is a need for a more systematic TTM design approach that introduces a more intelligent structure to the process.

Design *philosophies* materialise across some territories, whereas others dive straight into a linear prescriptive approach to design processes. Either way, the intent is to generate a robust design that interrogates different VRU design approaches for their appropriateness, as highlighted by Caltrans (2020).

Both approaches have advantages – with the former generating more flexibility and conceptualisation but can lack tangibility for designers and be essentially disconnected from what happens. Such a philosophy-based approach also requires more designer competency and technical understanding. Furthermore, philosophies predicated on simply *maintaining existing levels of accessibility* can hardly be called philosophies as their shallowness of practicality has little actual utility for designers where that approach is not possible. In some guidance, such as from Slovakia, this maintenance of accessibility is only moderately enhanced through a supplemental expectation that higher risk or volume areas (schools, hospitals) receive extra care (Ministerstvo dopravy a výstavby, 2022). Regardless, such *philosophies* have limited penetration into meaningful planning.

A linear prescriptive design approach generates more precision but sacrifices considered risk-based thought and relies on adherence to that process. Multiple contributors to the design process do emerge as a prominent necessity of later guidance (Austroads, 2021; Shaw et al., 2023; TfL, 2019; Waka Kotahi, 2023c) as well as the interlacing of peer review or design milestones to increase the robustness of the design and combat subjectivity (Caltrans, 2020; ODOT, 2023a; WisDOT, 2019).

Peer review as a concept is, in some places, advocated for universally (Austroads, 2021), whereas in others, only where non-conforming solutions are stipulated for review (Caltrans, 2017; ODOT, 2023a). Whilst NZ currently maintains a pseudo-peer review system through approval by the Road Controlling Authority (RCA), this will evolve under the new NZGTTM to be a more traditional peer review where the lead contractor will take the lead (Waka Kotahi, 2023c). A system for exploring and robustly assessing alternative TTM solutions has existed in New Zealand for many years through an Engineering Exception Decision (EED) system, where designers can apply critical thinking that manages risk better to be adopted (Waka Kotahi, 2019a). However, local authorities underutilised, abused, or sometimes refused the system (E. Mitrova, personal communication, 21 August 2023).

Quality data input is crucial for successful traffic management (ADOT, 2021). However, noncompliance with technical guidance remains a significant issue, often exacerbated by agencies' limited evaluations and compliance-focused approaches (Shaw & Oneyear, 2021; Gambatese & Johnson, 2014; Waka Kotahi, 2023c). For optimal safety, early designer engagement and adequate resource allocation in bid/tender processes are essential (Shaw et al., 2016).

Overall, aligning with NZ legislation and regulatory guidelines requires the hierarchy of controls, the 3Cs, and early TTM design consideration. Processes that use methodical peer review are also highly valuable.

Themes for the formation of vulnerable road user treatment good practice

This section aims to synthesise some prominent themes identified across the literature to inform future good practices in this area.

Amplify the why

This research has already established that there is a lack of coherent design guidelines for VRUs, a dearth of academic literature on the subject, and a historical lack of institutional attention (TfL, 2019; Shaw et al., 2016; Shaw & Oneyear, 2021; Mazumder et al., 2017). Despite being the most at-risk demographic with the least margin for error and the highest consequences, VRUs are often relegated to an afterthought in TTM planning and execution (TfL, 2019; Shaw et al., 2023).

The complexity of the TTM system is another layer that adds to the challenge. It involves many stakeholders, each with their own responsibilities and roles. The human-centric nature of TTM systems, particularly when serving VRUs, calls for a more explicit articulation of why these users require focused attention to ensure the safest possible work zones. This is especially pertinent given that TTM systems have historically been designed with a predominant focus on vehicle traffic, a bias that is still palpable in the language, terminology, and structure of existing guidelines (Ministry of Highways, 2023; Shaw et al., 2023; Transportation and Economic Corridors, 2020; Waka Kotahi, 2019a).

The need for a shift from vehicle-centric to human-centric guidelines is not just a matter of ethical or social justice but is imperative for the equitable treatment of VRUs (Shaw et al., 2016). Practitioners must *understand the why* behind different control measures, such as the types of signs used and what effect they are designed to elicit, to ensure their effective application. The lack of *why* is clear in auditing evidence (Kiddle, 2023; Mazumder et al., 2017; Shaw et al., 2016; Wood, 2023) and illustrates the potential for VRU TTM treatments to be either a tick-box activity for many or a poorly intellectualised process at best. A nuanced understanding allows for the increased deliberate use of controls to achieve specific outcomes (MNDOT, 2021a).

Humanising TTM guidelines can make them more accessible and encourage their use. This can be achieved using relatable images and personas that resonate with end-users (Tapp, 2015; Bennett et al., 2019; Waka Kotahi, 2023f). For example, Transport for London (TfL) reiterates that road workers are pedestrians and cyclists, fostering empathy for VRUs (TfL, 2019). This approach is particularly relevant when voluntary guidelines rely on intrinsic motivation.

However, the transition to a human-centric approach is fraught with challenges. These include resistance from stakeholders accustomed to vehicle-centric systems and the need for extensive retraining (Gambatese & Johnson, 2014; Shaw et al., 2016). Ongoing stakeholder training and development are essential for the effective implementation of TTM for VRUs and must be continually updated to reflect evolving best practices (National Technical University of Athens, 1998; Niska & Eriksson, 2014). There is a clear and pressing need to *amplify the why* in this space through a multi-dimensional approach that puts the protection of VRUs in front of practitioners from multiple directions. Future good practice must prominently lay out the reality of the plight of vulnerable road users, led by those with disabilities, for whom we should be designing TTM first. The inherent vulnerability of VRUs in work zones necessitates their prioritisation in TTM systems. Guidance without a good why is ineffective.

The lack of design coherence for VRUs (TfL, 2019), the inadequacy of guidance (Shaw et al., 2016), the lack of academic literature (Shaw & Oneyear, 2021) and the lack of institutional attention in TTM (Mazumder et al., 2017) all spell out a critical necessity to drastically amplify the level of discourse around VRUs in the realm of TTM. Evidence shows that VRUs are the most at risk, have the most negligible margin for error, and have the highest consequences (TfL, 2019). However, they have the least attention and are consistently an afterthought (Shaw et al., 2023). This has to change. Future good practice must prominently lay out the reality of the plight of vulnerable road users, led by those who have disabilities as who we should be designing TTM for first. The inherent vulnerability of VRUs in work zones necessitates their prioritisation in TTM systems.

Understand the characteristics, psychology, and needs of different Vulnerable Road Users

Risk subjects serves as an encompassing term to describe the diverse array of VRUs in TTM settings (Nivolianitou et al., 2006). Grouping VRUs into broad categories is inappropriate and poses safety risks, as Shaw et al. (2016) and Pyöräilykuntien Verkosto (2020) noted. The complexity of VRU categories extends beyond the simplistic division into those on foot and wheels. Each primary category contains numerous subcategories, as elaborated in Appendix B. Moreover, the intersectionality of disabilities or impairments can lead to compounded marginalisation, adding another layer of complexity to the treatment of VRUs (Doran et al., 2022). The existing literature and standards on TTM fall short of adequately addressing this diversity among VRUs. This gap compromises the efficacy and relevance of any good practice developed without a nuanced understanding of these risk subjects. For example, U.S. standards often make generic references to compliance with the Americans with Disabilities Act (ADA) without delving into the specific needs and characteristics of various VRUs (MDOT, 2022; NHDOT, 2022). Such superficial treatment is also evident in guidelines stipulating basic provisions, such as fencing with bottom rails to assist those using canes (NYDOT, 2023; WSDOT, 2022). Even the more recent and seemingly comprehensive guidelines from Transport for London (TfL) in 2019 offer limited exploration of the diversity of VRUs.

Temporary impairments, such as inebriation or drug use, represent another dimension of VRU diversity that is often overlooked. While some standards acknowledge these factors, the guidance remains cursory (National Technical University of Athens, 1998; Shaw et al., 2023; TfL, 2018). Psychological aspects, including decision-making, compliance, and other cognitive behaviours, also vary widely among VRUs. These psychological factors are critical for the effective design and implementation of TTM measures and warrant more thorough exploration in subsequent sections.

The treatment of VRUs in TTM is a complex issue that demands a more sophisticated understanding than is currently found in the literature and standards. The diversity of VRUs is not a list of categories but an intricate web of unique characteristics and needs. This complexity starkly contrasts the treatment of vehicular road users, whose characteristics are far less multi-dimensional. To genuinely cater to this diverse population, a significantly enhanced level of understanding and corresponding improvements in good practice and training are required.

Psychological Factors

A significant contributor to the effectiveness of TTM controls for vulnerable road users is the behaviours of those users themselves. One of the critical concepts that emerges from the literature is that of 'space syntax,' which Shaw et al. (2023) explore in depth. This concept suggests that VRUs are inclined to follow familiar and comfortable routes, which, in some references, are noted as the path of least resistance and most comfort (Misra & Watkins, 2018; Yang et al., 2012). This notion is supported by Koorey et al. (2017), who emphasise that the design of facilities must account for the psychological factors affecting VRUs. Similarly, MNDOT (2021a, 2021b) discuss how highly mobile and confident people will take shortcuts while less mobile people struggle with detours, highlighting that the psychology of VRUs could be represented on a spectrum. On one end, there is heavy apprehension or lack of travel due to perceptions of safety (Waka Kotahi, 2023f). For example, Yeon-Hong et al. (2015) found that only 24% of elderly pedestrians felt knowledgeable about traffic safety signs, suggesting that a lack of understanding could contribute to feelings of insecurity and, consequently, reduced mobility.

Conversely, high confidence or disillusionment leads to limited compliance and more deliberate rule-breaking (Puchades et al., 2018). Shaw and Oneyear (2021) documented that almost half of all pedestrians violated work zone closures by crossing mid-block into the closure or walking through the work zone on a closed sidewalk. Similarly, studies in Texas have observed comparable behaviours, indicating a pronounced overall reluctance to use pedestrian detours (Ullman & Trout, 2009). This spectrum underscores the need to treat VRUs as 'willing participants' in the TTM environment and have clear and deliberate consideration for the behaviours of VRUs.

The Hierarchy of Controls (HoC) is particularly relevant in this context. Engineering and isolation controls, preferred under the HoC, aim to eliminate the need for human decision-making, thereby reducing the psychological factors that VRUs bring into the equation (WorkSafe NZ, 2022b). In contrast, administrative controls, more commonly used in TTM, rely heavily on the public's choice of compliance or adherence. This reliance introduces uncertainty and variability into the system, making the effective use of the HoC a critical component of TTM design (Waka Kotahi, 2023c).

Detours, often considered the last option due to the concept of space syntax, introduce a high degree of compliance and potential conflict points with other hazards (Shaw & Oneyear, 2021; TfL, 2019). This deliberate non-compliance is not limited to pedestrians; cyclists exhibit similar tendencies. For instance, the British Columbia Ministry of Transportation and Infrastructure (2020) notes that detours are usually unrealistic for cyclists on rural highways due to few alternatives and substantial distances, implying that cyclists may opt for rule-breaking when faced with detours.

This is particularly problematic as legislative imperatives are not significant governing factors in pedestrian decision-making (Essa et al., 2018), meaning simply imposing rules (even if they are legally obligatory) is insufficient to entice compliance. The less the TTM environment interferes with the natural behaviour of VRUs, the less likely they are to make errors (MNDOT, 2021b).

The literature also highlights the importance of considering road user factors in the design and use of TTM (Austroads, 2021; Waka Kotahi, 2023c). For example, Shaw and Oneyear (2021) found a strong overall reluctance among pedestrians to use detours, while Lee et al. (2021) noted that nearly 50% of pedestrian-related collisions are due to pedestrian distraction and unawareness. These findings suggest that TTM measures should be designed to accommodate road user psychology and aid them in detecting and navigating a TTM site safely, keeping in mind that different people have varying perceptions of risk influenced by physiology and prior experiences (Koorey et al., 2017).

The psychological factors affecting VRUs in TTM environments are complex and varied. The literature suggests that these factors can be effectively managed through careful design that considers the natural behaviour and psychological inclinations of VRUs. The effective use of the Hierarchy of Controls can further mitigate these psychological factors by reducing the need for human decision-making in the system.

Improve the checking and acting parts of the PDCA cycle

Monitoring and evaluation are pivotal for enhancing safety, yet they often face cost, time, and lack of motivation obstacles (Amponsah-Tawiah et al., 2016; Haslam et al., 2005). The Check and Act components of the Plan-Do-Check-Act (PDCA) cycle are particularly deficient across existing guidance. Checking is essential for validating decision-making, especially when principle-based guidance allows for varied solutions (Daniel et al., 2022). However, technical accuracy is often lacking (Shaw et al., 2016), and the high level of residual uncertainty in TTM sites necessitates constant revisitation of control effectiveness. Moreover, checking is legally mandated under the Health and Safety at Work Act 2015.

While some guidance documents offer checklists for compliance, few provide mechanisms for assessing control effectiveness (Caltrans, 2020; FHWA, 2008). Effective checking should focus on risk management rather than compliance (Ardila & Patricia, 2019; WorkSafe NZ, 2022b). Thomas et al. (2023) propose a 60-second tool aligned with this intent, contrasting with NZ's compliance-based CoPTTM form. Quality control layers, including auditing, are primarily compliance-based and cover only a small percentage of sites (Austroads, 2021; CLOCS, 2022; Kiddle, 2023; Shaw et al., 2016; Wood, 2023). Public reporting mechanisms offer a novel approach to enhancing the feedback loop (ADOT, 2019; Mazumder et al., 2017; Niska & Eriksson, 2014).

Regarding the Act component, evidence for site-by-site and systemic feedback is sparse. Field staff and designers often have misaligned perspectives, affecting the feedback loop(Gambatese & Johnson, 2014). Despite daily evidence from field deployments, academic literature on TTM effectiveness for VRUs is limited. However, Niska and Eriksson (2014) demonstrate an evidence-based approach. Standards (particularly in the US) seem to lean on prescriptive means designed to encourage compliance-based thinking with a mindset focusing on avoidance of legal ramifications rather than good practice promoting the most optimal possible solution. Philosophically, I would label this as encouraging all participants in the TTM system to look backwards, over their shoulders about what they have to do to protect themselves and *comply*, rather than looking forward – and leaning into creative and well-risk-assessed solutions that promote the best possible environment for VRUs, which is much more aligned with the intent of the latter part of the PDCA cycle.

The role of permanent standards and minimum standards

The notion that permanent VRU treatment guidance should be transferable to temporary settings is a key principle in the recently published NZGTTM (Waka Kotahi, 2023c, p. 36). However, the applicability of permanent standards to temporary settings raises questions about risk management and the trade-offs between construction duration and VRU accommodations (Shaw et al., 2016; Shaw & Oneyear, 2021). Permanent standards, in essence, are design requirements aimed at providing optimal facilities for VRUs but do not necessarily eliminate risk. Therefore, the challenge lies in determining the practicability of applying these standards in temporary settings and establishing a mechanism to prevent infinite relaxation of these standards (British Columbia Ministry of Transportation and Infrastructure, 2020; Work Zone Safety Consortium, 2018).

Most U.S. standards mandate compliance with permanent requirements like the Americans with Disabilities Act and PROWAG but allow for approved relaxations (Caltrans, 2010; DDoT, 2008; MDOT, 2022; NHDOT, 2022; ODOT, 2018; VDOT, 2016; ATSSA, 2012, 2021). Despite this, temporary facilities often fall short of their permanent counterparts (Shaw et al., 2016). In NZ, the CoPTTM inconsistently applies the concept of desired and minimum standards, which is misaligned with legislative risk management requirements and perpetuates compliance-based thinking (Lutchman et al., 2012; Waka Kotahi, 2019a).

Integrating evidence-based research into permanent VRU standards, as exemplified by Kiwirail's rail crossing VRU guidance, enhances their value even in temporary settings. Good practice should involve a balanced approach considering permanent standards, construction experience, and construction staging. It should also resist the institutionalisation of minimum standards, opting for a top-down model that prioritises optimal facilities, with minimum standards as a last resort subject to peer review or consultation.

Layering of responsibility and audience

The layering of responsibility and audience in forming good practice guidelines interplay regulatory frameworks, stakeholder roles, and system dynamics. The already-explored outcome–process–prescription layering has apt relevance, as does Rasmussen’s (1996) risk management framework. Both these models highlight the different vertical components of a good practice system.

A good practice guide must serve multiple audiences, including those across the contracting chain - contracting PCBU (client/principal), contractor, subcontractors, engineer/designer, and workers, as depicted in WorkSafe NZ (2022b) *Keeping healthy and safe while working on the road or roadside guide* (Figure 20). Regulatory bodies such as road controlling authorities also play a crucial role in oversight and management (Shaw et al., 2016).

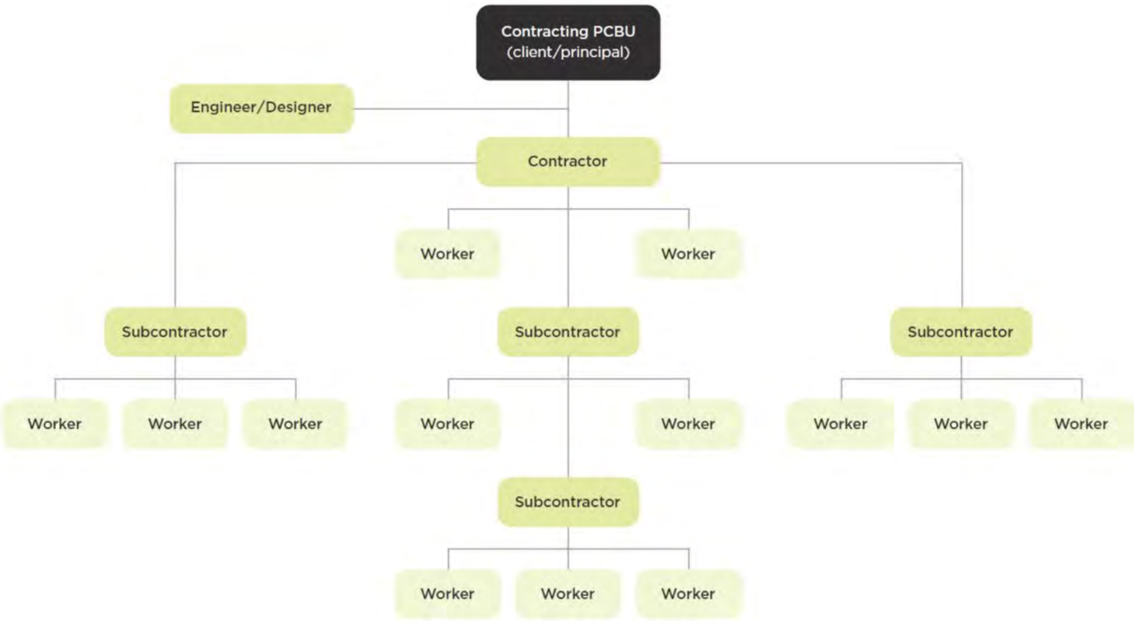


Figure 20 - PCBU contracting chain as presented by WorkSafe NZ (WorkSafe NZ, 2022b, p. 26)

The layering of expectations creates a matrix where one axis represents the rule layers and the other represents the audience, as depicted in Figure 21. Contracting PCBUs, for instance, often set standards through contractual frameworks, bearing a significant portion of expectations or standard setting (Shaw & Oneyear, 2021; WisDOT, 2019, p. 69). Shaw et al. (2016) further note that rulemaking for pedestrian and bicycle safety in work zones primarily occurs at the federal level, but implementation is mainly at the state, county, and municipal levels. This highlights the need for guidelines to be adaptable across different levels of governance and implementation.

	Outcome expectations	**Process expectations**	**Prescriptive expectations**
Regulators/agencies			

<table>
<tr><td>Contracting PCBUs (clients/principals)</td><td rowspan="6">Population of this matrix, in service of good practice for TTM, would contribute to clear articulation and understanding of the array of responsibilities across different system audiences.</td></tr>
<tr><td>Contractors</td></tr>
<tr><td>Sub-contractors (including TTM specialists)</td></tr>
<tr><td>Designers</td></tr>
<tr><td>Workers</td></tr>
<tr><td>Vulnerable Road Users</td></tr>
</table>

Figure 21 - Matrix of expectation layers and audiences of TTM VRU good practice guidance

VRUs are not just passive recipients but also an audience that can benefit from educational marketing materials, such as Shaw et al. (2023), which provides instructions on behaviours and explains the purpose of some signs specific to pedestrians. The value of such materials lies in their ability to educate VRUs about the TTM environment, thereby enhancing their safety.

Shaw and Oneyear (2021) emphasise the need for design guidelines that manage conflicts and clarify expectations for temporary pedestrian facilities. This is particularly relevant for contractors and TTM designers responsible for implementing these guidelines practically.

For a good practice guide to be effective, it must be modular, allowing for unbundling for each respective audience (Bruder et al., 2009; Patterson et al., 2016). This is supported by the principle of modularity in regulatory system design, which aims to reduce user complexity (Carden et al., 2021). Examples of this modularity are evident in separate design guidance provided in various jurisdictions (ADOT, 2019; Caltrans, 2017; MNDOT, 2021b; ODOT, 2023a), as well as field guides for practitioners (FHWA, 2008; MNDOT, 2018; Work Zone Safety Consortium, 2018).

However, the challenge lies in designing regulatory standards that are both efficient and effective while being simple enough for duty holders to understand (Carden et al., 2021). Over-specification of work requirements can be counter-productive, inhibiting adaptation and effective action (Black, 2007). Therefore, guidance should be flexible and adaptable to different organisations, as Corbett (2015) noted.

In summary, the layering of responsibility and audience in forming a good practice guide for VRUs in TTM environments necessitates careful consideration. Good practice must serve its audience, and therefore, the layering of guidance tailored to those audiences is necessary – ensuring that the correct layer of expectation (outcome, process, prescription) is chosen befitting of their level in the system and level of flexibility afforded by both regulations, psychological factors, and context. This supports the design of a modular good practice system with each module pitched appropriately at its audience and comprising a cohesive good practice framework.

Operationalising Good Practice

The operationalisation of good practice is further nuanced by the concept of *work as imagined* versus *work as done*, which has significant implications for the effective implementation of guidelines and standards. *Work as imagined* refers to the theoretical constructs, plans, and guidelines developed to guide practice. In contrast, *work as done* pertains to the actual practices that occur in the field, which may differ from the idealised versions due to various constraints and complexities (Hollnagel, 2014; Nemeth et al., 2011). The gap between these two can be a source of operational failures and risks, especially in high-stakes environments like treating Vulnerable Road Users in TTM (Patriarca et al., 2017).

Therefore, the operationalisation of good practice must account for this gap by ensuring that guidelines are not only theoretically sound but also practically feasible and adaptable to the realities of the field. This aligns with literature emphasising the need for operationalising good practice as a dynamic process that requires ongoing adaptation and evaluation (Carden et al., 2021; Damschroder et al., 2009). It is not enough to create good practice guides; effort must be invested in their operationalisation to ensure they are effectively translated into *work as done.*

The Guidance itself

The efficacy of any good practice guide is contingent upon its successful operationalisation in the field. Shaw's critique that standard setters are often disconnected from practitioners resonates here (Shaw & Oneyear, 2021). If the guidance does not result in good physical site establishments, efforts in its production are futile.

One of the critical elements in making a good practice guide actionable is its presentation. Ambiguous, abstract, and outcome-level expectations are insufficient for practitioners to give effect to (Hopkins, 2011). For instance, guidance from the Wisconsin Department of Transportation (WisDOT) (2019) employs case studies to illustrate good practices, a method supported by Mazumder et al. (2017). Case studies serve as a bridge between theoretical guidelines and practical implementation, and their use is noted by ATSSA (2012), Austroads (2021), and Waka Kotahi (2023c).

Visual aids further enhance the comprehensibility of the guide. For example, Bennett et al. (2019) use actual photos of people in speed graphs to humanise the data. This starkly contrasts with Austroads (2021), which lacks visual content, a significant shortfall given that visuals can be the backbone of good practice presentation (Garcia-Retamero & Galesic, 2010).

Koorey et al.'s (2017) non-prescriptive way of outlining methodologies—providing the fundamental solution, description, where it can be used, advantages, and disadvantages—offers a balanced approach that could be emulated.

The guidance must also be tailored to the audience. The FHWA employs various mechanisms such as specialist training courses, webinars, checklists, podcasts, and guides for end users like field staff and designers. Similarly, the U.S has field guides, and Sweden has different guides targeting different users. This is a testament to the need for good practice to be adaptable to various contexts and audiences.

However, the challenge remains in ensuring these guides reach the intended users. The guidance must fit within a system that includes training and competency, contracts and procurement, and agency leadership. Vermont's guidance, for example, presents reasonable solutions adjacent to bad ones, offering a balanced view that could benefit training and competency development.

The presentation of the guidance also matters. Carden et al. (2021)recommended a brief core standard document of around ten pages with various activity-specific Good Practice Guides (GPGs). This modular approach (as explored earlier) allows for easier digestion and application of the guidelines. It also aligns with the *amplify the why* finding, emphasising that once the rationale is established, there needs to be accessible good practices to deliver value to VRUs.

The operationalisation of good practice in the context of VRU and TTM in New Zealand hinges on several factors: the presentation and comprehensibility of the guide, its adaptability to various contexts and audiences, and its integration within a broader training and competency development system. These elements are not mutually exclusive but are interrelated components that contribute to the effective operationalisation of good practice.

The use of specific language

Using specific language in TTM guidance documents is critical for operationalising good practice. The language used in these documents can significantly influence the interpretation and implementation of safety measures, thereby affecting the overall risk profile of TTM activities, including VRUs.

The choice of directive language, such as *must*, *should*, and *optional*, reflects the guidance document's underlying philosophy. For instance, the frequent use of the term *must* indicate a more prescriptive approach, as observed in the TRVK (2022) technical guidance, where 0.6% of the document's words are *must* (302 instances). This term often correlates with legislative imperatives or non-negotiable safety outcomes. However, an overly prescriptive approach can stifle flexibility and innovation in risk management strategies (Carden et al., 2021).

The choice of directive language also interacts with the layers of expectations explored earlier - outcome, process, and prescription - that a guidance document aims to establish. For example, *must* is often used where legislative requirements dictate specific outcomes or there are no viable alternative processes. On the other hand, *should/shall* may be more appropriate when the guidance aims to be flexible, allowing for alternative but equally effective methods. This is particularly relevant in risk assessments, where various methodologies would be viable (Shepard, 2016).

Some guidance, such as the Department for Transport (UK, CLOCS (2023), MNDOT (2021a), and Worksafe NZ (2019), explicitly define these directive terms at the outset to reduce ambiguity. This practice enhances the document's clarity, ensuring that practitioners understand the level of obligation associated with each term. For example, *should* implies a strong recommendation but allows for deviations if justified, whereas *may* indicates a permissive condition with no obligation (MNDOT, 2018)

A comparison can be made across the original complete 92 TTM standards consolidated as part of this research to understand the use of these terms and the nature of the language used internationally across TTM guidance.

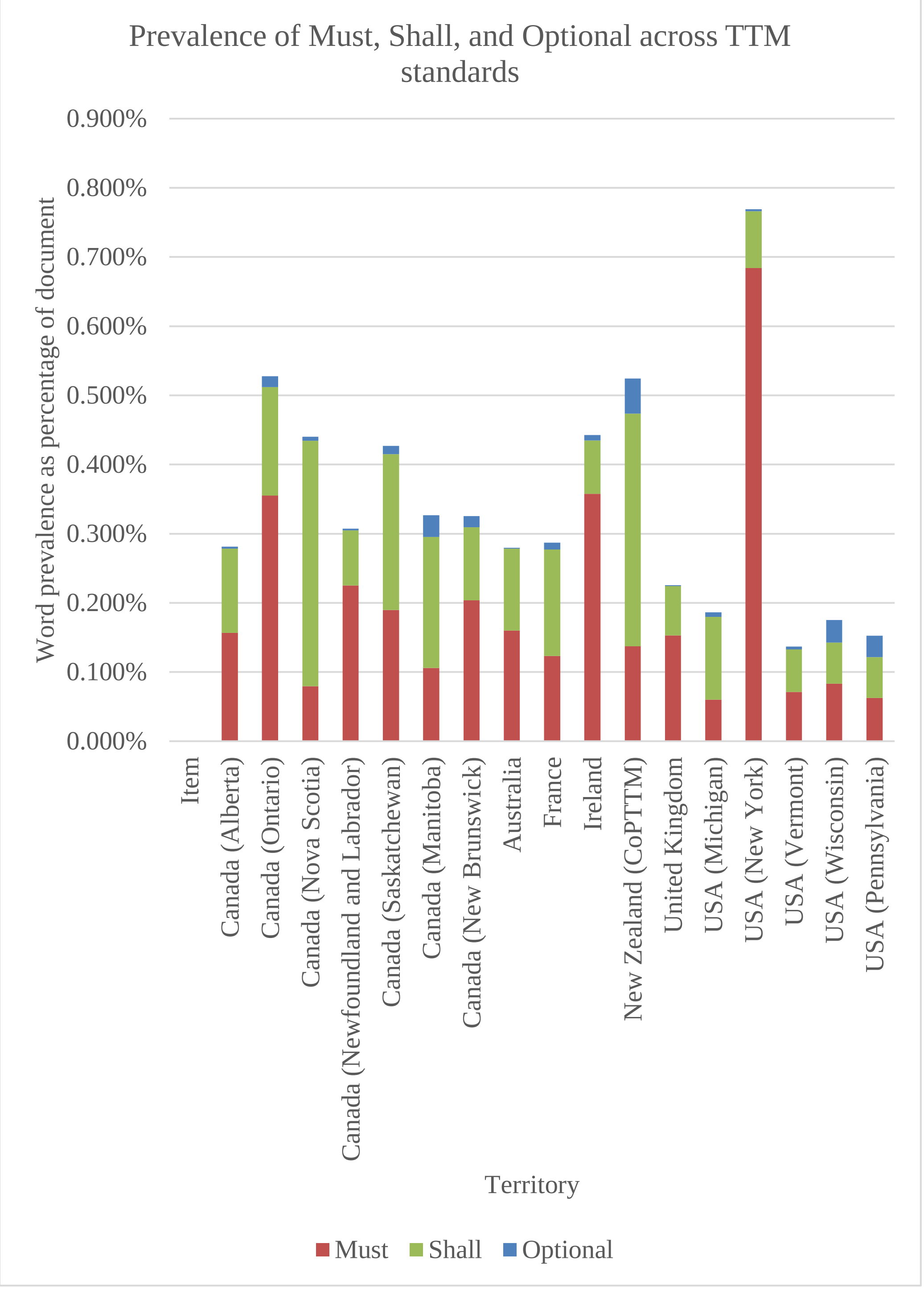


Figure 22 - Prevalence of Must, Shall, and Optional across TTM standards

This cross-standard analysis of language highlights New Zealand's existing wider use of the term *should* (or shall, or should not) compared to other territories whilst retaining a high degree of *must*. Of significant contrast is the newly published NZGTTM, which only utilises these terms: 0.09% (must) and 0.03% (should/shall). This shows a drastic reduction in the precision of the guidance provided going forward across NZ's overarching national standard, consistent with the exploration of this topic earlier in this research.

The term *optional* is problematic, however. Its use implies that the control measure is a matter of choice and not necessarily tied to the hierarchy of controls or risk assessment. For example, the New Zealand CoPTTM states that using illuminated wands is *optional (Waka Kotahi, 2019a)*. This could lead to a lax approach to implementing measures that could otherwise mitigate risks.

While requirements often stem from legal obligations, guidance documents also serve as repositories of what is reasonably practicable. Therefore, specific recommendations may carry near-mandatory weight, especially when the alternative would be a failure to manage risks adequately. For instance, the stipulation that signs must not block open cycle lanes is almost non-negotiable, given the high risk of not doing so. Whilst such a stipulation has no specific legislative foundation – the use of *must* in this context would be appropriate.

Finally, plain language is crucial for disseminating guidance, as mandated for public or crown entities under New Zealand's Plain Language Act (2022). Academic literature supports this, emphasizing that standards should be understandable to their intended audience (Rada, 1993; Walicki et al., 2005).

The choice of language in TTM guidance documents is not just a matter of semantics but a critical factor influencing the operationalisation of good practice. It reflects the guidance's philosophical stance, clarifies the obligation level, and has direct implications for risk management, particularly concerning VRUs. Therefore, future guidelines should aim for clarity, flexibility, and deliberate use of *must* and *should/shall*. Up-front clarification of these terms in guidance documents is advantageous.

Risk and its Treatment

Risk in this context

The concept of risk in this context is multi-faceted, encompassing the potential for physical harm and the psychological and social dimensions of road use. For instance, poorly designed or inadequately signposted TTM measures can induce stress and confusion among VRUs (Shaw & Oneyear, 2021), increasing the likelihood of risky behaviours and accidents (Puchades et al., 2018). Moreover, the risk is not uniformly distributed; factors such as age, disability status, and familiarity with the area can significantly influence an individual's vulnerability (Soathong et al., 2019; H. Wang et al., 2022)

Given the complexities involved and the evolving nature of the landscape of centralised overarching TTM practices in New Zealand (i.e. the retirement of CoPTTM and the release of the NZGTTM), a risk-based approach to TTM is imperative for the effective treatment of VRUs. This entails a comprehensive site-specific risk assessment that considers the specific needs and behaviours of VRUs, followed by the implementation of targeted risk mitigation strategies. Such an approach aligns with the principles of WorkSafe *keeping healthy and safe while working on the road and roadside guide*, and the newly released NZGTTM, which advocates for a user-centric, evidence-based framework for traffic management (Waka Kotahi, 2023c; WorkSafe NZ, 2022b).

A process for the treatment of risks

A noticeable finding is that international standards address various risks to VRUs in their guides. Some explore specific risks and treatments or controls in detail but ignore or only lightly touch on other risks (that other guides will explode forensically). No literature seems to explore the full spectrum of risks, and their method of presenting and categorising risks lacks structure. This gives rise to the need for a more comprehensive method of presenting risks. A handful of standards such as Austroads (2021), Department for Transport (UK) (2023), UNECE (2021), and Waka Kotahi (2023c) do provide risk assessment frameworks but in a general sense – and then their specific utility and application to VRU treatment is diluted. The UN Economic Commission for Europe (UNECE) diagram example is shown in Figure 23.

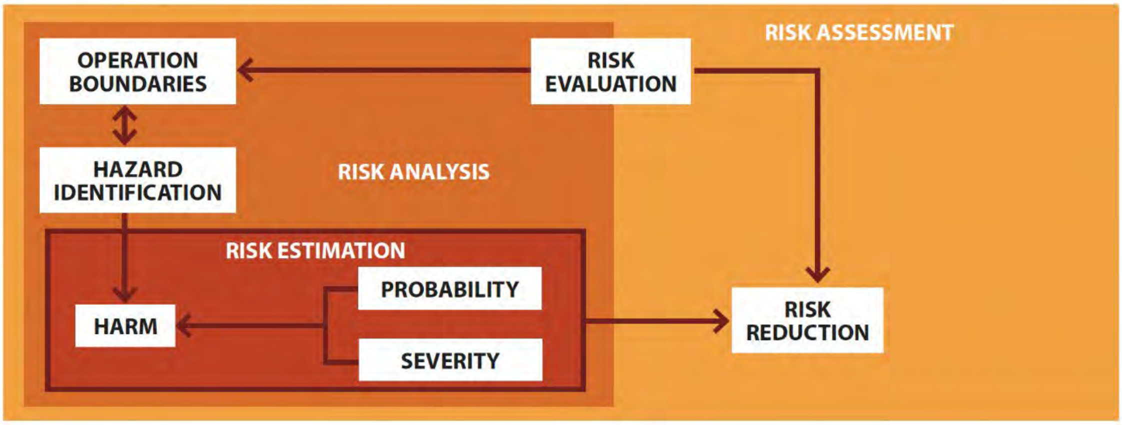


Figure 23 - TEM Guidelines on Workzone Safety Risk Assessment Process (UNECE, 2021)

Therefore, it becomes apparent through this literature review that a more deliberate and comprehensive planning framework for exploring risk to VRUs in TTM is needed. A framework that leverages components of existing risk theory but interlaces the unique considerations of VRUs and TTM contexts. A core reason a tailor-made framework is advantageous is the necessity for the subsequent good practice guide following this research to be digestible and deployable across the New Zealand TTM industry.

As already identified, the level of deliberate attention given to VRUs in TTM, coupled with the immaturity of current standards and practices, results in the need for a drastic improvement in the ability of practitioners, especially TTM designers (Shaw et al., 2016), to attribute more considered thought to the safety of VRUs. Accordingly, the following framework is put forward to enable TTM designers, the principal architects of the TTM planning process, to systematically dissect the risks associated with VRUs in TTM and arrive at more robust treatment plans that can be represented in traffic management plans. This planning framework is deliberately constructed to be easy for TTM designers or planners to digest, which is identified in this research as a prominent obstacle to the capability improvement of TTM practitioners in a system that amplifies the need for risk-based thinking. ISO 31000 (reference) (Figure 24) is a prominent, widely used risk framework, which itself is the backbone of the approach taken by Austroads (2021) – and provides the foundation for this model.

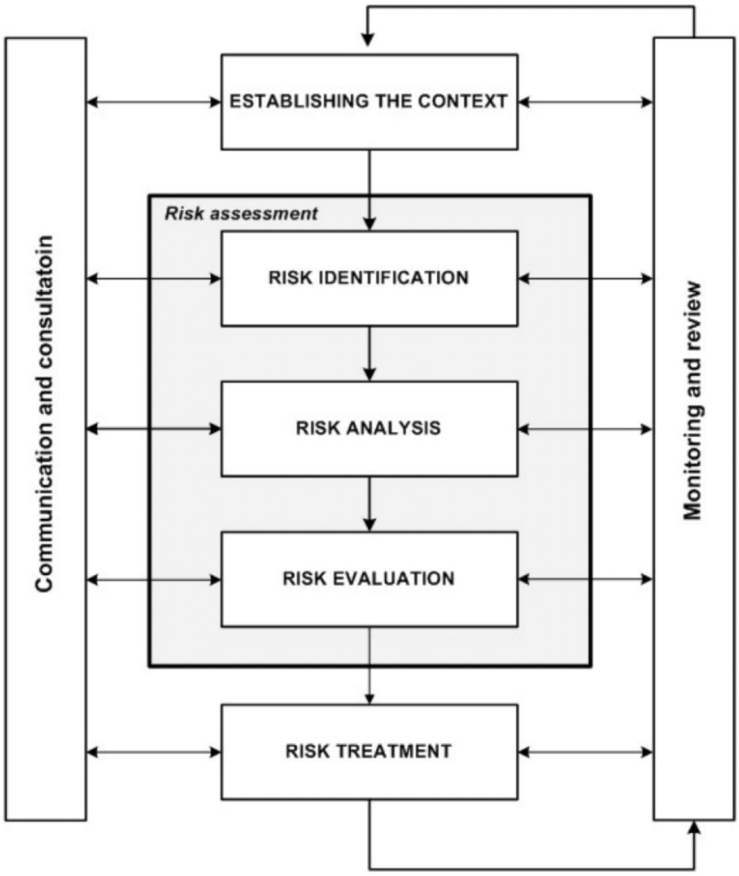


Figure 24 - ISO 31000 Risk Assessment Framework(ISO, 2009)

Figure 25 depicts the risk management planning framework composed of this research, with each component subsequently explored in framework order. Language for this framework has deliberately been selected to be digestible for eventual users to allow this insertion into future good practice.

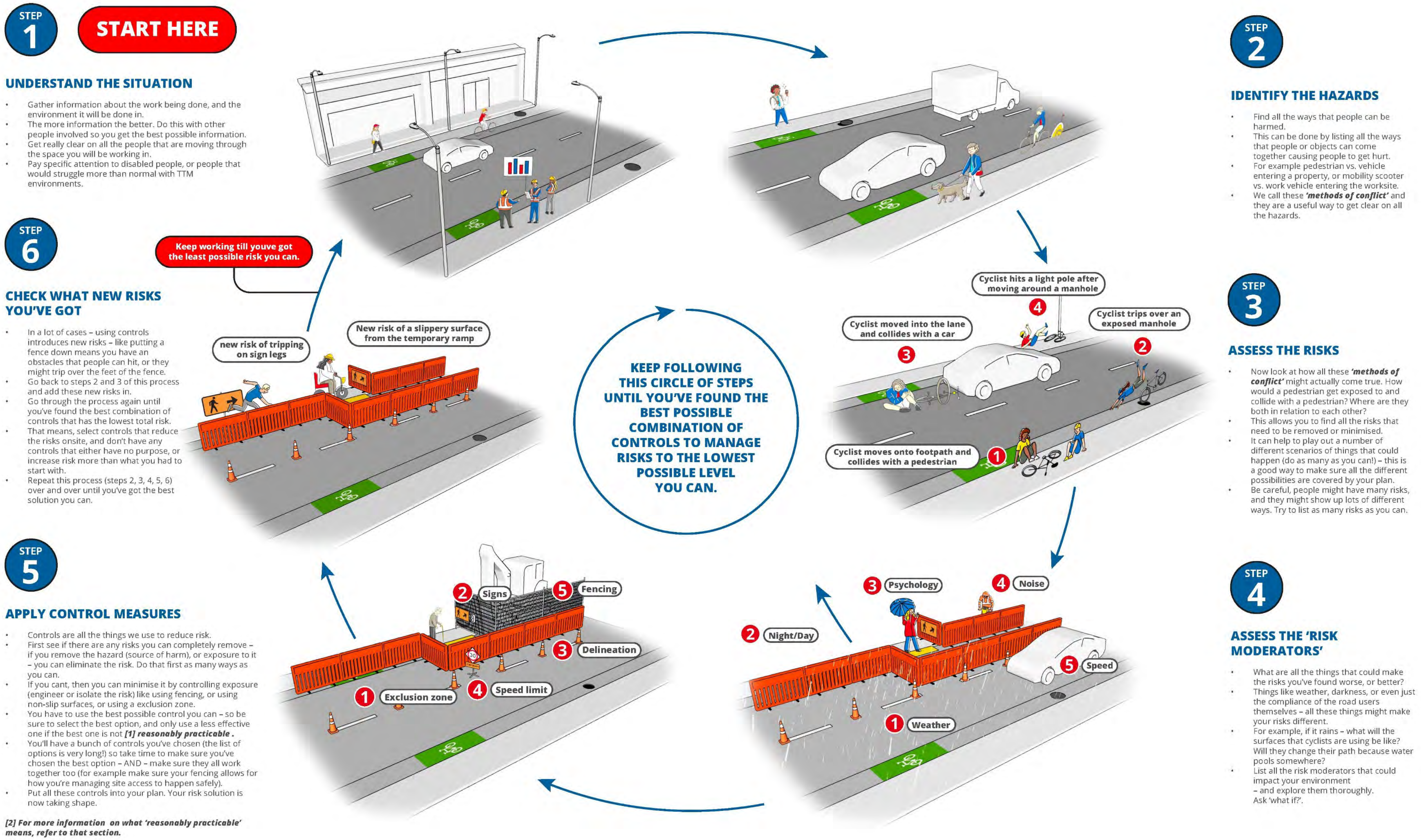


Figure 25 - Risk management planning framework for VRUs in TTM produced as part of this research (Designed for A3 presentation) [19]

[19] This diagram was produced by me as part of this research to serve the future good practice guide. It has been graphically enhanced by a design specialist.

Risk management in TTM traditionally adheres to a linear sequential process that involves identifying hazards, evaluating risks, and implementing controls (Waka Kotahi, 2019a, 2023c). However, the complexity of the TTM environment, particularly concerning vulnerable road users, necessitates a more systemic understanding.

The lighting example is an illustrative case point, revealing the interplay of variables that can act as risk factors, controls, or risk moderators depending on the context. In a TTM setting, darkness (night operations) can be identified as a risk moderator that increases the vulnerability of road users (Austroads, 2021; Niska et al., 2022; Shaw et al., 2023; Soathong et al., 2019). To mitigate this, temporary lighting is commonly employed as a control measure (prevalent across many international standards). However, the absence of inadequacy of lighting can itself act as a risk moderator, exacerbating the initial risk posed by darkness. This dual role of lighting—as both a control and a risk moderator—complicates the more straightforward linear approach to risk management.

Further adding to this complexity is that lighting can introduce new risks while serving as a control. For instance, glare from the lighting can impair visibility, and the physical infrastructure required for lighting, such as columns, can pose additional hazards. This multifaceted nature of a single factor like lighting underscores the need for an iterative and systemic approach to risk management, as advocated for by Elms (2019). New risks or moderators may emerge at different stages of the planning and implementation process, requiring reinserting these discoveries into earlier stages to re-evaluate and adjust treatment plans. Therefore, treating risk as if it is a *system* philosophically addresses some of these complexities in that components of that system act on others in different ways, at different stages, depending on the state of the system. The effort, therefore, should be applied primarily to profoundly understanding the components of the system and their relationships to seek optimal risk mitigation.

The composition of the risk management planning framework shown in Figure 25 seeks to provide a structure for future good practice in VRUs in TTM and a structure for exploring how existing guidance approaches managing risk for these users (as shown in the subsequent sections).

Understand the situation

The first step in the process, *establishing the context* in ISO 31000 (ISO, 2009), is a critical phase that lays the foundation for all subsequent risk management activities. The FHWA (2005) guidance for TTM design outlines this concerning work zones as *work zone impacts*, as shown in Figure 26.

Figure 26 - FHWA Work Zone Impacts Model (FHWA, 2005)

Most existing literature and guidance documents underscore the importance of intimately understanding the environment within which work will take place, much like this model encourages, which hereafter will be referred to as *reconnaissance*. Reconnaissance bridges the gap between work as imagined, work as designed, and work as done (Hollnagel, 2014). For instance, guidelines from various territories such as Caltrans (2020) and MDOT (2007) provide extensive advice on conducting site reviews to assess existing pedestrian facilities, pedestrian activity, and potential safety concerns. Many guidelines advocate for a comprehensive data collection process that informs the design and planning stages, thereby reducing the divergence between planned and actual work conditions (Hollnagel, 2014).

One of the critical aspects of effective reconnaissance is identifying and negotiating access needs for various stakeholders, such as businesses (Department for Transport (UK), 2023). Stakeholder negotiation is not a one-way street; TTM planning can influence construction methodologies and business operations as much as they can dictate TTM needs – and this is an important theme present across more evolved standards and some academic literature (Shaw et al., 2016). Trials, as highlighted in the literature, are another tool where empirical testing of planned interventions before full-scale implementation may be of value (Department for Transport (UK), 2023).

Guidelines from MNDOT (2021b) and ODOT (2023b) emphasise the need for an inventory of existing pedestrian facilities, including details like widths, slopes, and types of surfaces. These guidelines also stress the importance of understanding pedestrian traffic generators such as schools, shopping centres, and local businesses, which may require additional attention during the planning phase.

Moreover, NYDOT (2023) suggests that public involvement can be invaluable for understanding user needs and developing community-supported solutions. This is particularly crucial in environments with a high concentration of VRUs, where standard TTM measures may not suffice (MTO, 2022).

However, it is worth noting that while guidelines provide a structured approach to reconnaissance, they may not cover all the nuances of a specific TTM environment. For instance, the National Technical University of Athens (1998) suggests the development of multiple work zone accident scenarios when direct investigation is not feasible. This could serve as an alternative or supplementary method for gathering information.

In summary, *understanding the situation* involves thoroughly understanding the work environment, facilitated by comprehensive reconnaissance and public involvement. This step is a cornerstone for effective risk management, particularly for VRUs in TTM settings. It sets the stage for iterative design and systemic thinking, aligning closely with the risk-based approach in the New Zealand Guide to TTM (Waka Kotahi, 2023c).

Identify hazards (or hazard sources)

The focal point of this research is vulnerable road users as our risk subjects. To derive good practice in treating these subjects necessitates exploring the sources of harm for these users.

Basic categories of hazards provide a mechanism to simplify hazard sources from a TTM perspective – those that come from the existing environment (both dynamic and static), such as road users, existing facilities or infrastructure, or geometry. Furthermore, those that come from what is introduced (again, both static and dynamic), such as work vehicles, materials, and overhead falling risks from work above.

While the focus on overhead hazards is evident in guidelines such as those from MNDOT (2021b), ODOT (2018) and WisDOT (2019), other types of hazards receive varying degrees of attention across international territories. For instance, tripping hazards due to debris or uneven surfaces are rigorously addressed by MTO (2022). However, such meticulous detailing is less prevalent in guidelines from other regions, such as South Korea (MOLIT, 2022). Introduced activity hazards (machinery, materials and the like) are covered almost universally; however, some guidance explores nuances of these unique hazards, such as the risk of children using stockpiled materials as a playground (Shaw et al., 2023). In most cases, the risk of the surface condition is explored across all standards; however, many explore it with a perspective of how it has been impacted (by the activity), whereas others go as far as to consider the state of existing infrastructure that might receive additional VRU traffic due to the activity's presence (Shaw & Oneyear, 2021). Some of the lesser common explored hazards across standards are the presence of pipes or hoses across pathways (MNDOT, 2021b), compromised visibility lines for VRUs due to construction equipment, and the encroachment of vehicular appendages (like crane outrigger legs) into VRU pathways (Niska & Eriksson, 2014) as shown in Figure 27.

In some cases, vehicle entry and exit from worksites are highlighted (Waka Kotahi, 2023c); however, this is also minimally explored. The varied nature of specific hazard exploration across standards makes it challenging to discern good practice and consolidate the raft of generalised or specific and bespoke hazards. What is more advantageous is categorising these hazards into *sources* to generate a more complete picture of them.

Figure 27 - Construction hazard example provided in the international literature (Niska & Eriksson, 2014)

To delineate these sources, it is instructive to employ the concept of *methods of conflict*. This term serves as a framework for categorising the various interactions that can harm VRUs within TTM environments. Conceptually similar to Failure Modes as proposed by the U. S. Department of Defense (1949)[20], this approach seeks to categorise all the mechanisms of interaction that VRUs (risk subjects) can come to harm in a setting that involves TTM. Utilising the literature compiled as part of this research, such hazard sources are shown in Figure 28. A failure mode (or *method of conflict*) would be any interaction between these hazard sources and our risk subjects (VRUs).

Several categories of 'methods of conflict' can be identified in TTM settings – however, a few examples are explored below:

[20] as part of Failure Modes and Effects Analysis (FMEA)

- Cyclist vs. Road User Vehicle: This conflict arises when cyclists and motorised vehicles vie for the same road space, often leading to dangerous overtaking or intersection-related risks.
- Pedestrian vs. Worksite Vehicle Entering: This occurs when a pedestrian is in the path of a vehicle entering or exiting a worksite, creating a risk of collision.
- Cyclist vs. Pedestrian: This conflict can happen in shared spaces with cyclists and pedestrians, such as crosswalks or shared-use paths.
- Cyclist vs. Worksite Static Hazard: This involves a cyclist coming into contact with a static object like an excavation pit, construction equipment, or other physical barriers within the TTM zone.
- Pedestrian vs. Road User Vehicle: Similar to the cyclist vs. road user vehicle conflict, it involves pedestrians who may be at risk during road crossings or walking along roadways without adequate pedestrian facilities.
- VRU vs. Environmental Factors: This includes conflicts arising from poor lighting, weather conditions, or road surface conditions that make it difficult for VRUs to navigate safely.
- Inter-VRU Conflicts: These conflicts occur between different types of VRUs, such as cyclists vs. e-scooter riders or pedestrians vs. skateboarders.

By mapping each of these *methods of conflict*, a definitive picture of different failure modes can be identified. Such a map can be provided to practitioners to supercharge their risk assessment process and encapsulate how harm can materialise. As a critical global shortfall in most existing standards, this enhanced method of encapsulating failure modes provides a more comprehensive mechanism for increasing the utility of future good practice and overcoming several of the guidance shortfalls and themes identified earlier.

Figure 28 - Diagram of hazard sources for a VRU risk subject in a TTM setting[21]

Appendix N shows the hazard sources in tabular form, with supporting notes. A connection between each hazard source is an opportunity for harm (hence the term *method of conflict*); however, we are primarily concerned with the central risk subject of a vulnerable road user in this context.

Specific exploration of two hazard sources is warranted given some unique findings: rail crossings and noise.

[21] This diagram was produced by me as part of this research to serve the future good practice guide. It has ben graphically enhanced by a design specialist.

Despite their significance, rail crossings receive limited attention in existing TTM standards. A review of 92 complete standards revealed that rail crossings were mentioned only 154 times across 20 documents. Notably, 49 of the 92 standards originated from the United States, a country with a road-rail interface prevalence comparable to NZ (NZ has approximately 31.9 level crossings[22] per 1000 km of public roads, while the U.S. has 31.8 per 1000 km (Central Intelligence Agency (CIA), 2023; Kiwirail, 2023a; UNECE, 2023; Waka Kotahi, 2023b).

This underrepresentation is concerning given the elevated risk environment rail crossings pose for VRUs. Research indicates that the interface between road and rail at level crossings is a significant risk factor for VRUs, and the introduction of TTM in these environments can amplify this risk (Turner et al., 2021; WorkSafe NZ, 2022b). The urgency of addressing this gap is underscored by safety alerts released by Kiwirail in 2018 and 2021, explicitly concerning TTM and rail crossing interfaces (Kiwirail, 2023b). Although the most recently released WorkSafe (2022b) TTM guidance does include guidance on rail crossings (Section 23), it is a relatively new addition and may not yet have a widespread impact.

Secondly, noise. Noise at a worksite poses a multifaceted risk, particularly for pedestrians navigating through or near Temporary Traffic Management (TTM) zones. While the health implications of sustained exposure to high noise levels are well-documented, including hearing loss and stress-related health issues (Basner et al., 2014), the immediate concern in a TTM context is the impairment of auditory cues that pedestrians rely on for situational awareness and safety (H. Wang et al., 2022). Auditory cues, such as the sound of approaching vehicles or warning signals, are critical for making informed decisions while crossing streets or navigating work zones. Worksite noise can mask these essential cues, increasing the risk of accidents.

Moreover, the contemporary prevalence of headphone use exacerbates this issue. Pedestrians engrossed in music, podcasts, or phone calls may voluntarily reduce their

[22] A rail or level crossing is an intersection where a railway line crosses a road or path at the same level, equipped with safety features to manage the interaction between trains and road users.

ability to hear external sounds. When this personal choice is combined with the elevated noise levels of a worksite, the pedestrian's auditory perception can be severely compromised, further escalating the risk of an accident (Basner et al., 2014).

Evaluate risks

To achieve a robust risk evaluation, it is imperative to consider the myriad variables that contribute to risk intersections. These variables include the routes and paths VRUs might take, spatial considerations, and the timing and coordination of plant and materials. Such an approach aligns with the guidelines outlined in the NZGTTM (Waka Kotahi, 2023c), which advocates for a meticulous description and assessment of risks and how they might materialise. The Austroads (2021) guide further elaborates on this by emphasising the need for an extensive understanding of all users' needs, which can then be translated to assessing risk for those users.

This comprehensive evaluation produces a roadmap for treatment, facilitating the methodical assignment of control measures. These measures should align with the hierarchy of controls, a concept well-articulated by MTO (2022), which suggests starting with the most effective approach and justifying decisions for implementing less effective measures. However, not all guidelines offer such a nuanced approach. For instance, some literature promotes a more prescriptive model, attaching controls to problems more linearly, thereby neglecting the complexities of site specificity (NYDOT, 2023; WisDOT, 2019).

A prevalent method for evaluating risks is using risk matrices, which assign quantitative measures to the likelihood and severity of risks (Cox, 2008). While this method is widespread, it is not without criticism. The assignment of a likelihood and severity classification does not absolve the legal necessity to continue managing risk until it is no longer practicable. This point is corroborated by a multitude of literature that debunks the efficacy of risk matrices in this context (Ball & Watt, 2013; Baybutt, 2014; Cox, 2008; Duijm, 2015; Glen & Rhys, 2009; Ristic, 2013). For this reason, a risk matrix-based approach is not advocated for in developing good practice in this field as it exacerbates the gravitation to a risk management approach devoid of critical thinking, which is crucial for this context (Duijm, 2015).

An important finding is a need for the utility of the process and step of risk evaluation to be applicable across the spectrum of TTM settings – such as mobile operations and static operations. Most international guidance solely focuses on treating risk for VRUs where the activity (and its accompanying TTM) is static. A select few standards provide guidance related to mobile TTM environments, which are as numerous as static ones[23] (Austroads, 2021; FSGV, 2021; TfL, 2018; TRVK, 2022). Any good practice guidance related to evaluating risks to VRUs in TTM must be undertaken regardless of the type and method of TTM being proposed or enacted – to ensure the applicability of the good practice across the spectrum of settings.

The evaluation of risks culminates when the risks for the site have been suitably mapped to withstand expert scrutiny. This involves understanding how and where risks would materialise and under what conditions. This aligns with the concept of *failure modes* from the Failure Modes and Effects Analysis (FMEA) process.

Assess the risk moderators

Some variables are not necessarily hazards or risks in their own right but intensify (amplify) or dampen primary risks (Cox, 2008; Kaplan & Garrick, 1981). In this context, these are referred to as *risk moderators*[24] as they intervene in the risk process, altering the trajectory of outcomes (Aschengrau & Seage, 2013). Across the spectrum of literature explored as part of this research, a range of risk moderators were identified and catalogued for utilisation as part of this framework in Table 17. In some cases, such moderators could be categorised as *aleatory uncertainties* outside the direct control of the works involving TTM (Aven, 2016) but have a variable impact on the risks present or the effectiveness of controls utilised. For example, weather, where increased rainfall may turn a previously

[23] This is due to all static sites requiring some form of mobile operation to establish and disestablish the static TTM equipment in each case.

[24] In some literature, and ISO 310000:2009, these are referred to as *risk drivers* (Kaplan& Garrick, 1981).

stable surface into a slippery one, amplifying the effect of a hazard under those circumstances.

Risk moderators	Description
Weather	Including conditions like rain, snow, fog, high winds, and temperature extremes affecting visibility and the performance of both people and materials.
Time of Day/Lighting	Dusk, dawn, or nighttime conditions impact visibility and awareness.
Traffic Volume	Fluctuating levels of road traffic, including peak and off-peak hours.
Seasonal Changes	Seasonal migration of wildlife or higher tourist activity affecting road environment patterns.
Events or Holidays	Sporting events, festivals, public holidays, or other gatherings influencing road environments temporarily.
Emergency Situations	Accidents or emergency events redirecting traffic or creating unpredictable patterns.
Technological Failures	Network outages, traffic light malfunctions, and other technical issues affecting navigation or decision-making.
Noise Pollution	Non-project-related noise affecting communication or concentration among construction workers and road users.

Table 18 - List of risk moderators relating to VRU treatment in TTM

Across guidance and literature, these *risk moderators* are explored extensively. In some cases, they are categorised as risks themselves; in other cases, they are categorised as considerations worthy of input to assessing risk. Each *risk moderator* is not afforded equal or universal attention across international literature, with some receiving extensive coverage (weather, traffic volume) and others receiving only pocketed attention (technological failures, noise pollution).

While weather is a more prominent topic, its coverage is often superficial. The word weather is found only 436 times across only 52 of the 92 complete original international and territorial standards collated for this research. Weather is commonly mentioned as a consideration – requiring attention during planning or deployment of controls (British Columbia Ministry of Transportation and Infrastructure, 2020; MNDOT, 2018) but receives very little attention regarding *how* such effects might materialise for VRUs in

TTM environments. However, Tanishita et al. (2023) explored the correlation between weather and VRU injury rates and found that *bad weather* lowers fatality risk and the volumes of VRUs.

Two intersectional but extremely critical moderators that are prominent across almost all literature are time and space. The duration for which hazards are present directly correlates with the level of exposure to those hazards. Some literature posits this relationship as linear, with the FHWA employing a formula that computes the risk of collision as a product of worksite length (distance) and time (Rista et al., 2017). While there is merit in causing higher disruption for a lesser duration to mitigate risks (Shaw et al., 2016), this approach necessitates an exploration of the trade-offs involved, as explored earlier, such as the quality of temporary facilities, potential reductions in the construction programme, and the possibility of installing final permanent facilities earlier (Shaw et al., 2016)

Redundant equipment, materials, and hazards that expedite multi-day works carry the added risk of disproportionately impacting VRUs (Shaw et al., 2023). It is crucial to distinguish between time and duration as risk moderators. When the work occurs, *time* considers peak flows, which can differ for cyclists and pedestrians compared to vehicle traffic (FSGV, 2021; National Technical University of Athens, 1998; Pyöräilykuntien Verkosto, 2020). Duration, conversely, pertains to how long the work takes and the associated spatial considerations (Shaw et al., 2023). In some cases, durations of work are categorised for ease of determining TTM treatments befitting of the length of the works such as *long-term, short term* or *mobile* (ARTBA, 2023; Department for Transport (UK), 2023; FSGV, 2021; UNECE, 2021; Waka Kotahi, 2019a) Such categorisation of duration serves only as one mechanism to differentiate the amount of exposure which is simply a *risk moderator* (every additional moment of exposure multiplies risk if all other variables remain unchanged).

Both timing and duration are not static variables but exist on a spectrum that requires meticulous planning and execution. A common expectation in traffic management is to minimise disruption to road users (Cerema, 2000; CROW, 2020; Government of Ireland, 2009; Junta Autónoma de Estradas, 1997; LRA, 2012; Majandus- ja Taristuminister, 2018; Manitoba Infrastructure and Transportation, 2015). While some standards, such as the NZGTTM, suggest that this expectation may conflict with achieving the safest outcomes (Waka Kotahi, 2023c), this is not necessarily the case. Safety, or the presence of residual risk, is a function of the number of hazards and the level of exposure to those hazards. A reduction in the footprint of a worksite often contributes to a decrease in both hazards and exposure. Therefore, minimising disruption and reducing risk are not mutually exclusive but can be harmoniously balanced. This is articulated well by Austroads (2021) as *design balance* (Section 2.4).

This balance is articulated differently across various guidelines. For instance, New Brunswick Transportation and Infrastructure (2021) states that safety is paramount and achieved through minimal impacts and the most minor intrusion. In contrast, ODOT (2023a, p. 23) states, "The purpose of the transportation management program is to minimize disruptions to public traffic, including motorists, bicyclists, and pedestrians, the freight industry and communities without compromising public or worker safety, or the quality of work being performed." which semantically positions disruption ahead of safety. The art of TTM design lies in optimally incorporating these priorities and maximizing their correlation wherever possible. Effective TTM design, particularly concerning VRU safety, minimises disruption by recognizing that any alteration to existing facilities generates additional risks. These risks are associated with the traversal of alternate environments, the standard of those alternative facilities, and the level of compliance and understanding by users (Austroads, 2021).

A brief exploration of other selected risk moderators is undertaken below as explored by the evaluated literature;

- Children are often drawn to construction sites due to the allure of stockpiled materials and machinery (Shaw et al., 2023). Existing guidance suggests that good design can mitigate this issue, emphasising the need for tall fencing and other barriers to prevent unauthorised access (Shaw et al., 2023). The proximity of construction sites to residential areas should be considered in the design phase to minimise the risk of children wandering into hazardous zones (Shaw et al., 2023).

- Impairment due to alcohol or drugs significantly elevates the drivers' and pedestrians' risk of accidents (Shaw et al., 2016; Soathong et al., 2019). Existing guidelines indicate that nearly half of pedestrian fatalities involve some form of impairment (Soathong et al., 2019). The focus is on cognitive impairments such as reduced visual attention and vigilance, particularly when blood alcohol concentration reaches 0.08% (Charlton & Starkey, 2013).
- Space constraints often lead to the closure of sidewalks, bike lanes, or traffic lanes, resulting in discontinuous pathways for non-motorised mobility (Mazumder et al., 2017). Guidelines recommend that the routing follow the order of preference: along the existing route, sidewalk bypass, and then detour (MNDOT, 2021a, 2021b). The focus is minimising the road length where traffic management is placed to reduce risk (Waka Kotahi, 2019a). This somewhat ties back to the previously mentioned moderator of time and duration but adds the dimension of space.
- High traffic volumes, especially for VRUs, necessitate more extensive plans for pedestrian access and safety (VTrans, 2021). Pedestrian exposure varies widely and has rarely been considered in temporary pedestrian design guidance (Shaw & Oneyear, 2021). Existing guidelines emphasise the need for clear warning signage, adequate surface conditions, and proper signing and marking of detours as methods of mitigating higher volumes; however, these controls are superficial, and guidance does an inadequate job of exploring the variances in VRU volume and how such variances can be managed most effectively in terms of risk (Shaw et al., 2016). Some guidelines recommend that work on busy roads should be carried out during off-peak times to minimise the impact (FSGV, 2021) or coordination with works on the same road or in the same area should be undertaken to minimise traffic disturbances (Shaw et al., 2016).
- Complex road environments, such as those with downhills and curves, have been identified as factors that increase fatality risk (Tanishita et al., 2023). Furthermore,

the type of road environment, such as rural or urban, affects the risk levels for VRUs (Tanishita et al., 2023). Rural roads may not have large numbers of pedestrians but may be the only route to a particular destination. Guidelines recommend that rural pedestrian needs should be carefully evaluated (NYDOT, 2023).

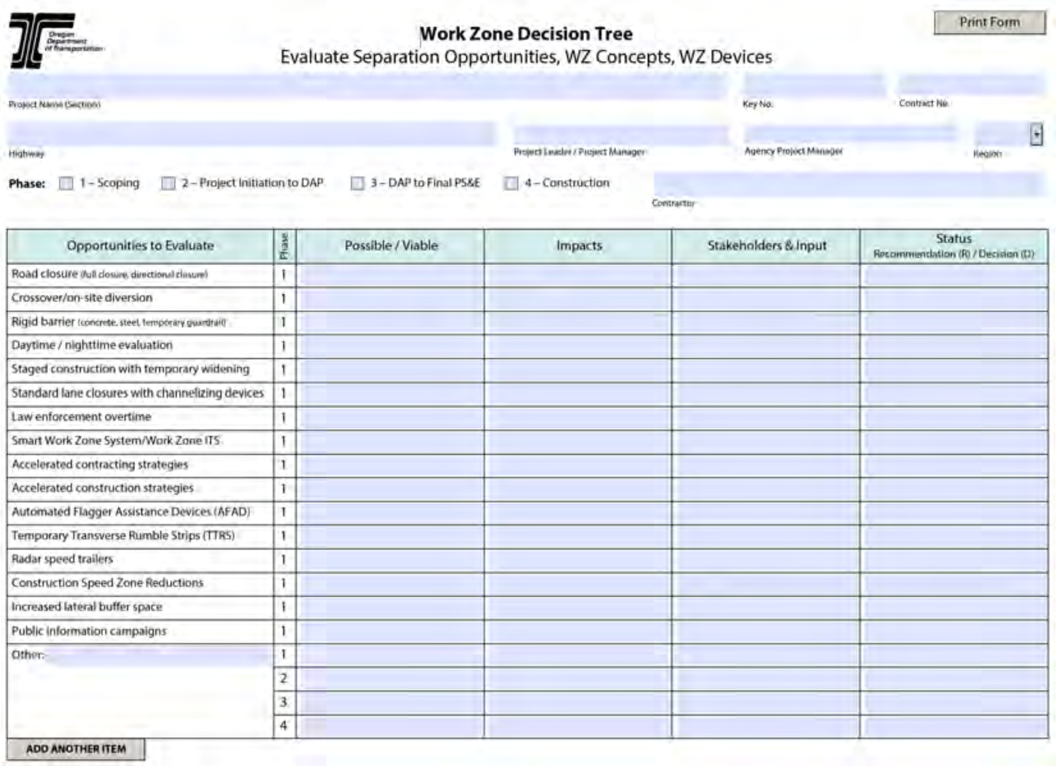
- Adequate lighting is crucial for pedestrian safety and personal security. Many guidelines stress the importance of temporary lighting in work zones to deter collisions and help VRUs see tripping hazards (MDOT, 2022; Shaw et al., 2023). The risk of crashes may increase due to low visibility at night (NYDOT, 2023). Visibility is a critical factor in pedestrian safety, with guidelines recommending improvements such as high-visibility crosswalks and adequate lighting (Lee et al., 2021; Shaw et al., 2023). Obstructed views are major accident risk factors (Berghoefer et al., 2023). Guidelines suggest that visibility can be compromised when permanent lighting is taken out of service
- High noise levels could interfere with the ability of pedestrians to use auditory cues for safety (H. Wang et al., 2022).
- Poor surface conditions, such as uneven surfaces, large cracks, and potholes, increase the risk of accidents (Mazumder et al., 2017). Cyclists are particularly vulnerable to rough surfaces (Department for Transport (UK), 2023). Low-quality and narrow cycle paths cause cyclists to look down more, affecting their gaze behaviour (Vansteenkiste et al., 2014).

Apply controls (treat risks)

In many cases, the literature explored as part of this research dedicated significant attention to the targeted and detailed attribution of controls to risks based on pre-determined criteria. What is vital with risk controls is not just their individual intent and purpose (which requires deliberate and detailed knowledge by designers) but also their synergy together (Hollnagel et al., 2006)

The treatment of risk through the application of controls that work individually but also in concert is explored by Leveson (2004) as part of his Systems Theory Framework, which recognises safety as a system property emerging from interactions between system components – which can lead to better outcomes (than simply considering risk controls as individual isolated interventions). When viewed in tandem with Reason's Swiss Cheese Model, which discusses the multi-layering of defences to mitigate risk (Reason, 1990), the concept of multiple layers of risk controls (individually and as a system) becomes valuable.

In some cases, literature explores these groupings of controls as fundamental TTM controls (Waka Kotahi, 2023c) or closure types (ADOT, 2019; Helsingin Kaupunki, 2022; MIT, 2019; MNDOT, 2018; MoDOT, 2020; MTO, 2022; SALAR, 2019; vejdirektoratet, 2020; WisDOT, 2019) where control combinations are predetermined. Some guidance follows an order of preference approach, seeking to mirror the philosophy of the hierarchy of controls (MNDOT, 2018; MTO, 2022; TfL, 2019; Waka Kotahi, 2023c; WisDOT, 2019). ODOT (2023a) uses a 'decision tree' to assist designers in arriving at viable options (Figure 29).


Print Form

Work Zone Decision Tree

Evaluate Separation Opportunities, WZ Concepts, WZ Devices

Project Name (Section) — Key No. — Contract No.

Highway — Project Leader / Project Manager — Agency Project Manager — Region

Phase: ☐ 1 – Scoping ☐ 2 – Project Initiation to DAP ☐ 3 – DAP to Final PS&E ☐ 4 – Construction

Contractor

Opportunities to Evaluate	Phase	Possible / Viable	Impacts	Stakeholders & Input	Status Recommendation (R) / Decision (D)
Road closure (full closure, directional closure)	1				
Crossover/on-site diversion	1				
Rigid barrier (concrete, steel, temporary guardrail)	1				
Daytime / nighttime evaluation	1				
Staged construction with temporary widening	1				
Standard lane closures with channelizing devices	1				
Law enforcement overtime	1				
Smart Work Zone System/Work Zone ITS	1				
Accelerated contracting strategies	1				
Accelerated construction strategies	1				
Automated Flagger Assistance Devices (AFAD)	1				
Temporary Transverse Rumble Strips (TTRS)	1				
Radar speed trailers	1				
Construction Speed Zone Reductions	1				
Increased lateral buffer space	1				
Public information campaigns	1				
Other:	1				
	2				
	3				
	4				

ADD ANOTHER ITEM

Figure 29 - ODoT WorkZone Decision Tree (ODOT, 2023a)

Interestingly, the only prominent foundational component of NZ's soon-to-be-retired CoPTTM that employs this method (of selecting a TTM methodology in order of preference) is related to pedestrians (Figure 30) (Waka Kotahi, 2019a).

C13.2.3 Alternative routes

Where the activity impacts a footpath and minimum footpath widths cannot be maintained, alternative routes with a firm smooth surface and no trip hazards are to be provided in the following order of preference:

1. onside of road reserve away from the carriageway
2. between the working space and carriageway (but not into the live lane)
3. into the carriageway (either in a parking lane or a suitably delineated and protected section of the existing traffic lane)
4. use footpath controllers to guide pedestrians around the operation

   Note: This option may be combined with any of the other options to increase safety for pedestrians
5. across the carriageway to a footpath on the opposite side with delineation of the crossing points and kerb ramps to assist mobility vehicles and pushchairs

   Note: This option is strongly discouraged and is not to be used if options 1, 2, 3 or 4 are feasible (only use where there is a pedestrian or a signalised crossing **or** on a level LV or level 1 road with a speed of less than 65km/h).

Figure 30 - CoPTTM guidance on alternative pedestrian routes(Waka Kotahi, 2019a, p. 241)

The value of such structured decision-making, or predetermination, is in the presentation of consistent combinations of controls (that work in consort) to both road users (for a more consistent experience) and TTM practitioners (for consistency of design and deployment). However, the consequence of such predetermination is the generalisation of the management of unique site-specific risks and the potential for templated solutions that are not the best possible total solution for each unique circumstance.

It is essential to differentiate between *predetermining controls* and providing a *decision process*. A decision process, such as the one put forward in MNDOT (2018) guidance (Figure 31), does not pre-determine - but progressively narrows the available options using site-specific input data – akin to the previously mentioned *process expectations*. Such processes present a valuable balance between structure, prescription, and corraling risk management toward optimal solutions.

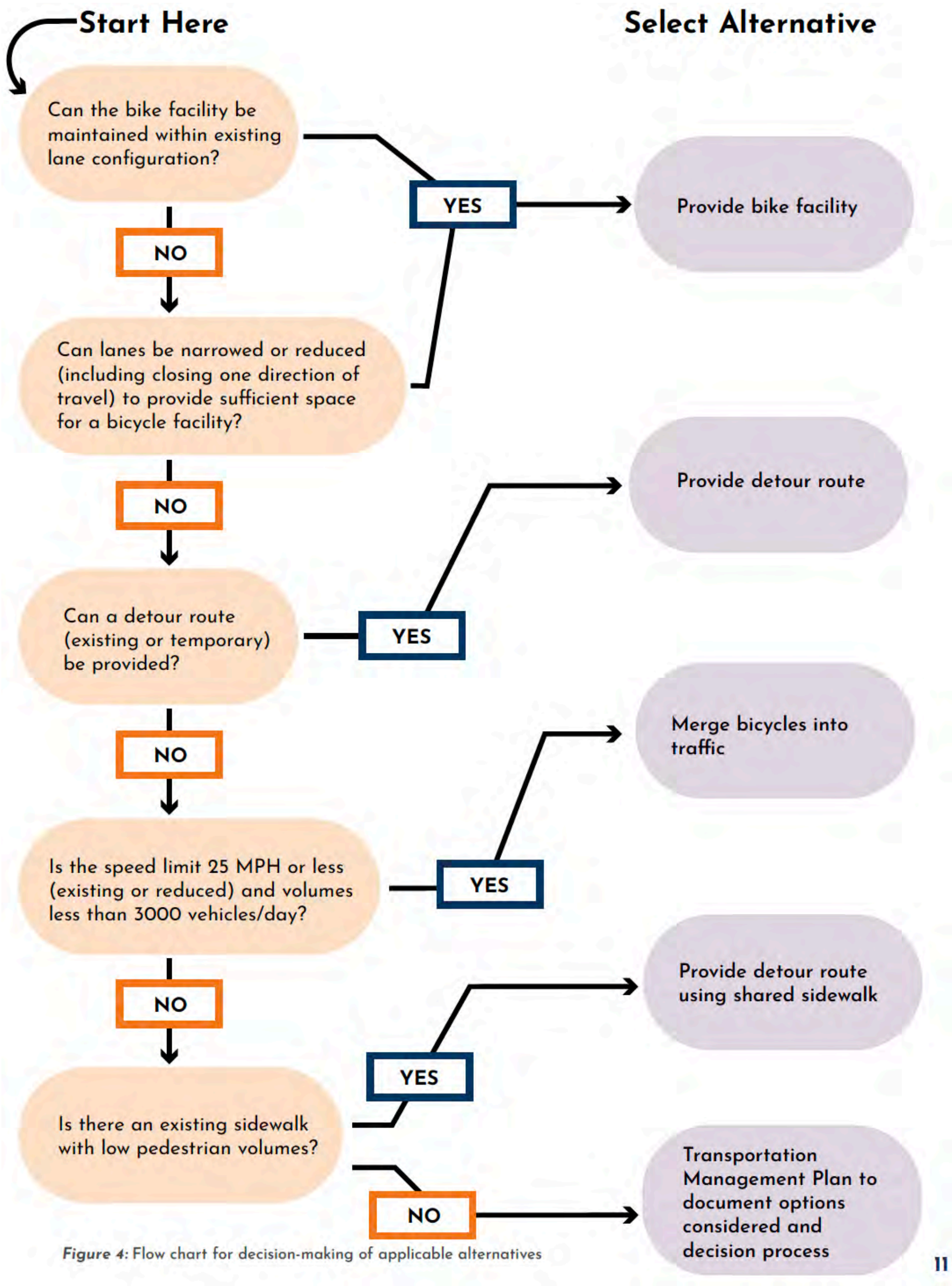


Figure 31 - MnDOT design process for cyclist treatments in TTM (MNDOT, 2021a)

Predetermination in TTM, wherein specific controls are mandated under given conditions, risks incongruence between the control and its intended risk mitigation. This risk is exacerbated for VRUs when coupled with the historically vehicle-centric focus of TTM. Designers should continuously assess three elements: the individual purpose of each control, its direct risk-mitigative connection, and its synergy when combined with other controls.

Take the example of deploying a fence in TTM. While it serves the individual purpose of restricting unauthorised entry, its efficacy is amplified when used with other controls like directional signs and safety zones. Here, the fence isolates and guides movement, and the safety zones offer an added layer of protection. The controls collectively form a system that mitigates multiple risks.

This highlights the need for an iterative, holistic evaluation process ensuring controls are fit for their purposes and synergistically effective when deployed in concert.

Existing international guidance provides foundational physical control measures for VRU risk management, a range of which are explored below in alphabetical order.

Accommodation of Bus Stops [25]

Some guidance and literature emphasise the importance of accommodating bus or transit stops. MNDOT (2021b) suggests that transit stops should be maintained or relocated, with the latter requiring coordination with the transit agency to ensure accessibility. VDOT (2016)further elaborates that if work activities displace transit stops, a proper diversion path or relocation should be established, possibly requiring flaggers [26] to assist pedestrians. Shaw and Oneyear (2021) indicate that pedestrian nonconformance often occurs near transit stops, suggesting additional studies and practical solutions to manage conflicts between pedestrians, buses, and other motorised traffic.

Advanced Technologies

The use of advanced technologies to assist with enhanced safety for VRUs in TTM is explored briefly by Mazumder et al. (2017), who explore using Bluetooth technology to warn users as they approach work zones. No other guidance explores this topic; however, technological advancements may add safety value in these environments in future.

[25] In many examples these are referred to as Transit Stops
[26] U.S term for manual traffic controllers, or those who typically operate stop/go paddles for TTM.

Advanced Warning and Signage

Advanced warning serves to notify pedestrians and other VRUs of upcoming changes in their travel environment, allowing them time to adjust their behaviour accordingly (Caltrans, 2017; ODOT, 2023a). Morgan et al. (2010) highlight the importance of forward signage as a significant contributor to potential safety, allowing drivers to make lane changes in a more controlled manner.

The purpose of advanced warning is not just to inform but to guide behaviour to minimise risk. It serves as a preemptive measure to prepare VRUs for what they are about to encounter, thereby reducing the likelihood of accidents or conflicts (Varhelyi et al., 2020). General signage, on the other hand, serves a more comprehensive role than advanced warning. It provides ongoing guidance and regulatory information throughout the TTM environment (Morgan et al., 2010). ODOT (2018) guidelines focus on two essential components in signing a temporary pedestrian facility: Advance Notification, and Positive Guidance and continuity. VTrans (2018) stresses that signs should be clear, direct, and consistent throughout the work zone (Vermont, 2018) but not saturating to confuse (Weekley et al., 2013).

Some international signage approaches demonstrate messages not found in NZ, such as in Figure 34. Such messaging is valuable concerning the safety of VRUs, especially when vehicular traffic and cyclists are asked to co-exist. Signage can be more detailed and explanatory for VRUs due to their lower speed and closer proximity to the signs. Shaw and Oneyear (2021) argue that the graphic design of pedestrian signage can afford to be more complex than that of motor vehicles. They suggest that map-type signs and complex diagrams can be placed where pedestrians can safely stop to study the route (where alternate routes are used). This is

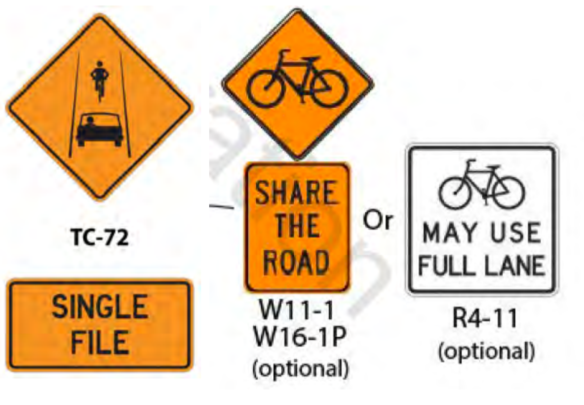


Figure 32 - Examples of US and Canadian signage without comparable NZ equivalents (Department of Public Works, 2023; WisDOT, 2019)

supported by Lee et al. (2021), who recommend signs with high visibility and superior design to reduce the disruption of pedestrian awareness. MNDOT (2021b) provides an example of this approach (Figure 33).

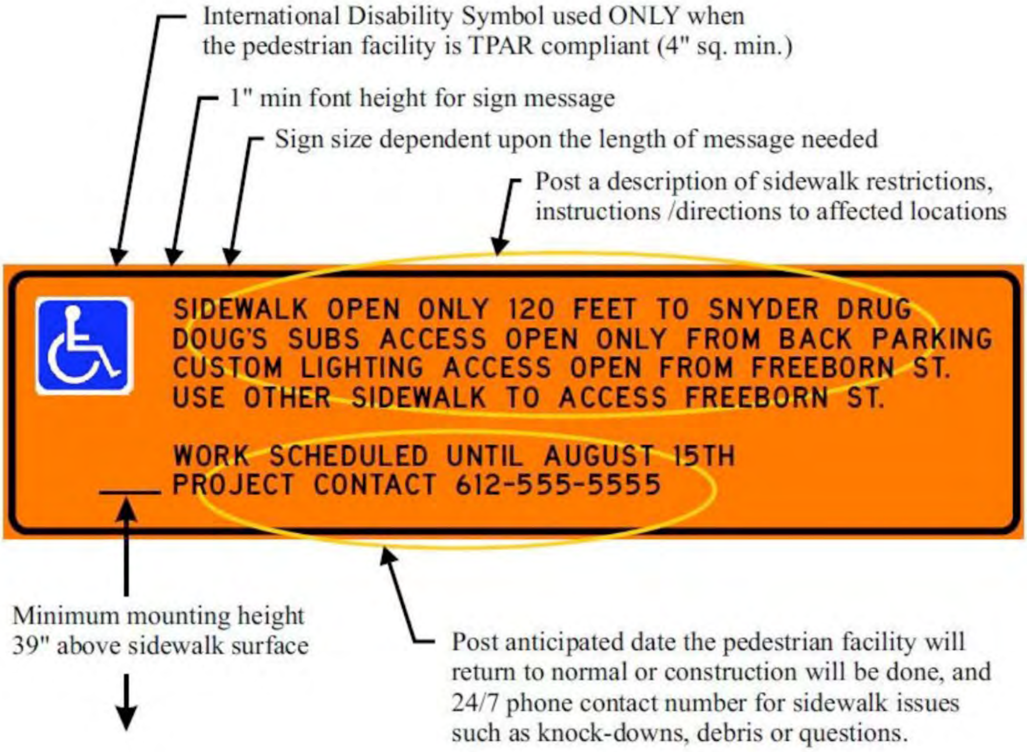


Figure 33 - Example informational pedestrian signage (MNDOT, 2021b)

A finding of Niska and Eriksson (2014) relates to the visibility of signs in low light conditions where they highlight that standard reflectivity on traffic signs is designed around vehicle headlights – and cyclists' lighting is usually insufficient to afford them with comparable visibility of signs where they are placed for VRUs. This further reinforces the case for good temporary lighting where VRUs are involved.

Across international guidelines, there is a common emphasis on using standardised signage catalogues to ensure consistency in messaging and user experience. In New Zealand, this standardisation is provided by the obligatory Traffic Control Devices (TCD) Rule 2004. The CoPTTM in New Zealand also provides specific guidelines for using that signage for temporary paths and detours (Waka Kotahi, 2019a). With the advent of the NZGTTM, this CoPTTM guidance will disappear, meaning good practice guidance relating to this topic will have to fill that void.

Audible Messaging

Audible messaging is an underutilised control in New Zealand's TTM contexts, both in guidance and practice. Notably practical for visually impaired users, this control also holds broader applicability as a mechanism for encouraging compliance with controls requiring public adherence. Caltrans (2020) advocates for audible information devices for informing pedestrians with visual disabilities about sidewalk closures, operational through motion sensors or push buttons. Echoing this, MNDOT (2021b) and NHDOT (2022) propose the use of Audible Message Devices (AMDs) during pedestrian detours, except when pedestrian channelisers suffice. For messaging content, Shaw and Oneyear (2021) underscore the need for clear, simple wording, targeting key details like initial turning instructions and block-based distance measures. Adding a technological facet, Liao (2014) designed a prototype smartphone app to convey work zone information to visually impaired pedestrians audibly. In a broader context, Koorey et al. (2017) argue that voice messages surpass visual cues in efficacy, particularly in urban settings. Complementing this, the ATSSA (2012) offers an in-depth guide on AMD features, including weatherproofing and volume control. This collective body of work signals the rising acknowledgement of audible messaging as a pivotal control for enhancing VRU safety in TTM schemes, warranting its exploration within New Zealand’s unique TTM environment.

Communication with Public

Communication with the public serves as an administrative control to inform, engage, and guide road users. International guidelines stress the significance of pre-work notifications for the broad public, including schools and businesses, through diverse channels (Caltrans, 2017). MNDOT (2021a, 2021b) advocates explicitly for various offline and online tools and stresses the value of concise, visual formats, including maps and stakeholder engagement. NYDOT (2023) and ODOT (2023a) emphasise frequent public outreach and public involvement processes to tailor solutions to community needs.

VTrans (2021) and WSDOT (2022) address the necessity of advance notice for bicycle detours and pedestrian access. Pyöräilykuntien Verkosto (2020) and Strnad et al. (2019) modernise communication by incorporating social media and real-time websites. Academically, Mazumder et al. (2017) endorse a diverse outreach campaign, while Puchades et al. (2018) argue for educational campaigns aimed at cyclists to alter risk perception and understanding of controls.

For future good practice in New Zealand, the communication strategy should be multifaceted, utilising both traditional and digital channels to effectively inform and engage the public. This should include clear and visual formats, regular public involvement, and specific outreach tailored to vulnerable road users.

Cone Bars

New Zealand’s utilisation of cone bars (Figure 34) is unique across international guidance, with no documented equivalent found across other literature.

Figure 34 - Cone Bar use for access prevention (New Zealand)

However, such a control for temporary prevention of access used with cones is not without issue. All US standards, under the American Disabilities Act 1990, stipulate a required detectible bottom edge to accommodate for cane use by visually impaired persons. Some standards go as far as to stipulate such a requirement in other cases, such as around sign placements, as shown in Figure 37. Cone bars, whilst contained with the CoPTTM as a control measure and heavily utilised across worksites in NZ (Waka Kotahi, 2019a), do not manage risk for visually impaired users. This risk is highlighted directly in CalDOT (2020), which prohibits using tape, rope, or plastic chains strung between devices for this very reason. This risk must be addressed for these cone bars to be considered good practice going forward.

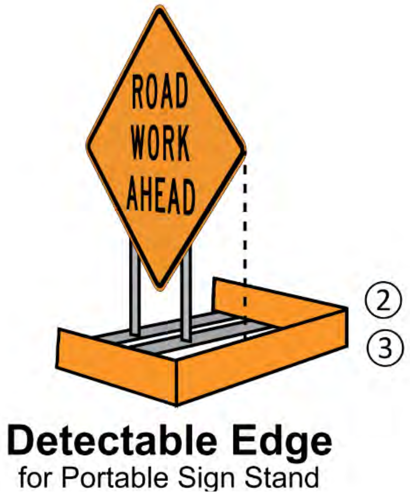


Figure 35 - Detectible edge around temporary sign (MNDOT, 2021a)

Detours of Vulnerable Road Users

The overarching consensus is that detours should be a last resort, employed only when accommodating VRUs within the work zone is unfeasible (British Columbia Ministry of Transportation and Infrastructure, 2020; Caltrans, 2010; MDOT, 2022). This preference stems from recognising that detours often have low compliance rates, especially when they deviate significantly from the original path (Shaw et al., 2016).

The planning of detours should be integrated into the initial stages of construction planning rather than being an afterthought (Shaw et al., 2016). Early planning allows for considering key detour route factors such as the suitability of surfaces and the route's capacity, including signalised crossing points that may require longer crossing phases (MNDOT, 2021b; VTrans, 2021). Detours should be as direct and safe as possible to minimise travel time and distance, and clear and concise signage is emphasised to guide VRUs effectively (MDOT, 2022; MNDOT, 2021a).

The psychological component of detours is significant; the longer the detour and the more it deviates from the original path, the lower the compliance (Shaw et al., 2016). This is highlighted in Niska and Eriksson (2014) with a case study example (Figure 36) showing a detour example that generated low compliance.

Figure 36 - Low compliance detour example (Niska & Eriksson, 2014)

This is corroborated by studies indicating that cyclists and pedestrians are sensitive to detour lengths and are likely to ignore them if they are too circuitous (Niska & Eriksson, 2014; Shaw & Oneyear, 2021).

Moreover, detours should be designed to maintain or even improve the quality of the original route. This includes considerations for surface material, facility width, and signalised crossings (MNDOT, 2021b; TRVK, 2019). In cases where detours are unavoidable, they should be well-marked, safe, and efficient, with graded ramps meeting accessibility requirements (NYDOT, 2023; VTrans, 2021).

Cyclists to Dismount

The British Columbia Ministry of Transportation and Infrastructure (2020) suggests that requiring cyclists to dismount should be avoided when possible and only considered if the reason for dismounting is immediately apparent. The manual also stipulates that cyclists should not be expected to walk for more than 50 meters. Similarly, NYDOT (2023) guidelines advise instructing cyclists to dismount and use pedestrian routes only in extreme circumstances where roadway widths are insufficient or construction conditions make cycling hazardous. MTO (2022) echoes this sentiment, stating that instructing cyclists to dismount for short distances may be more beneficial than providing a detour.

Academic literature also provides insights into the effectiveness of such measures. A study by Essa et al. (2018) found that compliance with bike dismount signs increased from 17% to 36% after their placement, but it is worth noting that only 36% of cyclists complied with the sign in a shared space section.

Given these findings, future good practice should consider the *cyclists to dismount* instruction as a last resort, to be used only when the rationale is clear, alternative routes are impractical or unsafe, and compliance with such an instruction is likely to be low (introducing another risk that the control chosen will not be effective). The measure should be applied for short distances to ensure compliance and effectiveness. Furthermore, the reason for the dismount instruction should be immediately apparent to cyclists to encourage compliance.

Escorting VRUs, VRU controllers, or Temporary Removal of Hazards

Using Traffic Control Persons (TCPs) is a common practice in Canada, specifically in British Columbia, to manage vehicular and pedestrian traffic within work zones (British Columbia Ministry of Transportation and Infrastructure, 2020). VTrans (2021) guidelines allow for the assignment of a Pedestrian Escort to assist pedestrians through the work zone when other alternatives are infeasible. In Australia, traffic management workers are recommended to direct pedestrians to appropriate crossing points when permanent controls are not in place (Austroads, 2021). NZ’s CoPTTM includes the most extensive outline of the role of a Footpath Controller, which includes guiding pedestrians and managing other road users (Waka Kotahi, 2019a). Academic literature also suggests the temporary removal of work operations to allow pedestrians to pass through (Shaw &

Oneyear, 2021), which is advantageous where the hazards are somewhat transient. This aligns with the philosophy of disrupting VRUs' original route as little as possible. Furthermore, the Americans with Disabilities Act 1990 guidelines recommend providing a guide in advance to assist disabled or impaired persons (ATSSA, 2021).

For future good practice, the temporary removal or pausing of hazards, such as ceasing tree pruning momentarily to allow VRUs to pass through, should be considered early as it involves maintenance of existing facilities and aligns with the elimination (or at the very least, substitution) layer of the hierarchy of controls. The role of footpath controllers should be clearly defined, including their responsibilities and sufficient training. The use of VRU escorts or guides, particularly for disabled or impaired individuals, should be considered.

Fencing

A nuanced understanding of fencing and barriers is imperative. Barriers are engineered to capture or redirect errant vehicles, whereas fencing aims to deter unauthorised entry (NYDOT, 2023; Waka Kotahi, 2019a), not serving as a re-directive barrier (AT20).

Fencing is emphasised in international guidance and academic literature for its role in delineating work areas and safeguarding both the public and the work zone (British Columbia Ministry of Transportation and Infrastructure, 2020). The utility of fencing goes beyond demarcating space; ODOT (2023a) describe Pedestrian Channelising Devices (PCDs) as interconnected systems directing pedestrians through work zones.

The geographical variance in fencing utilization is noteworthy. Shaw and Oneyear (2021) document a more widespread application of fences to segregate pedestrians from work areas in Europe and Australasia, even specifying strength requirements for fences adjacent to deep excavations. ODOT (2018) and the Government of Ireland (2009) recommend minimum heights for pedestrian fences at 1.0m and 1.2m, respectively. An empirical investigation by Niska et al. (2022) highlights the need for fences higher than 1.1m to prevent rollovers. Additionally, sufficient anchoring or deflection space for the fencing is vital for cyclist safety.

The material choice for fencing diverges based on jurisdictional requirements. While ODOT (2018) prefers lightweight polyethylene, Shaw et al. (2018) cite the use of 4-foot-tall metal fences in European work zones.

Figure 37 - Temporary fencing example with detectible bottom rail (WisDOT, 2019)

Caltrans (2010) and VTrans (2018) underscore the necessity for detectable bottom and top rails for visually impaired individuals, which aligns with regulations from the Americans with Disabilities Act of 1990 and the Manual for Uniform Traffic Control Devices (FHWA, 2023) (Figure 37). Such exploration of accessibility features is overlooked in current NZ guidance.

A summary of fencing characteristics consolidated from the international guidance is given below to inform future fencing standards in NZ good practice.

Characteristic	Dimensions/Stipulations
Height of Bottom Rail	No higher than 2 inches (50.8mm) above the ground surface (Caltrans, 2020; Shaw et al., 2023; VDOT, 2016; VTrans, 2021).
Height of Top Rail	Ranging from 0.6m (cycling only) (MTO, 2022), to at least 32 inches (812.8mm) (Caltrans, 2020),

	to 1.0m (Austroads, 2021; MTO, 2022; Shaw et al., 2023; VDOT, 2016; VTrans, 2021) to 1.1m (Niska et al., 2022) to 1.2m (Government of Ireland, 2009; Waka Kotahi, 2019a).
Detectable Edging	Must be continuous, with a minimum width of 6 inches (Americans with Disabilities Act 1990).
Ballast Location	Behind or internal to the device (Government of Ireland, 2009; VDOT, 2016; VTrans, 2018).
Drainage	An opening with a maximum height of 2 inches (50.8mm) above the walkway surface (Government of Ireland, 2009; VDOT, 2016; VTrans, 2018).
Hand Guidance	Top surface in a vertical plane perpendicular to the walkway with a continuous height of 32-38 inches (812.8 – 965.2mm) (VDOT, 2016; VTrans, 2018)
Interlocking	Devices should interlock to prevent gaps between devices (VDOT, 2016; VTrans, 2018; Waka Kotahi, 2019a)
Infil	Lattice filling (FSGV, 2021) or in NZ, gaps of no bigger than 100mm (Waka Kotahi, 2019a)

Table 19 - Consolidation of fencing characteristics from international standards

The international guidance and literature on the use of fencing in TTM for VRUs underscore its role in separating work areas, preventing access, and channelising users. Future guidelines should continue distinguishing between fencing and barriers to avoid confusion and provide preferred, minimum dimensional, and design stipulations.

Kerb Ramps

Kerb ramps facilitate smooth transitions between differing vertical levels, mainly when regular pathways are obstructed (Shaw & Oneyear, 2021). These ramps are a mainstay in U.S. guidelines due to Americans with Disabilities Act 1990 requirements, as reflected in widely adopted examples like Oregon's Figure 38 pedestrian ramp. ODOT (2018) (Figure 38) and MNDOT (2021a) (Figure 39, Figure 40) offer a particularly digestible representation of these standards.

Figure 38 - Temporary pedestrian ramp example (ODOT, 2018)

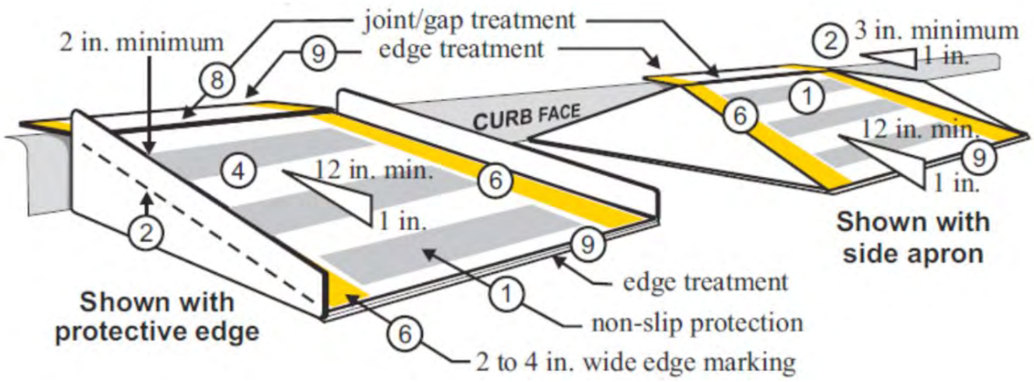


Figure 39 - Kerb Ramp design graphic 1 (MNDOT, 2021b)

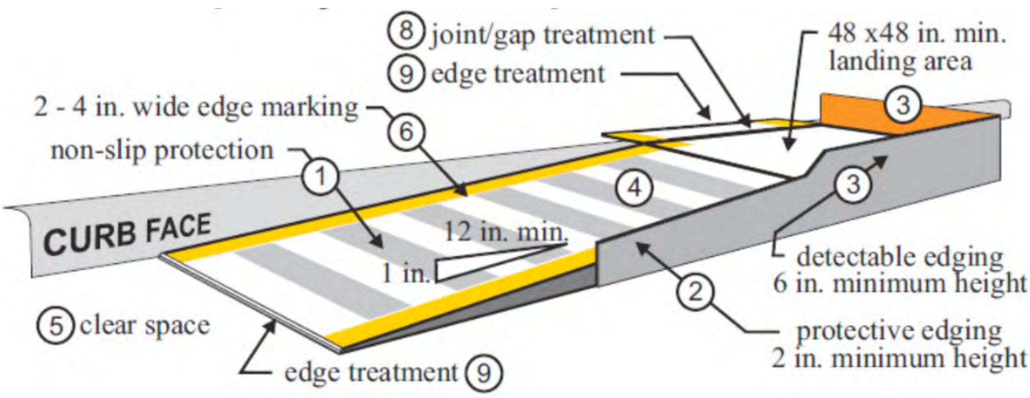


Figure 40 - Kerb Ramp design graphic 2 (MNDOT, 2021b)

Width is a variable aspect in international standards. While U.S. states such as MDOT (2022) and MNDOT (2021b) suggest a minimum width of 4 feet (1.22m), Austroads (2021) advocates for a broader minimum of 1.8 meters. The unifying theme is providing ample space for all pedestrians, including those using mobility aids.

Regarding the gradient, a maximum slope of 1:12 is predominantly endorsed; however, minor exceptions are allowed for shorter rises. For instance, Caltrans (2010) permits slopes between 1:10 and 1:12 for a rise not exceeding 6 inches. Shaw and Oneyear (2021) pose the viability of steeper slopes, up to 1:8, under temporary conditions provided that high-friction surface treatments are employed.

The choice of surface material is also pivotal for accessibility, calling for a firm, stable, and non-slip texture. Among the recommended materials are concrete, bituminous, steel, rubber, and wood. Particular attention should be paid to skid resistance, especially on steep ramps (Shaw et al., 2023). Shaw and Oneyear (2021) extend the discussion on surfacing options without undermining these fundamental principles.

Ancillary features such as edge protection, handrails, and detectable warning surfaces are frequently advised for enhanced safety. Specifically, a minimum edge protection of 2 inches (50.8mm) is suggested to avert wheel run-off, and handrails are endorsed for rises over 6 inches. Detectable warning surfaces are also mentioned for the ends of ramps.

Future NZ good practice should prioritise the following: minimum ramp width of 4 feet (1.2 meters), a generally accepted maximum slope of 1:12 with allowances for specific conditions, the utilisation of firm and non-slip surface materials, and the inclusion of additional safety features like edge protection and handrails.

Lighting

Lighting in TTM serves a dual purpose: as a control measure to enhance the safe navigation of VRUs through complex roadwork environments and is a potential hazard if poorly implemented. Strategic deployment of temporary lighting is essential where its absence poses safety risks. NZ's CoPTTM guidelines require adequate illumination for pedestrian and cyclist detours (Waka Kotahi, 2019a) but face practical challenges such as theft of amber flashing warning lamps (E. Mitrova, personal communication, 21 August 2023). Complementing these are international guidelines. MDOT (2022), for example, notes that adequate lighting contributes to pedestrian safety by ensuring visibility and personal security. Similarly, ODOT (2018) and WisDOT (2019) dictate that any existing lighting removal should be supplemented by temporary plans that meet or exceed previous illumination levels.

Special attention should also be given to lighting forms. Balloon lighting, often recommended for its ability to mitigate glare, is mentioned by MDOT (2022) and ODOT (2018). This is corroborated by academic research, such as that of Shaw et al. (2016), highlighting the risk of glare from poor lighting implementations. Shaw et al. (2023) further cite a Canadian study revealing the vulnerability of cyclists and pedestrians to low-light conditions, reinforcing the critical role lighting plays in TTM.

Future good practice should prioritise the individual and collective efficacy of lighting controls. This involves strategically deploying adequate lighting and integrating temporary, glare-minimising forms, especially where existing lighting is inadequate.

Road Marking or Tape

MoDOT (2020) endorse temporary pavement markings for crosswalks to ensure pedestrian accessibility, emphasising a conventional (but temporarily installed) approach to road markings as control measures. Contrarily, Shaw et al. (2023) warn against relying solely on tape for demarcating hazardous areas, advocating its use in less perilous contexts. On the innovative front, the ATSSA (2020) discusses the potential of varied coloured and high-contrast markings to effectively guide different categories of VRUs, although they note the lack of utility for long-cane users. The distilled conclusion for future NZ good practice is the judicious application of temporary road markings and tape, emphasising high-contrast colours for visual effectiveness while refraining from their isolated use in high-risk scenarios.

Safety Zones

Safety zones, referred to as exclusion zones in the newly published NZGTTM, are designed to provide a buffer space for human error, reducing the likelihood of VRUs coming into direct contact with hazards (Ullman et al., 2011). For instance, Austroads (2021)specifies a minimum clearance of 1.2 meters from plastic mesh fencing to the nearest traffic lane for speeds up to 60 km/h.

In NZ, lateral safety zones are already extensively used, particularly for separating road users and VRUs where they are adjacent (Waka Kotahi, 2019a). Department for Transport (UK) (2023) also states that safety zones are necessary when diverting the footway into the carriageway. However, the utility of safety zones is not confined to this specific use case. For example, TRVK (2019) stipulates that a shut-off device must be placed at least 2 meters before a shaft, and Ireland's guidelines advocate for a buffer zone between pedestrians or cyclists and the work area. These examples indicate that safety zones between worksite hazards and VRUs are also critical (currently, New Zealand's guidance does not necessitate this).

Future good practices should continue to incorporate these zones, be adaptable to various hazards, and be designed considering the dynamic nature of road user behaviour.

Sharing the Road

Sharing the Road is a methodology that emerges as a last resort when spatial constraints preclude the provision of segregated pathways for vulnerable road users (VRUs) and vehicular traffic (Austroads, 2021; MNDOT, 2021b; TfL, 2018; VTrans, 2018). International guidelines and literature offer various stipulations for implementing this approach, often focusing on speed limits, lane widths, and traffic volumes.

MNDOT (2021b) guidelines specify that merging bicyclists into mixed traffic should only be considered where the speed limit is 25 MPH (40km/h) or less, and traffic volumes are below 3,000 AADT[27]. VTrans (2018) sets these limitations at 20 MPH (32 km/h) and

[27] Annual Average Daily Traffic. A general measure for the traffic volume on a road (although this is an annual average so daily and hourly actual volumes may vary significantly).

2,000 AADT. British Columbia Ministry of Transportation and Infrastructure (2020) suggests that a temporary shared lane may be created only in low-speed environments (≤ 60 km/h). NZ’s CoPTTM specifies that a 30 km/h temporary speed limit (TSL) must be used before a merge to alert motorists when cyclists are integrated into the traffic lane (Waka Kotahi, 2019a).

NYDOT (2023) guidelines echo the importance of engineering judgment, emphasising a lane width requirement of at least 12 feet (3.66m) where cyclists and vehicles share space. In the academic realm, Puchades et al. (2018) highlight that avoiding mixed traffic can be a strategy to cope with perceived risk, indicating that the s*hare-the-road* methodology is less preferred due to the introduction of additional risks.

If a *share-the-road* methodology is employed, information to users about the presence of VRUs is crucial. British Columbia Ministry of Transportation and Infrastructure (2020), for example, advises using *Share the Road* signs where such a methodology is employed, whereas ODOT (2018) uses *Bicycles on Roadway* signs when bike lanes or sidewalks are closed due to construction. This use of signage is particularly relevant for New Zealand, which currently lacks specific signage indicating the sharing of road space between VRUs and vehicles, although it does have permanent signage for shared spaces among VRUs.

Given the inherent risks associated with the *Share the Road* methodology, this approach must be deployed judiciously and in contexts where it is necessary due to spatial constraints. When employed, it should be accompanied by robust signage and as close to speed parity as possible to minimise the consequences of interactions if they were to happen.

Shuttle Transport

Internationally, shuttle services for VRUs in TTM contexts are generally a last-resort measure. They come into play when constructing temporary walkways is impracticable, such as during bridge replacements (NYDOT, 2023). ODOT (2023a) stipulates these services as a special-case solution for unavailable pedestrian routes leading to significant detours. Capacity considerations indicate that shuttles should accommodate at least two

ADA passengers in powered chairs and a maximum of ten non-disabled individuals. WisDOT's (2019) policy aligns with ODOT (2023a), advising on-site shuttles for high pedestrian volumes and on-call services for low volumes. Austroads (2021), too, entertains shuttle services, particularly for rural roads where VRUs need assistance traversing the construction site. Furthermore, Shaw et al. (2023) suggest that local public transit systems might, in certain circumstances, provide a cost-effective and practical alternative for circumnavigating closures.

For future NZ good practices, shuttle transport should be positioned as a last resort due to the accompanying time and compliance challenges.

Speed Limits and Enforcement

Speed management for vehicular road users in TTM environments is a critical control measure for ensuring the safety of adjacent VRUs (MNDOT, 2018, 2021a; MTO, 2022; Shaw et al., 2016). Extensive research highlights the relationship between speed and consequences concerning VRU safety (Corben et al., 2006; Corben & Healy, 2015; Islam, 2023; Tanishita et al., 2023).

The Advanced Research on Road Work Zone Safety (ARROWS) Project underscores the importance of setting the right 'expectations' for drivers approaching work zones, including appropriate speed limits (National Technical University of Athens, 1998).

The Appropriate Spoeeds for All People (ASAP) Project canvassed 22 territories across Europe, Australia, Canada and the United States to explore the parameters for assigning temporary speed limits in TTM environments. VRU presence or risks were not any of the parameters listed, and only 13 of the 22 listed some condition related to VRU-like characteristics (i.e. workers on foot or proximity of workers to traffic) (Thomson et al., 2014). This highlights that neither the original standards consider VRU presence as a substantial parameter for vehicle speed management in TTM environments, nor was this highlighted in the research itself.

Speed management for VRUs themselves, particularly cyclists, is another crucial aspect. Niska and Eriksson (2014) discuss using chicanes to manage cyclists' speed (Figure 41), although the effectiveness of current barriers in speed reduction is questioned.

Figure 41 - Example of cyclist speed reduction chicane (Niska & Eriksson, 2014)

Enforcement is a critical component in ensuring compliance with speed limits. WisDOT (2019)state that visible law enforcement decreases speeds and increases driver attentiveness. The Students Acting to Reduce Speed (STARs) project (Europe) notes that drivers are unlikely to modify their speed without the risk of enforcement or penalty, advocating for continuous enforcement mechanisms like speed cameras over spot checks (Weekley et al., 2013).

Given the evidence, future good practice should incorporate speed management strategies that explicitly account for VRU presence and risks. The absence of such considerations in the ASAP project's findings indicates a need for international guidelines to evolve. Speed management should not be limited to vehicular road users but should also extend to VRUs, with mechanisms like chicanes for cyclists being explored further for efficacy. Lastly, enforcement strategies should be data-driven, targeting hot spots and periods where law enforcement would most effectively ensure compliance with speed limits.

Tactile Pavers

Tactile pavers, often referred to as Temporary Detectable Warning Surfaces (TDWS) or Tactile Ground Surface Indicators (TGSI), serve a critical function in alerting visually impaired pedestrians to changes in their walking path, particularly at intersections where pedestrian routes cross vehicular traffic(Koorey et al., 2017; MNDOT, 2021b). These surfaces are commonly implemented in rubber, vinyl tiles, ceramic tiles, concrete paving blocks, and metals like cast iron and stainless steel (Shaw et al., 2023).

Shaw et al. (2023) recommend using tactile pavers in temporary pedestrian conditions lasting 48 hours or more, emphasising their necessity when the existing route already incorporates such features. For shorter durations, particularly in high-traffic pedestrian areas or near facilities accommodating the visually impaired, portable ramps with anti-skid surfaces or detectable treatments are strongly advised. In the context of rail crossings, TGSI devices are specified to guide visually impaired users on where to stand clear of the rail corridor and the orientation of the crossing path (Koorey et al., 2017)

For future good practice, implementing tactile pavers should be considered not just an optional feature but a necessary component for ensuring the safety and navigability of visually impaired road users.

Temporary Walkway Bridges

Temporary walkway bridges are an option for maintaining the continuity of pedestrian and bicycle pathways. These structures are particularly beneficial for crossing excavated areas, trenches, or other zones with uneven or unstable surfaces (Mazumder et al., 2017; Shaw et al., 2023), as shown in Figure 42. The need for such bridges is accentuated when the occupied area is extensive, and the volume of pedestrian traffic is high (Mazumder et al., 2017). Such an option could be preferential to a detour due to the lower level of compliance with alternative routes.

Figure 42 - Temporary walkway bridge example(ODOT, 2018)

Bridges should be robust, stable, and free from structural defects such as cracks or holes (Mazumder et al., 2017). Bridges should have wheelchair-accessible entrance and exit ramps (ODOT 2018). Shaw et al. (2023) provide specific guidelines on the minimum width requirements for these temporary structures, which mirror other diverted pathways (48-60 inches (1.22m – 1.52m)), although bridge widths of up to 96 inches (2.44m) are suggested where there are high volumes.

NZ’s guidance does not currently guide temporary walkway bridges, although some products are publically available. For their general utility, such bridges should be included in good practice to diversify the options considered by those planning TTM measures for VRUs.

Temporary Crossings

Temporary crossings for vulnerable road users (VRUs) necessitate a multifaceted approach for adequate safety. International norms offer varied insights. Vermont's guidelines call for standard accessible features like pushbuttons in temporary pedestrian signals and adjusted walk-phase timing for slower walkers. ODOT (2023a) stresses that if permanent installations have pedestrian signal heads, their temporary counterparts should, too. This aligns with NZ's CoPTTM, which sets visibility standards at temporary crossings (Waka Kotahi, 2019a). Australia mandates that temporary crossings maintain the functionalities of their permanent predecessors and accommodate diverse needs. The Government of Ireland (2009) posits high pedestrian and cyclist traffic could warrant retaining or adding temporary signal points.

Academic discourse enriches these considerations. Berghoefer et al. (2023) argue for the effectiveness of speed bumps at junctions, although NZ's CoPTTM guidance cautions their risk to cyclists (Waka Kotahi, 2019a). Mazumder et al. (2017) elaborate on marking and managing temporary crosswalks, including traffic control devices and flaggers for motorised traffic management. Soathong et al. (2019) highlight road crossings as a principal factor in pedestrian crashes, accentuating the need for meticulous design in temporary installations.

Future good practices should adopt a nuanced, safety-focused approach to temporary crossings for VRUs to align with emerging international best practices and academic findings. This could encompass adjustable walk-phase timing, sightline maintenance, and contingency for high-traffic areas. Importantly, these measures should be tailored to local risk profiles, accommodating the community's unique needs and various types of road users.

Temporary Cycleways

Where cyclists cannot maintain their existing route(s) – a temporarily diverted path (but not a detour) is an option presented across most international guidance. The NZ CoPTTM stipulates that the minimum width for a temporary cycle lane varies depending on the speed limit. For instance, a single-directional cycle lane should be 1.0m wide if the speed limit does not exceed 50km/h and 1.5m if it does. For two-way cycle lanes, the width should be 2.0m or 2.2m, depending on the speed limit. Notably, a minimum lane width of 1.5m is required for uphill lanes, as cyclists tend to move from side to side while climbing (Waka Kotahi, 2019a).

A comparison of international requirements for temporary cycleways is shown in Table 19.

Cycleway Type	Selection of Territories	Stipulated Temporary Cycle Width Requirement
Single direction cycleway	Lithuania	0.8m without oncoming traffic (LRA, 2012)
	Denmark	1.0m for one-way (vejdirektoratet, 2020)
	New Zealand	**1.0m for a speed limit of ≤50km/h** **1.5m for a speed limit of >50km/h (Waka Kotahi, 2019a).**
	Canada (Ontario)	1.2m between painted lines (MTO, 2022)
	Denmark Ireland	1.2m minimum (Government of Ireland, 2009; vejdirektoratet, 2020)
	Germany	1.5m (1.3m for short bottlenecks) (FSGV, 2021)
	Ireland	1.5m desirable (Government of Ireland, 2009)
	Canada (Ontario)	1.5m between physical barriers (MTO, 2022)
	Sweden	2.1m minimum in exceptional cases (SALAR, 2019)
Two-way cycleway	Denmark	1.7m for two-way (vejdirektoratet, 2020)
	New Zealand	**2.0m for a two-way cycle lane (Waka Kotahi, 2019a).**
Shared facility [28]	Denmark	1.5m for shared (vejdirektoratet, 2020)
	Lithuania	1.6m for total pedestrian and bicycle path (LRA, 2012)
	New Zealand	**2.2m for shared footpaths and cycleways (Waka Kotahi, 2019a).**
	Canada (Ontario)	3.0m for multi-use paths (MTO, 2022)
	Ireland	3.0m for shared facility (Government of Ireland, 2009)
	Sweden	3.05m for two bikes in width (SALAR, 2019)

Table 20 - Temporary cycleway dimensional requirements from international standards

[28] In some cases shared facilities are clearly indicates as shared between cyclists and pedestrians, but in other cases the guidance language is ambiguous to whether the reference is to shared multi-modal users or shared between bi-directional cyclists.

The international guidelines generally align with New Zealand's standards, with most temporary cycleway requirements being consistent, such as surfacing requirements, level differences, visibility expectations and signage. Some additional expectations can be collated, such as the lateral shift requirements when deviating cyclists should be no more than 6:1[29] (MTO, 2022), and deviations should be longitudinally clear of hazards by at least 2 metres (Niska & Eriksson, 2014).

A key finding to be carried through to future good practice is that the presentation of *minimum widths* often occurs first. This is philosophically incongruent with the Health and Safety Act 2015, which demands the best possible level of risk management rather than the gravitation to a minimum standard. The presence of the minimum standard should not be presented first, but a preferred width (and secondly, the potential use for minimums).

Temporary Walkways

Providing temporary walkways for people on foot is necessary when regular routes are disrupted (Shaw et al., 2023). Such temporary walkways may use adjacent spaces (to the permanent walkway) such as berms or may need to be directed into the carriageway into a segregated space.

All international guidance provides for temporary walkways as this methodology is universal across TTM settings as required to maintain the continuity of routes for people on foot as best as possible. Most guidance provides stipulations regarding temporary walkway widths summarised from a range of jurisdictions in Table 20.

Width	Territory
1.0m	Lithuania (LRA, 2012)
1.22m minimum 1.52m desirable	All US territories (U.S Access Board, 2023)
0.9m in some circumstances 1.2m minimum	**New Zealand (Waka Kotahi, 2019a)**

[29] Six longditudinal metres for every one lateral metre of shift.

1.3m	Germany (FSGV, 2021)
1.5m	Sweden (SALAR, 2019) United Kingdom (Department for Transport (UK), 2023)
1.8m	Australia (Austroads, 2021) Canada (Department of Transportation & Works, 2018; Manitoba Infrastructure and Transportation, 2015; New Brunswick Transportation and Infrastructure, 2021; Transportation and Economic Corridors, 2020) Ireland (Government of Ireland, 2009)

Table 21 - Temporary walkway widths from international guidance

Additional guidance is given, particularly in the United States, regarding long stretches of constrained widths requiring passing spaces every 200 feet (61m) (Figure 43) (Shaw & Oneyear, 2021).

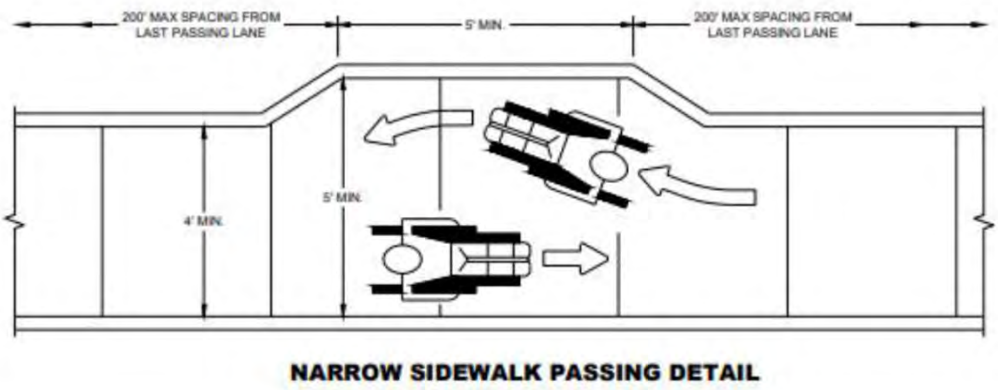


Figure 43 - Example passing detail for temporary walkways (Shaw & Oneyear, 2021)

Temporary walkways have several other considerations, such as surfacing, separation from adjacent hazards, and ramps, which are all covered separately in this research. A selection of additional guidelines minimally explored in NZ practice are below:

- The quality of the walking surface is a critical factor. Guidelines often recommend that the surface be firm, stable, and slip-resistant (MNDOT, 2021b; ODOT, 2018).
- The cross-slope should not exceed certain limits, often set at 2% (MDOT, 2022; MNDOT, 2021b).

Trench Covers

The topic of trench covers in the context of TTM is scarcely addressed in the literature. However, Shaw et al. (2023) provide some guidance on using temporary covers and footplates for work operations that involve trenching or similar hazards. These temporary covers are designed to prevent injuries to pedestrians, workers, and cyclists. The guidelines recommend using a textured surface treatment or a non-slip coating; the covers should be slip-resistant, even when wet. If these covers are to remain in place for an extended period, such as overnight, and are subject to parallel vehicular traffic, anchoring them to the pavement is advised. Furthermore, the structural integrity of the trench should be assessed before installing any foot or road plate to ensure that the ground conditions are sound (Shaw et al., 2023).

Temporary Road Safety Barrier System (TRSBS)

Temporary Road Safety Barrier Systems (TRSBS) are primarily engineered to redirect or capture errant vehicles, serving as a mechanism to absorb crash energy (Shaw et al., 2023). They are not designed to prevent access but to minimise the distance an errant vehicle deviates from the travelled way (Shaw et al., 2023). In the context of VRUs, these barriers could provide positive separation between pedestrians and motorised traffic (MDOT, 2022); however, their use comes with specific considerations. For instance, the deflection zone behind the barrier must be accounted for (WisDOT, 2019).

It is essential to align the use of TRSB systems with their engineering purpose, which is to absorb crash energy and redirect errant vehicles. This involves careful planning to ensure sufficient space for barrier deflection. Barriers should be used with other TTM measures to create a holistic safety ecosystem for all road users.

Walkway Covering

International guidance and literature on covered walkways primarily focus on dimensions, material quality, and safety features. DDoT (2008) mandates a clear and unobstructed ceiling height and width of not less than 8 feet (2.44m), respectively, in

CBD areas and 6 feet (1.83m) in other areas (Figure 44). MNDOT (2021b) guidelines stipulate a seven-foot (2.13m) vertical clearance and recommend using warning tapes and sleeves on corner poles. ODOT (2023a) suggests that covered walkways should be well-lit for nighttime use, mainly when work activities occur above pedestrian pathways.

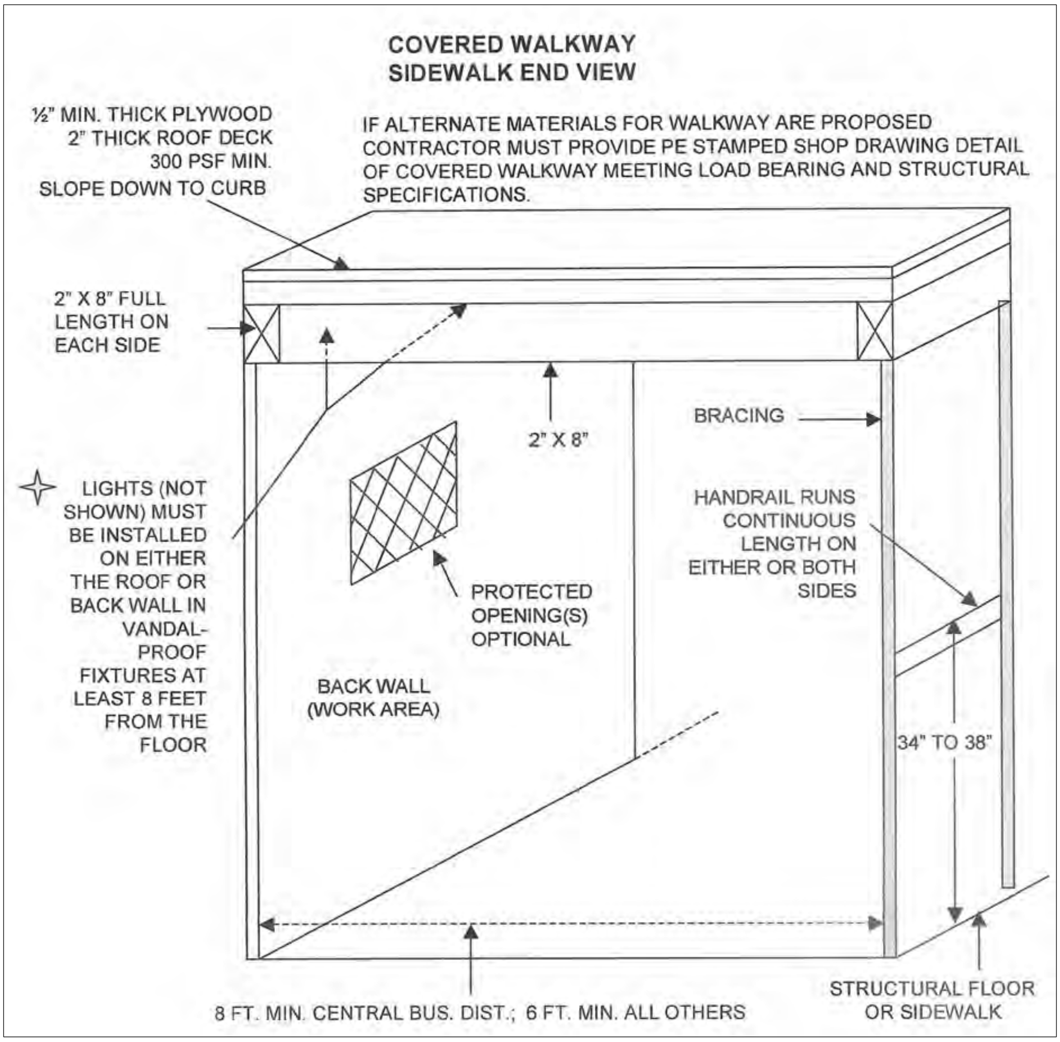


Figure 44 - Covered walkway standard example (DDoT, 2008)

WisDOT (2019) advises that the use of overhead protection should be an option of last resort, recommending detours for pedestrians away from overhead work, which somewhat conflicts with previous findings around detours being a last resort – although this order of preference is heavily contingent on the risk profile of the specific situation. ODOT (2023a) suggests the use of covered walkways for work carried out at 4.5 meters or less from a public walkway; however, height (in terms of clearance) is somewhat irrelevant if there is a risk of falling objects, then the resolution of that risk would be necessary regardless of the height at which that risk exists. Academic literature by Mazumder et al. (2017) provides more extensive guidelines, including solid material, adequate lighting, and safety features like nonslip surfaces and wire screens covering openings. Shaw et al. (2023) recommend a minimum width of four feet (1.22m) for covered walkways and five feet (1.52m) for covered bikeways.

Treatment of introduced risks

It is imperative to recognise that each control measure deployed to mitigate existing risks inherently introduces new dimensions of risk that require meticulous evaluation (Aven, 2016). For instance, installing temporary fencing adjacent to pedestrian walkways may inadvertently create hazards for cyclists or introduce tripping risks (Figure 45). This phenomenon underscores the necessity for a dynamic risk assessment process that continually adapts to the evolving landscape of hazards (TfL, 2018).

Figure 45 - Example of non-trip feet for temporary fencing (WisDOT, 2019)

Furthermore, the effectiveness of control measures is contingent upon competent personnel's correct understanding, deployment, and maintenance (Hopkins, 2011). This section will explore various mechanisms through which risks are introduced by deployed

TTM controls, as gleaned from the review of the included literature. The findings will be contextualised within the framework of potential integration into future NZ good practice guidelines.

Control Deterioration, variability, or redundancy

The literature highlights the dynamic nature of pedestrian networks, particularly in work zones, where temporary obstructions, detours, and surface irregularities can pose challenges for VRUs, including those with mobility or vision impairments (Lee et al., 2021). This variability in environments necessitates a continuous assessment of controls to ensure their efficacy over time.

Deterioration of controls is a critical concern. For instance, vandalism can compromise the integrity of controls, particularly in isolated locations (Koorey et al., 2017). This is covered by Shaw et al. (2023), who highlight that the choice of fencing considers its primary purpose (preventing access to hazards), security, particularly when unattended, and the risk of deterioration.

Redundancy in controls is equally problematic. The NZ CoPTTM states that equipment must not impede users when not in use, and redundant equipment must be stacked away from travelled paths (and for no longer than 48 hours without use) (Waka Kotahi, 2019a). Similarly, temporary road markings and barricades should not remain in place when they function poorly (Niska & Eriksson, 2014). Work Zone Safety Consortium (2018) further emphasises the need to remove obstacles from sidewalks or paths when workers are absent, underscoring the risk of redundant controls.

The very nature of controls in TTM is that they serve a specific and direct purpose. Worksites are dynamic, and as such, the continuous provision of unchanged controls has the risk that they become redundant in some way (and thus present clutter and risk themselves), or they deteriorate – and no longer function effectively in line with their original intent. Either way, installing physical controls in TTM to manage safety brings with it an obligation to ensure control efficacy after that.

Pathway capacity and standard, or new points of conflict or interaction

This topic concerns where VRUs are diverted to new routes, but the standard of those facilities is either inferior (to what they have come from) or includes new risks like new crossing points or hazards. Shaw et al. (2023) emphasise that the surfaces of temporary pedestrian and bicyclist facilities must always be firm, stable, and slip-resistant. This is particularly pertinent when existing walkways are expected to experience a significant increase in pedestrian traffic due to their use as designated detours. The authors further note that traffic signal timing should be adjusted to accommodate changes in pedestrian and bicyclist volumes at intersections and crossings that remain open during construction. Niska et al. (2022) argue that if the existing cycling infrastructure is substandard, it is unreasonable to expect that a construction site can offer better conditions for cyclists. This underscores the importance of maintaining, if not improving, the standard of facilities to which VRUs are diverted. TfL (2018) also stresses the need to focus on people walking or cycling around work sites to ensure they are not deterred by poor TTM, including through the use of substandard diversion routes (not just by distance but by quality).

Moreover, Shaw et al. (2023) discuss using tactile warning pavers to warn blind and visually impaired pedestrians approaching points of conflict with faster traffic. These detectable treatments should be used whenever a ramp or slope leads to a crosswalk or when visually impaired pedestrians must be alerted to cross-traffic, such as temporary driveways used by construction vehicles – especially new temporary crossing points. Such a provision (of temporary tactile pavers) is uncommon in New Zealand and not contained in any existing guidance.

International guidance and literature advocate for maintaining high standards in diversion routes and carefully treating new points of conflict – much more so than existing NZ guidance.

Loss or impact to access for properties

The deployment of TTM controls, particularly in areas interfacing with walkways and cycleways, can inadvertently impact access to adjacent properties and businesses. This phenomenon is not just a logistical inconvenience but constitutes a form of risk arising from the controls meant to manage other risks. Shaw and Oneyear (2021) highlight that while the United States Manual on Uniform Traffic Control Devices (MUTCD) provides methods for detouring pedestrians around sidewalk closures, these methods often prove unsatisfactory as they do not adequately consider access to homes and businesses in the affected area (FHWA, 2023). Similarly, Shaw et al. (2016) explicitly mention the loss of property access as a risk introduced by TTM controls.

International guidelines, such as from the British Columbia Ministry of Transportation and Infrastructure (2020), emphasise customising traffic control layouts to maintain access and mobility, particularly in urban settings characterised by frequent turns, cross-movements, and significant pedestrian movement. Caltrans (2010, 2020) underscores the importance of maintaining pedestrian access to businesses, residences, and transit stops. The DDoT (2008) and MDOT (2022) also stress the importance of maintaining access to properties and businesses.

Future good practices in NZ should focus on the iterative assessment and customisation of TTM controls to ensure they do not inadvertently restrict access to properties and businesses.

Sign Placement

Sign placement relates to the challenges posed by installing physical TTM signs, particularly their potential impacts on VRUs. While a necessary part of TTM, these signs can paradoxically become hazards. They may encroach upon space designated for VRUs, serve as trip hazards on footpaths, or even present hazards at head height that pedestrians may collide with, as shown in Figure 46 and Figure 47. International guidance does cover the subject well and is universally steadfast on the need for signs to be placed in a manner that does not compromise the safety or mobility of VRUs.

Figure 46 - TTM sign impacting VRUs 1

Figure 47 - TTM sign impacting VRUs 2

One of the recurring themes in the guidelines is the height and projection of signs into pedestrian pathways. For instance, California, Minnesota, and New Hampshire all stipulate that signs and devices mounted lower than 7 feet (2.1m) above the temporary pedestrian pathway should not project more than 4 inches (101mm) into accessible pedestrian facilities. This standard aims to prevent signs from becoming obstacles that VRUs might collide with (Caltrans, 2010; MNDOT, 2021b; NHDOT, 2022).

The concept of the *pedestrian box* explored by Shaw et al. (2023) (Figure 48) is particularly instructive. The PROWAG guidance specifies that a height of at least 80 inches (2.0m) should be clear of any obstacle, including signs. No intrusion greater than 4 inches (101mm) is allowed into this box, and no protrusions are permitted in the lower 27 inches (686mm) (U.S Access Board, 2023). This guidance is precise about acceptable methods for mounting signs in pedestrian areas, reducing the risk of collisions or trips.

Figure 48 - Depiction of the pedestrian box concept (Ashe, 2019)

ODOT (2023a) guidelines delve into the complexities of sign supports and mounting heights, cautioning against the placement of signs in locations designated for bicycle or pedestrian traffic. The guidelines also warn against mounting temporary pedestrian signs on barricades or fencing due to creating a pinch point or tripping hazard.

NZ's CoPTTM also addresses sign placement, stating that signs must not encroach on marked cycle lanes or footpaths unless it is safe. The guidelines recommend using delineation devices, such as cones, next to signs to indicate the extent of encroachment into cycle lanes or footpaths (Waka Kotahi, 2019a).

Site Access or Exit

The issue of site access and exit in TTM settings is complex, particularly concerning VRUs. The dynamic nature of worksites can necessitate frequent entry and exit of work vehicles, which can introduce new risks despite the controls in place. For instance, the tragic incident involving a cyclist in Christchurch, New Zealand, in 2019 underscores the gravity of this issue (Guildford & Kitchin, 2019). International guidelines offer some insights into managing these risks. NHDOT (2022) suggests that access across pedestrian walkways should be minimised, as it often leads to changes in grade and rough terrain, compelling pedestrians to attempt risky non-intersection crossings.

Similarly, MTO (2022) advises providing construction vehicle ingress/egress signs visible to pedestrians. These guidelines implicitly acknowledge that controls to manage site access and exit can inadvertently create new hazards, such as grade changes and visibility issues, particularly affecting VRUs. Whilst international literature is limited on this issue – it is an essential inclusion from a good practice perspective.

Visibility

Installing physical controls, such as barricades and construction equipment, can inadvertently obstruct sightlines, increasing the risk of incidents (Shaw et al., 2016). Such obstructions limit the ability of VRUs to navigate safely and increase the cognitive workload for all road users due to the added complexity in the visual field (Shaw et al., 2016).

Policy from Gatukontoret Malmö City is restrictive about blocking cycle lanes, acknowledging the high risk of cyclists running into barriers in the dark (Niska & Eriksson, 2014). Work Zone Safety Consortium (2018) also stresses the importance of maintaining good sightlines for pedestrians and motorists at intersections and crossings. Devices used to prohibit pedestrian access or provide protection from hazards should be designed and installed in a manner that does not impede visibility.

Considering the sight lines of VRUs should be a key consideration when arranging TTM so as not to introduce additional risk by placing controls that might block visibility.

Water pooling

Shaw and Oneyear (2021) emphasise the need to prevent water ponding due to inadequate drainage, highlighting the importance of proper surface design. Similarly, Shaw et al. (2023) underscore the necessity of careful attention to drainage, especially when temporary facilities involve the construction of entirely flat surfaces. They suggest the incorporation of grooves or drain holes to prevent rainwater from accumulating on the temporary surface. Furthermore, concerning pedestrian ramps, Shaw et al. (2023) indicate that depending on design, material, and location, it may be necessary to include a pipe or other means of carrying stormwater under the ramp.

Whilst not a significant emergent risk, nor one that features widely across lots of guidance, water pooling does deserve mention regarding the risk of TTM controls deployed within VRU environments.

CHAPTER 5: CONCLUSIONS, LIMITATIONS, AND FUTURE RESEARCH

Conclusions

The ethos of this research is rooted in the pressing need to address the challenges faced by VRUs in NZ TTM environments. As permanent VRU infrastructure increases alongside increased urbanisation – TTM environments become more complex (Elvik et al., 2009b), and the relentless pursuit of more active mode travel means TTM sites are challenged by higher volumes of more diverse VRUs with a broader spectrum of needs and heightened vulnerability (Woodcock et al., 2013; Wang et al., 2022; Čabarkapa, 2020; Yannis et al., 2020; Bennett et al., 2019). Add the impending shift to a less compliance-focused and more risk-based TTM system in New Zealand, and there is a chasm that needs to be addressed to protect VRUs in TTM environments, as they are being killed and seriously injured faster than ever before (Waka Kotahi, 2023a).

Effective TTM requires understanding engineering, psychology, law, and social constructs (Rahman et al., 2017; Yang et al., 2015) and a recognition of the dual focus on safety and road function, requiring an adept capability with risk management (Rista et al., 2017; FHWA, 2017; Strnad et al., 2019). It is no wonder that given the multi-disciplinary nature of effective VRU treatment in TTM, VRU safety is so often compromised, with data showing a disproportionate number of VRU accidents and a perpetual shortfall of safety for these users (Garrard et al., 2008; Waka Kotahi, 2023a; Thomas et al., 2023; Kiddle, 2023; Wood, 2023). There is a pressing need for comprehensive good practice in this area - a context-sensitive, adaptable standard that consistently yields superior results.

In this case, using an integrative review allows for the broad canvassing of any credible literature that can serve the formulation of good practice, including grey and academic literature and legislative instruments. Unsurprisingly, international literature serves as a vast lake of practices regarding VRUs in TTM; however, establishing a credible catchment is imperative. This led to the selection of OECD countries with similar democratic climates and Occupational Health and Safety (OHS) legislative foundations to New Zealand.

The legislative context is also foundational for TTM good practice, and this research identifies 33 distinct legislations with 104 unique provisions relevant to VRUs in TTM (New Zealand Parliamentary Counsel Office, 2023a). However, there is a lack of explicit guidelines for treating

VRUs in existing legislation, indicating a gap that needs to be addressed (Waka Kotahi, 2019a; 2023c, 2023d).

Several valuable models and frameworks are identified that can help inform a more structured approach to VRU TTM good practice in NZ. Among these, the *Layers of Expectations* framework (Hale & Swuste, 1998) and the Pla-n-Do-Check-Act (PDCA) are particularly relevant. The former provides a three-layered approach—outcome, process, and prescriptive expectations—that can guide decision-making and risk assessment in TTM (Viegas et al., 2020; Carden et al., 2020). The latter, a continuous improvement loop, aligns well with the workflow of TTM and offers an opportunity for detailed evaluation of safety measures for VRUs (Shaw & Oneyear, 2021; Mazumder et al., 2017).

Existing guidelines for TTM often lack the rigour needed to address the complexities of VRUs (Shaw et al., 2016). The scarcity of academic literature on the subject further exacerbates this gap (Shaw & Oneyear, 2021). Moreover, these guidelines frequently suffer from ambiguity and lack iterative improvements, making them less effective in practice (Demirkesen, 2020; Gidey et al., 2014). Therefore, clarity, specificity, and utility in guidelines are imperative for effective implementation in New Zealand's TTM environments.

The principles governing TTM and VRUs also warrant attention. While foundational principles like safety, mobility, and comprehensibility exist, they often lack contextual adaptation and are not easily digestible for practitioners. The Safe System approach and the Hierarchy of Controls (HoC) offer promising avenues for enriching TTM guidelines but are underutilised (TfL, 2019). The principle of *lowest total risk* aligns well with NZ's legislative frameworks but is not yet fully integrated into TTM practices.

Regarding VRUs, existing guidelines often lack specificity and actionable directives (Shaw & Oneyear, 2021; MNDOT, 2018). The treatment of VRUs should be part of a systemic approach that integrates with legislative frameworks, risk management, and training (WorkSafe NZ, 2022b). The high prevalence of impaired persons in New Zealand further necessitates special planning in TTM (Doran et al., 2022).

The *check and act* aspects of the PDCA cycle reveal gaps in monitoring and evaluation due to barriers like cost, time, and lack of motivation (Amponsah-Tawiah et al., 2016; Haslam et al., 2005). Existing guidance often focuses on compliance rather than risk-based assessment(Waka Kotahi, 2022). Independent audits are limited and often compliance-based, lacking the depth needed for meaningful adjustment (Austroads, 2021; TfL, 2019; Waka Kotahi, 2019a).

The role of permanent and minimum standards in TTM also presents a complex landscape. Permanent controls are not always applicable to temporary settings, and minimum standards often promote compliance-based thinking (British Columbia Ministry of Transportation and Infrastructure, 2020; Work Zone Safety Consortium, 2018; Lutchman et al., 2012). The layering of responsibility across multiple stakeholders necessitates modular design in guidelines (Black, 2007; Carden et al., 2021).

Operationalising good practice in TTM for VRUs is a complex task that requires ongoing adaptation and evaluation (Carden et al., 2021; Damschroder et al., 2009). The presentation and comprehensibility of the guide, the use of specific language, and the gap between theoretical plans and actual field practices all contribute to the effectiveness of TTM guidelines (Shaw & Oneyear, 2021; Hopkins, 2011; Erik, 2014; Nemeth et al., 2011).

Risk and how it is managed are at the centre of treating VRUs in TTM environments. A drastic increase in maturity in this domain requires a bespoke evidence-driven risk assessment framework to support drastically improved TTM designs that prioritise VRU safety and enact the themes and findings explored above. Existing international and local targetted risk frameworks are inadequate in addressing the specific needs of VRUs in New Zealand's evolving TTM landscape. Risk's multi-faceted nature, including physical, psychological, and social dimensions, requires a comprehensive, user-centric approach (Shaw & Oneyear, 2021; Puchades et al., 2018). The initial step in this process involves a thorough understanding of the work environment, which can be achieved through comprehensive reconnaissance and stakeholder involvement (Hollnagel, 2014; Department for Transport (UK), 2023).

Upon understanding the situation, the identification of hazards and the evaluation of risks become paramount. The focus should be on VRUs as risk subjects, with hazards categorised into existing environmental factors and introduced elements (Shaw & Oneyear, 2021; MNDOT, 2021b). Although commonly used, risk matrices have been critiqued for lacking critical thinking and not being universally applicable across various TTM settings (Cox, 2008; Duijm, 2015). Moreover, risk moderators such as weather, time, and traffic volume are often inconsistently addressed in international literature, leading to incomplete risk assessments (Shaw et al., 2016).

The application of controls is a nuanced process that requires both individual intent and a synergistic function of multiple controls (Hollnagel et al., 2006). While some frameworks offer predetermined combinations of controls, these often risk generalisations and may not account for unique, site-specific risks (Waka Kotahi, 2023c; ADOT, 2019). The lack of focus on the synergistic function of controls in existing frameworks is a significant gap that needs to be addressed.

Specific controls such as the accommodation of bus stops, advanced technologies, and signage require amplified attention. NZ also lacks some international sign messaging approaches and underutilises audible messaging (Caltrans, 2020; MNDOT, 2021b). Similarly, controls like cone bars, unique to NZ, are not aligned with the more considered American Disabilities Act of 1990, posing a risk for visually impaired individuals. Detours, often poorly planned, have low compliance rates and require early planning and a significant psychological component to be effective (Shaw, 2016; Niska, 2014).

The material, dimensions, and other features are crucial for effectiveness regarding more specific controls like fencing, kerb ramps, and lighting. For example, the height and material of fencing can vary, but it must meet specific minimum standards for effectiveness. New Zealand's guidelines lack specific guidance on temporary walkway bridges and walkway covering, a gap that needs to be addressed.

Finally, the treatment of risks that TTM controls have introduced is an area that requires immediate attention. Control measures can introduce new risks, and their effectiveness relies on competent personnel (Aven, 2016; WisDOT, 2019). Dynamic pedestrian networks require continuous control assessment, and issues like vandalism and control redundancy must be addressed.

In conclusion, the need for a paradigm shift from stating to applying principles and from compliance-based to risk-based assessment is evident. The existing frameworks for TTM in New Zealand and internationally are inadequate for treating the multi-faceted risks faced by VRUs. A new, tailor-made framework is essential for improving the capabilities of TTM designers in New

Zealand. This framework should be comprehensive, adaptable, and user-centric, incorporating international best practices while addressing the needs and gaps identified in the New Zealand context. It should also be dynamic, allowing for ongoing risk assessment and the modification of controls as needed.

Limitations

One of the most significant constraints of this research is the geographical focus on New Zealand and OECD countries. While this provides a targeted lens, it also means that potentially valuable practices from other regions are overlooked. Future research could be enriched by a more global perspective, especially from countries with different traffic conditions and cultural attitudes toward road safety.

Another limitation is what can be termed an *Operationalisation Void*. The research identifies what are considered good practices but does not empirically test these practices in real-world conditions. This perpetuates a cycle where theoretical good practices are discussed but not validated, making it difficult to gauge their effectiveness.

Resource allocation is also a notable gap in the research. While the study identifies good practices, it does not consider the financial and workforce resources needed to implement them. Without this information, the feasibility of applying the research findings in real-world settings remains an open question.

Legal liability is another area that the research does not categorically resolve. While efforts have been made to align the findings with existing legislation, the complex legal frameworks make this a challenging endeavour. Without empirical testing and validation, it is unclear how these evolved TTM propositions would stand up to legal scrutiny, which is a significant consideration for any practical application.

The research also falls short in comprehensively integrating psychology and environmental science findings, crucial for a holistic understanding of VRU treatment in TTM. The human factors involved in road safety and the environmental impact of traffic management schemes could add depth to the research but are currently underexplored.

Equity considerations are another limitation. While the research does explore a broad range of VRUs, it does not provide explicit strategies for ensuring that the needs of the most marginalized are met. This remains a significant gap, given that road safety measures should ideally benefit all road users, not just the majority.

Environmental conservation is also not assessed. In an era where sustainability is a growing concern, the environmental impact of new TTM schemes is a crucial factor that the research does not address.

The lack of longitudinal data is another limitation. The research is cross-sectional, providing a snapshot rather than a long-term view. This restricts the study's ability to track the effectiveness of control measures over time, which is vital for understanding their real-world impact.

The research also has a limited scope on new risks introduced by control measures. While it acknowledges that new risks could arise, it does not explore how these are managed or prioritised, leaving a gap in our understanding of the complete risk management lifecycle in TTM.

Lastly, the research operates on an assumption of competency among personnel implementing the control measures but does not define what competency means or how it should be measured. This is a systemic need, as the effectiveness of any TTM scheme is highly dependent on the skills and training of the people implementing it.

In summary, while the research provides valuable insights into TTM practices for VRUs in New Zealand, these limitations highlight areas that require further exploration for a more comprehensive understanding of the subject.

Future Research

The continued development of improved VRU treatments in TTM environments directs attention towards several future research avenues. The limitations within existing guidelines warrant a multi-disciplinary, iterative, and inclusive approach to improving TTM for VRUs. Specifically, the current practice could benefit from an enhanced mechanism for aggregating good practices that have been rigorously tested and refined. A recommendation would be to hand down so-called good practices and subject them to empirical validation through real-world testing, thereby allowing for continuous refinement.

In parallel, an issue begging for attention is the nebulous language often employed in TTM guidelines. Future research should focus on removing and resolving linguistic uncertainty to foster practical and unambiguous applications. Guidelines could be analysed through linguistic models to identify vague or overly complex terminology, enhancing clarity and improving practical implementation.

Identifying *competent personnel* as a critical factor in the efficacy of control measures adds another layer. Currently, the discourse bypasses how competency can support exemplary practice implementation. This gap should catalyse future studies investigating the interplay between personnel competency and the efficacy of good practice. Attention could be focused on how good practice compilation can be harmonious with competency development systems – maximising the result for VRUs. This could involve examining the existing training protocols, certification processes, and professional development courses that aim to ensure personnel competence.

The efficacy of control measures, particularly those embedded in the good practice realm, seems contingent on the presence of competent personnel. Future studies could explore training modules and skill-upgrading frameworks that align with good practice implementation. Additionally, this competency paradigm could be further refined by investigating the extent to which the competency of those implementing it mediates the effectiveness of a good practice guide. This focus could help ensure that inadequately trained personnel do not compromise the iterative enhancements to good practices.

Introducing decision trees in TTM practices, especially in risk control measures, could offer a more nuanced approach that would benefit VRUs. Future studies might explore the development and validation of decision-tree models tailored to New Zealand's unique demographic and geographic context. This could allow for more site-specific risk assessments, thereby reducing the propensity for generalisation, which may not serve the varied needs of VRUs.

Moreover, the observed lag in technological adoption within New Zealand's TTM practices suggests a ripe avenue for exploration. Subsequent research could investigate the integration of audible messaging and Bluetooth warning systems tailored explicitly for VRUs. Likewise, the appropriateness of physical controls and devices for people with disabilities is virtually unexplored in NZ and must be a focus to validate the safety of all road users, especially those most disenfranchised by current in-use equipment like cone bars.

Given New Zealand's increasing prevalence of TTM and the unique needs of its VRUs, future research must target these multiple facets to evolve a more integrative, robust, and context-sensitive approach. Through a focus on empirical validation, linguistic clarity, competency integration, nuanced risk assessment, and technological modernisation, there is substantial scope for elevating the quality of TTM practice in New Zealand. These avenues provide a roadmap for the maturation of TTM practices, ensuring they are attuned to the complexities and particularities of VRU needs.

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APPENDICES

Appendix A – New Zealand and International Death and Serious Injury (DSI) Raw Data and Analysis

Linear Regression - TTM DSIs as a proportion of all DSIs over time (2001 - 2021)

Model Summary[b]						
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics	
					R Square Change	F Change
1	.860[a]	.740	.726	.00850917	.740	54.036

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.004	1	.004	54.036	<.001[b]
	Residual	.001	19	.000		
	Total	.005	20			
a. Dependent Variable: TTM DSIs as a proportion of all DSIs						
b. Predictors: (Constant), Year						

Auckland Transport raw auditing data (Kiddle, 2023)

Year	Audits undertaken	Inadequate provision of pedestrians or cyclists	The proportion of sites audited with inadequate provision for pedestrians or cyclists
2015	1790	276	15.42%
2016	1664	307	18.45%
2017	2662	439	16.49%
2018	2192	431	19.66%
2019	1804	394	21.84%
2020	1471	330	22.43%
2021	1124	314	27.94%
2022	1980	411	20.76%

Bivariate Correlations across DSI data (within and outside TTM environments), including Vulnerable Road Users and sub-groupings

		Cyclist DSIs (all)	Pedestrian DSIs (all)	VRU DSIs (all)	DSIs (all)	VRU DSIs (TTM sites)	Cyclist DSIs (TTM sites)	Pedestrian DSIs (TTM sites)	DSIs (TTM sites)
Pedestrian DSIs (all)	Pearson Correlation	-0.260							
	Sig. (2-tailed)	0.256							
	N	21							
VRU DSIs (all)	Pearson Correlation	.462*	.732**						
	Sig. (2-tailed)	0.035	0.000						
	N	21	21						
DSIs (all)	Pearson Correlation	0.417	.530*	.801**					
	Sig. (2-tailed)	0.060	0.013	0.000					
	N	21	21	21					
VRU DSIs (TTM sites)	Pearson Correlation	0.414	-0.063	0.293	.596**				
	Sig. (2-tailed)	0.062	0.788	0.197	0.004				
	N	21	21	21	21				
Cyclist DSIs (TTM sites)	Pearson Correlation	.536*	-0.091	0.302	0.247	.509*			
	Sig. (2-tailed)	0.012	0.695	0.183	0.281	0.019			
	N	21	21	21	21	21			
Pedestrian DSIs (TTM sites)	Pearson Correlation	0.400	-0.017	0.331	.623**	.926**	0.267		
	Sig. (2-tailed)	0.073	0.940	0.142	0.003	0.000	0.243		
	N	21	21	21	21	21	21	21	
DSIs (TTM sites)	Pearson Correlation	0.373	-0.056	0.267	.614**	.898**	0.257	.892**	
	Sig. (2-tailed)	0.096	0.808	0.243	0.003	0.000	0.260	0.000	
	N	21	21	21	21	21	21	21	
Vehicle Kilometres Travelled (NZ)	Pearson Correlation	0.380	-0.156	0.185	.506*	.855**	0.381	.828**	.932**
	Sig. (2-tailed)	0.089	0.499	0.422	0.019	0.000	0.088	0.000	0.000
	N	21	21	21	21	21	21	21	21

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

New Zealand DSI data from Waka Kotahi's Crash Analysis System (CAS) (Waka Kotahi, 2023a)

Crash year	Driver DSIs	Passenger	Null (victim not recorded)	Cyclist	Pedestrian	Equestrian	Skateboard, in-line skate	Wheeled pedestrian	VRU DSI	All DSI	% of VRU of total	VRU DSI in TTM	Cyclist DSI in TTM	Pedestrian DSI in TTM	DSI in TTM
2001	497	7	0	162	338	4	2	2	508	1012	50.20%	0	0	0	16
2002	535	3	0	159	386	1	4	2	552	1090	50.64%	1	0	1	15
2003	516	7	0	158	355	1	4	3	521	1044	49.90%	2	1	1	23
2004	510	9	0	178	333	1	3	4	519	1038	50.00%	2	0	2	20
2005	465	10	0	151	296	0	3	2	452	927	48.76%	2	0	2	27
2006	529	6	0	178	330	1	7	5	521	1056	49.34%	5	0	5	30
2007	501	6	0	220	294	0	5	7	526	1033	50.92%	5	8	0	23
2008	532	9	0	215	311	1	4	14	545	1086	50.18%	3	0	3	31
2009	436	1	0	173	278	0	5	4	460	897	51.28%	1	1	0	18
2010	467	1	0	182	290	0	1	10	483	951	50.79%	4	1	3	30
2011	441	6	0	195	246	0	6	2	449	896	50.11%	1	0	1	29
2012	465	12	0	188	276	0	10	4	478	955	50.05%	3	1	2	25
2013	470	1	0	207	271	1	4	10	493	964	51.14%	4	1	4	25
2014	452	4	1	170	281	0	4	6	461	918	50.22%	1	0	1	24
2015	464	5	1	157	293	0	6	6	462	932	49.57%	4	2	2	28
2016	491	3	1	189	300	0	11	11	511	1006	50.80%	14	5	10	51
2017	557	5	2	216	339	0	4	16	575	1139	50.48%	11	2	9	71
2018	528	11	0	191	336	0	6	12	545	1084	50.28%	8	3	5	60
2019	549	116	7	217	292	0	1	19	529	1201	44.05%	16	5	10	68
2020	440	115	24	162	291	1	0	10	464	1043	44.49%	13	0	7	70
2021	505	123	15	189	292	0	0	17	498	1141	43.65%	8	0	8	62
Total	**10350**	**460**	**51**	**3857**	**6428**	**11**	**90**	**166**	**10552**	**21413**		**108**	**30**	**76**	**746**

Appendix B – Vulnerable Road User Types and Descriptions

People on Foot	People on Wheels
Pedestrians	Cyclists
Child Stroller Pushers	Cargo Bike Riders (Sub-set of Cyclists)
Hearing Impaired (May be a sub-set of Pedestrians or other wheeled modes)	Electric Scooters
Mobility Impaired with or without an aid such as a cane, walker, or crutches	Electric Wheelchair Users (Sub-set of Wheelchair Users)
Visually Impaired (May be a sub-set of Pedestrians, or other wheeled modes) with or without an aid such as a cane, or guide dog	ElliptiGO Riders (Sub-set of Cyclists)
Runners	Equestrian Riders[1]
	Handcycle Users (Sub-set of Cyclists)
	In-line Skaters
	Kick Scooter Users
	Manual Wheelchair Users (Sub-set of Wheelchair Users)
	Mobility Scooters
	Pedi-cabs (Sub-set of Cyclists)
	Recumbent Bike Riders (Sub-set of Cyclists)
	Roller Skaters
	Segway Users
	Skateboarders
	Tandem Cyclists (Sub-set of Cyclists)
	Tricycles (Sub-set of Cyclists)
	Unicyclists (Sub-set of Cyclists)

[1] Whilst this category is titled 'those on wheels' – equestrian riders has been added as a sub-category for simplicity.

Appendix C – Grey Literature – Canada and Other Included Countries

Doc No.	Territory	Agency/Authority	Standard Name	Pages	Peds	Cyclists	Diagrams?	Notes	Current Version/Edition	Month/Year Published	Editions	Major Renewal cycle	Standing	VRU Pages	Relevant Diagrams
C1	Australia	Department of Infrastructure, Transport, Regional Development and Communications	Austroads Guide to Temporary Traffic Management (AGTTM)	650	369	383	lots	Provides a glossary definition for vulnerable road user: "Pedestrians, cyclists, motorcyclists." Is broken into 10 parts	1.1	Sep-21	2	2	Third Party GPG (non-legally binding not-for-profit Good Practice Guide)	PDF pages 6, 7, 9, 10, 14, 16, 17, 22, 23, 36, 37, 43, 49, 53, 54, 55, 57, 58, 59, 62, 67, 78, 88, 82, 84, 88, 92, 93, 94, 95, 96, 102, 105, 106, 112, 113, 115, 116, 119, 120, 122, 127, 128, 130, 132, 138, 139, 141, 142, 143, 144, 148, 149, 150, 156, 157, 158, 159, 165, 166, 167, 168, 169, 172, 173, 174, 177, 189, 191, 198, 199, 200, 201, 203, 204, 207, 208, 211, 218, 220, 221, 225, 226, 227, 229, 230, 233, 234, 238, 253, 256, 264, 265, 270, 271, 272, 274, 275, 277, 279, 282, 286, 290, 295, 301, 305, 309, 321, 322, 326, 337, 341, 347, 348, 350, 351, 352, 356, 361, 371, 379, 380, 395, 398, 400, 409, 420, 421, 430, 431, 439, 440, 446, 447, 459, 462, 463, 465, 467, 468, 472, 474, 477, 479, 481, 491, 493, 495, 503, 510, 511, 513, 514, 515, 516, 519, 522, 528, 529, 535, 605, 606, 611, 612, 613, 614, 615, 616, 621, 627, 628, 636, 637, 639	PDF pages 559, 566, 567
AT1	Canada (British Columbia)	British Columbia Ministry of Transportation and Infrastructure	Traffic Management Manual for Work on Roadways (TMM)	815	108	156	some	editions were 1999, then 2015, then 2020	2.0	Aug-20	3	5	State/Province Authority GPG (Standards document published jointly by Government Minsitry and local authority)	s2 p8 (PDF 48) s18 p4-15 (PDF 518-529) find and save/extract glossary as well PDF pages 30, 31, 34, 42, 43, 48, 49, 51, 72, 92, 101, 106, 110, 113, 114, 116, 130, 132, 133, 134, 143, 145, 146, 147, 153, 154, 158, 161, 166, 175, 182, 188, 241, 250, 262, 274, 285, 317, 378, 434, 435, 406, 408, 410, 411, 414, 484, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 567, 573, 574, 575, 577, 579, 595, 597, 599, 664, 670, 671, 672, 685, 688, 706, 734, 735, 736, 741, 781, 797, 810	PDF page 406-415
AT2	Canada (Alberta)	Transportation and Economic Corridors, Government of Alberta	Traffic Accommodation in Work Zones Manual	187	10	10	lots	Manual is primarily electronic with hyperlinks etc throughout. Editions were 2008, then 2018, then 2020	2.1	Apr-20	3	10	State/Province Authority GPG (Standards document published jointly by Government Minsitry and local authority)	s5.4 (PDF 9) s5.7 (PDF 10) find and save/extract glossary as well PDF pages 8, 9, 10	none

AT3	Canada (Ontario)	Ministry of Transportation, Ontario (MTO)	Ontario Traffic Manual Book 7: Temporary Conditions	580	199	247	lots	Editions were 2014, then 2020 (small) then 2022 Has a field edition and an office edition a traffic protection plan (TPP) is required by the Ontario OHS Act Must comply with the Ontario AODA (Accessibility for Ontarians with Disibilities Act) Great glossary	2.0	Apr-22	3	8	State/Province Authority GPG (Standards document published jointly by Government Minsitry and local authority)	s3.7.1 p49-58 (PDF 73-82) p118-123 (PDF 142-147) find and save/extract glossary as well PDF pages 6, 7, 9, 10, 11, 12, 13, 18, 21, 27, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 72, 118, 119, 120, 121, 122, 123, 152, 158, 169, 180, 182, 184, 187, 188, 189, 190, 191, 192, 193, 196, 201, 218, 244, 248, 249, 250, 251, 281, 282, 283, 284, 285, 301, 302, 303, 304, 337, 338, 339, 340, 341, 342, 343, 344, 371, 372, 373, 374, 375, 411, 412, 413, 414, 415, 416, 417, 418, 445, 446, 447, 448, 449, 485, 513, 514, 516, 518, 523, 529, 530, 534, 543, 544, 545, 547, 550, 551, 552, 553, 555	Drawing TS23 (PDF 305) Drawing TI16 (PDF 325) Drawing TI17 (PDF 326) Drawing US27 (PDF 361) and Drawings US29, US30, UI27, UI28, UI29, DS19, 20, DS, 21, DS22, DI27, DI28, DI29 (numbers top left of each drawing page)
AT4	Canada (Nova Scotia)	Department of Public Works, Nova Scotia	Temporary Workplace Traffic Control Manual	368	20	53	lots	Editions are 2009, 2018, 2023 Standard does not have any drawings for vulnerable road users Standard just generally taks about protection/accomodation/consideration of bicyclists and pedestrians in all cases	3	Apr-23	3	5	State/Province Required Standard (Provincial government minimum standards enacted by the Provincial Minister under Parliamentary Act. Covered on Page 2-1 of document.)	page 7-5 page 8-2 page 8-12 (sign TC-47) page 8-14 (sign TC-68, TC-70-71 etc.) page 8-15 (sign TC-72, 73) Page 13-19 Page 8-22 - signs There are no drawings. Find and save glossary too - called definitions in this case PDF pages 17, 18, 25, 26, 27, 43, 46, 56, 57, 58, 59, 66, 71, 79, 81, 82, 101, 108, 111, 119, 124, 133	none
AT5	Canada (Newfoundland and Labrador)	Department of Transportation & Works, Newfoundland & Labrador	Traffic Control Manual	281	1	9	lots	editions are 1999, 2006, 2011, 2013 No guidance at all - one isntruction around rumble strips being placed to have clear cycle path	5	Aug-18	5	5	State/Province Required Standard (Provincial government minimum standards	page 33 get definition page as well PDF pages 50,47, 230, 252	none

								beside, that's it. "Temporary rumble strips should not be placed on roadways used by bicyclists unless a minimum clear path of 4 feet is provided at each edge of the roadway or on each paved shoulder."					enacted by the Ministry of Transportation and Works)		
AT6	Canada (Saskatchewan)	Ministry of Highways, Saskatchewan	Traffic Control Devices Manual for Work Zones	222	1	0	lots	editions are 1998, 2013, 2019, 2023	3.12	Jul-23	4	4	State/Province Authority GPG (Non-legally binding guideline produced by provincial government to facilitate adherance to legal regulation. Mandatory for Ministry employees)	pedestrians and cyclists are pretty much not mentioned at all Get glossary pages (100-19 - 100-22) PDF pages 20, 21, 22, 23	none
	Canada (Manitoba)	Manitoba Infrastructure and Transportation	Work Zone Traffic Control Manual	60	0	0	lots	Editions are 2013 and 2015 and nothing since	2	Jun-15	2	8	State/Province Authority GPG	no pages to be extracted, nothing relevant	none
AT7	Canada (New Brunswick)	New Brunswick Transportation and Infrastructure	Work Area Traffic Control Manual	119	7	2	lots	editions are 2009, 205, 2019, 2021	4	Mar-21	4	2	State/Province Authority GPG	PDF pages 8, 9, 15, 22	none
C2	Czech Republic, Estonia, Finland, France, Germany, Ireland, Italy, Latvia, Lithuania, Portugal, Slovakia, Spain, Sweden	European Union Road Federation (ERF)	ERF Towards Safer Works Zones	36	1	0	some		1	Jul-19	1	N/A	Centralised EU Good Practice Guide	PDF pages 7	none

C3	Belgium, Germany, Ireland, Slovenia, Sweden	Conference of European Directors of Roads	IRIS Guidance Document on Temporary Traffic Management	43	3	2	none		1	Jun-19	1	N/A	Centralised EU Good Practice Guide	PDF pages 16, 17	none
C4	Czech Republic, Italy, Lithuania, Slovakia, Slovenia, Sweden	UNECE Trans-European Motorways Project	TEM Guidelines on Workzone Safety	52	5	3	some		1	Feb-22	1	N/A	Centralised EU Good Practice Guide	PDF pages 4, 6,	none
C5	Belgium, Germany, Ireland, Slovenia, Sweden	European Transport Safety Council	Preventing Road Accidents and Injuries for the Safety of Employees (PRAISE): Road Safety at Work Zones	42	10	7	none		1	May-11	1	N/A	Centralised EU Good Practice Guide	PDF pages 2, 5, 7, 9, 11, 12, 15, 20, 21, 24, 27	none
C6	Denmark, Finland, Germany, Netherlands, Slovenia, Sweden	ERA-NET ROAD II	Scoring Traffic at Roadworks (STARs) project	120	1	0	none		1	Oct-13	1	N/A	Centralised EU Good Practice Guide	PDF pages 30, 70	none
	Belgium	Federal Public Service Mobility and Transport	Ministerial Order of 7 May 1999 on the signage of construction sites and obstacles on public roads	26	0	0	none	Original published in 1999. Excludes the Walloon region - which is covered by a different regulation (itemised in this sheet separately) No valuable content on VRU at all - can be excluded	[unknown]	Aug-23	[unknown]	[unknown]	EU Standard + National Regulation (Ministerial second tier legislation/ regulation)	none	none
	Belgium (Walloon)	Public Service of Walloon	Walloon Government Order of 16 December 2020 on the signage of construction sites and obstacles on public roads	29	0	0	none	Walloon-specific regulation regarding TTM signage and arrangement No valuable content on VRU at all - can be excluded	2	Aug-23	2	2	EU Standard + National Regulation (Ministerial second tier legislation/ regulation)	none	none
	Czech Republic	Ministry of Transport	[no accessible stand-alone national TTM										EU Standards Only	none	none

			standard found]												
C7	Denmark	Danish Road Directorate	Instruktion Råden over vejareal (Road Space Instructions for State Roads)	276	16	138	lots		[unknown]	Nov-20	[unknown]	[unknown]	EU Standard + National Regulation (Directorate from the road directorate (second tier rules))	PDF pages 16, 31, 32, 37, 43, 45, 52, 53, 54, 55, 59, 65, 66, 69, 75, 88, 89, 95, 97, 100, 101, 103, 104, 105, 106, 107, 110, 111, 112, 113, 114,115, 116, 117, 118, 119, 122, 123, 124, 125, 126, 127, 128, 140, 141	English PDF pages 106, 107
C8	Estonia	Republic of Estonia Transport Administration	Nõuded ajutisele liikluskorraldusele (Requirements for Temporary Traffic Management)	59	4	4	lots		2	Jul-18	2	3	EU Standard + National Regulation (enacted regulation under Road Traffic Act (second tier legislation))	PDF pages 1, 5, 9, 47, 48, 50, 51	English PDF pages 47-53
C9	Finland	Finnish Municipal Engineering Association	Tilapäiset liikennejärjestelyt katu- ja yleisillä alueilla (Temporary traffic arrangements in the street area)	59	0	3	lots	editions are 1999 and 2013	2	Jan-13	2	14	EU Standard + Third Party GPG (Good practice guide produced by a municipal engineering authority)	PDF Pages 1	English PDF pages 2, 3, 4, 7, 8, 11, 12, 13
C10	Finland	Finnish Network of cycling municipalities	Pyöräilijöiden tarpeet työnaikaisten tilapäisten liikennejärjestelyiden toteutuksessa (The needs of cyclists for temporary workers in the implementation of traffic arrangements)	17	15	34	images only		[unknown]	Dec-20	[unknown]	[unknown]	Regional authority conglomerate good practice guidance	full document is relevant	none
	France	Ministry of the Interior	Signalisation temporaire - Manuel du chef de	96	0	1	lots	Specific standard retrieved is for bi-directional roads (divided roads	1	Jul-00	1	N/A	EU Standard + National GPG	no pages to be extracted, nothing relevant	none

			chantier : routes bidirectionnel les (Temporary Signs and Signals - Site Manager's Manual: Bi-directional Roads)					(motorways) standard not retrieved as little relevance to VRU)							
C11	Germany	Federal Ministry of Transport and Digital Infrastructure	Richtlinien für die verkehrsrecht liche Sicherung von Arbeitsstellen an Straßen (Guidelines for the traffic safety of work sites on roads)	321	80	116	lots		[unk now n]	Aug-21	[unk now n]	[unk now n]	EU Standard + National GPG	PDF pages 14, 16, 19, 20, 21, 24, 25, 26, 28, 33, 34, 35, 37, 38, 39, 40, 41, 42, 43, 45, 46, 69, 77, 79, 80, 82, 83, 84, 85, 88, 89, 90, 92, 94	English PDF pages 69, 82, 84-92
	Germany (Hessen)	Hessen Mobil (State Transport Authority)	Handbook on Construction Site Management	68	3	3	none	Came with extensive drawings but none relate to pedestrian or cyclist management	4.1	Oct-20	4	[unk now n]	Regional GPG	no pages to be extracted, nothing relevant	none
C12	Ireland	Department of Transport (Ireland)	Temporary Traffic Measures and Signs for Road Works	122	31	47	lots	Originally called "Guidance for the Control and Management of Traffic at Road Works" which had two editions - 2007, 2010	3	Aug-19	3	9	EU Standard + National GPG	PDF pages 5, 10, 30, 31, 32, 41, 42, 50, 62, 73, 74, 103, 110	PDF page 110
	Italy	Ministry of Infrastructure and Transport	Individuazion e della procedure di revisione, integrazione e apposizione della segnaletica stradale destinata alle attivita' lavorative che si svolgono in presenza di traffico veicolare (Identification of revision	27	4	1	none	Two editions - 2013, 2019	2	Jan-19	2	6	EU Standard + National Regulation (Interminist erial Decree (regulation))	no pages to be extracted, nothing relevant	none

			procedures, integration and affixing of road signs for activities work that takes place in the presence of vehicular traffic)												
	Japan	Ministry of Land, Infrastructure, Transport and Tourism	道路工事保安施設設置基準 (Road Construction Safety Facility Installation Standards)	24	8	0	some		5	May-19	5	13	National Authority GPG (Standards document published jointly by Government Minsitry and local authority)	no pages to be extracted, nothing relevant	English PDF page 18
	Latvia	Ministry of Transport	Noteikumi par darba vietu aprīkošanu uz ceļiem (Regulations on equipping workplaces on roads)	58	14	0	lots	Editions 1993, 1999, 2001	3	Oct-01	3	20	EU Standard + National Regulation	no pages to be extracted, nothing relevant	English PDF page 33
C13	Lithuania	Ministry of Transport and Communications	Dėl automobilių kelių darbo vietų aptvėrimo ir eismo reguliavimo taisyklių (Order Regarding the Approval of Rules for Road Work Site Coverage and Traffic Regulation)	154	98	86	lots	Editions 2004, 2012	2	Apr-12	2	11	EU Standard + National Regulation	PDF pages 4, 5, 11, 16, 23, 24, 30, 31, 32, 37, 38, 99, 100, 117, 118, 119, 120, 121, 122, 123, 124, 127, 128, 129, 130, 132, 135, 138, 139, 140, 141, 142, 143, 144, 145, 148, 149, 150, 151	English PDF pages 138-144
	Luxembourg	Ministry of Mobility and Public Works	[no accessible stand-alone national TTM standard found]										EU Standards Only		
	Netherlands	Ministry of Infrastructure	Werk in Uitvoering 2020 - Serie	[unknown]	[unknown]			Document unavailable due to paywall	5	Jul-20	5	5	EU Standard + Third Party		

		and Water Management	(Work in Progress 2020 - Series)										GPG (Not for profit produced but sponsored/ partnered by government agencies and private companies as a centralised good practice guide)		
C14	New Zealand	Waka Kotahi NZ Transport Agency	Code of Practice for Temporary Traffic Management (CoPTTM)	567	108	73	lots	Editions 2001, 2005, 2013, 2019	4	Nov-18	4	5	National Authority GPG (unapproved code of practice)	PDF pages 5, 11, 12, 13, 14, 17, 42, 65, 68, 70, 71, 86, 92, 93, 105, 106, 110, 112, 134, 158, 182, 183, 187, 195, 197, 201, 207, 224, 230, 234, 237, 238, 239, 240, 241, 242, 243, 244, 245, 251, 256, 257, 285, 289,329, 335, 341, 345, 349, 356, 361, 365, 368, 380, 382, 383, 384, 385, 386, 388, 389, 390, 391, 396, 402, 405, 421-424, 425, 426, 428-430, 430, 481, 486-488, 489, 516	PDF pages 421-424, 428-430, 486-488, 491, 492
C15	New Zealand	Waka Kotahi NZ Transport Agency	New Zealand Guide to Temporary Traffic Management (NZGTTM)	86	31	36	some	one edition, newly released, April 2023	1	Apr-23	1	N/A	National Authority GPG (centralised guideline)	PDF pages 7, 10, 11, 19, 23, 26, 28, 30, 33, 34, 35, 39, 42, 44, 45, 49, 50, 54, 63, 64, 65, 66, 67, 70, 71, 72, 78, 82, 86, 87, 93, 95, 97, 99, 104,105	PDF pages 104, 105
	Portugal	junta autónoma de estradas (Autonomous Road Board)	Manual de Sinalizacao Temporaria (Temporary Signaling Manual)	82	0	0	lots	Very old. Only one version available. Seems to not be relevant anymore (found a masters thesis explaining the ggap since it was released)	[unknown]	Jun-97	[unknown]	[unknown]	EU Standard + National GPG	no pages to be extracted, nothing relevant	none
C16	Slovakia	Slovak Road Administration	Technické Podmienky Používanie Dopravného Značenia A Dopravy Zariadenie Na Označovanie Pracoviskov (Technical Conditions Use Of Traffic Signs And Traffic Equipment For Marking Workplaces)	135	15	20	lots		5	Jan-22	5	9	EU Standard + National Regulation (ministerial procedural document)	PDF Pages 6, 7, 16, 17, 23, 64, 65, 66, 67, 70, 71, 72, 76, 77, 78-80, 81, 84, 85, 86, 87	English PDF pages 78-80, 86, 87

	Slovenia	Ministry of Infrastructure	Pravilnik o načinu označevanja in zavarovanja del na javnih cestah in ovir v cestnem prometu (Regulation on the method of marking and securing works on public roads and obstacles in road traffic)	42	3	2	none		2	Jan-07	2	8	EU Standard + National Regulation (Regulation (second tier legislation))	no pages to be extracted, nothing relevant	none
C17	South Korea	Ministry of Land, Infrastructure and Transport	도로안전시설 설치 및 관리지침 (Road Safety Facility Installation and Management Guidelines)	49	35	2	none	Editions - 2016, 2021. Machine translated using Google Translate	2	Jun-21	2	5	National Authority GPG	PDF Pages 4, 9, 13, 18, 20, 21, 22, 23, 30, 31, 33, 48, 49	none
	Spain	Ministry of Transport, Mobility and Urban Agenda	Manual de ejemplos de senalizacion de obras fijas (Manual of examples of signaling of fixed works) Senalizacion de obras norma de carreteras (Signaling of standard road works) Senalizacion movil de obras (Mobile signaling of works)	209	1	0	lots	No subsequent issues. Very old.	1	Jun-97	1	N/A	EU Standard + National Regulation (Transport authority regulations (second tier legislation))	no pages to be extracted, nothing relevant	none
C18	Sweden	Swedish Transport Authority	Trafikverkets tekniska krav för Arbete på väg (technical	43	24	26	none	Editions are 2012, 2013, 2014, 2019	4	Dec-19	4	5	EU Standard + National GPG (transport	PDF Pages 8, 10, 13, 14, 18, 21, 22, 27, 31, 36, 37, 40, 43	none

			requirements for Work on the road)										authority good practice guide)		
	Sweden	Swedish Transport Authority	För din och trafikanternas säkerhet: Arbeta med vägmärken och skyddsanordningar (For your safety and the safety of road users: Work with road signs and protective devices)	60	8	9	none		4	Jul-20	4	[unknown]	EU Standard + National GPG (transport authority good practice guide)	no pages to be extracted, nothing relevant	none
	Sweden	Swedish Transport Authority	Arbeta med väghållningsfordon: Hur du ska varna, vägleda och värna för en säkrare arbetsmiljö (Working with road maintenance vehicles: How to warn, guide and protect for a safer working environment)	32	2	2	none		1	Mar-22	1	N/A	EU Standard + National GPG (transport authority good practice guide)	no pages to be extracted, nothing relevant	none
C19	Sweden	Swedish Association of Local Authorities and Regions (SALAR)	Gatuarbete I Tätort: Handbok Till Stöd För Planering Och Genomförande (Street Work in Urban Areas: Hanbook to Support Pllanning and Implementation)	144	51	82	none		1	Sep-19	1	N/A	EU Standard + National GPG (Centralised good practice from local government conglomerate body)	PDF pages 5, 26, 27, 45, 46, 47, 48, 51, 63, 70, 72, 73, 74, 79, 80, 81, 89, 90, 91, 92, 99, 102, 103, 104, 105, 109, 116, 122, 133, 134, 136	none
C20	United Kingdom	Department for Transport/Highways Agency Department for Regional	Traffic Signs Manual: Chapter 8 - Traffic Safety Measures	743	217	104	some	first published 2006, then 2009, 2017, 2020. Date on document says 2009, however 'Part	4	Mar-20	4	3	Code of practice to enable fulfillment of	PDF pages 8, 10, 12, 16, 18, 24, 25, 26, 34, 35, 39, 41, 42, 43, 44, 48, 59, 61, 62, 63, 70, 72, 81, 83, 85, 86, 91, 102, 110, 112, 113, 114, 115, 116, 119, 134, 145, 151, 152, 153, 154, 157, 262, 296, 297, 298, 300, 344, 346, 348, 350,	PDF page 119

		Development (Northern Ireland) Transport Scotland Welsh Assembly Government	and Signs for Road Works and Temporary Situations					3' is the 'update document' which was last update 2020 (all updates are held in a separate Part).					legislative duties	352, 353, 357, 361, 365, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 381, 383, 384, 385, 386, 388, 389, 393, 394, 395, 410, 434, 439, 440, 446, 496, 524, 525, 526, 528, 576, 577, 578, 612, 614, 619, 620, 635, 645, 646	
C21	United States	Department of Transportation	Work Zone Operations Best Practices Guidebook	349	50	2	none	Published 2013, and then additional addendum 2017	2	Dec-17	2	6	Guidance only - conglomeration of Good Practice	PDF pages 1, 7, 10, 44, 116, 119, 300, 302, 303, 308, 310, 316,	none
	United States	Department of Transportation	Implementing the Rule on Work Zone Safety and Mobility	103	3	0	none	no updates - just a guidance document on how to follow federal rule	1	Dec-05	1	N/A	Guidance on how to implement a federal rule (and applies where federal funding is given for roading)	no pages to be extracted, nothing novel	none
	United States	Department of Transportation	Field Guide on Installation and Removal of Temporary Traffic Control for Safe Maintenance and Work Zone Operations	20	1	1	none		1	Aug-08	1	N/A	Field guide for install/removal	no pages to be extracted, nothing novel	none

Appendix D – Grey Literature – United States

Doc Number	Territory	Agency/Authority	Standard Name	Pages	Peds	Cyclists	Diagrams?	Notes	Current Version/Edi	Editions	Month/Year Published	Major Renewal	Standing	VRU Pages	Relevant Diagrams
	Alabama	Alabama Department of Transportation	https://www.dot.state.al.us/publications/Design/pdf/SpeedLimitWorkZone.pdf	16	2	0	none	*For determining speed limits for work zones only							
	Alaska	Alaska Department of Transportation	https://dot.alaska.gov/stwddes/dcsprecon/assets/pdf/preconhwy/chapters/chapter14.pdf	11	1	1	none								
	Arizona	Arizona Department of Transportation	https://azdot.gov/sites/default/files/2023-08/TrafficControlDesignGuidelines2019.pdf	49	15	5	lots		[unknown]	[unknown]	Sep-19	[unknown]	State-level Guidance Policy	no pages to be extracted, nothing relevant	none
AT 8	Arizona	Arizona Department of Transportation	Implementation Guidelines for Work Zone Safety Management	89	21	7	none	VRU specific	[unknown]	[unknown]	Sep-21	[unknown]	State-level Guidance Policy	don't remove any pages, whole document is useful	none
	Arkansas	Arkansas Department of Transportation	https://www.ardot.gov/wp-content/uploads/2021/12/2021-WZ-Final-Rule-Policy-ARDOT-11-24-21.pdf	36	0	0	none								
	California	California Department of Transportation	https://dot.ca.gov/-/media/dot-media/programs/traffic-operations/documents/tmp/tmp-guidelines-07202122763-rt1.pdf	63	46	22	none								
AT 9	California	California Department of Transportation	Pedestrian Accessibility Guidelinesfor Highway Projects	40	146	5	none	VRU specific	[unknown]	[unknown]	Nov-17	[unknown]	State-level Guidance Policy	don't remove any pages, whole document is useful	none
AT 10	California	California Department of Transportation	Pedestrian Considerations For California Temporary Traffic Control Zones	2	81	2	some	VRU specific	[unknown]	[unknown]	Jun-10	[unknown]	State-level Guidance Policy	don't remove any pages, whole document is useful	PDF pages 7, 8, 14, 16, 21

AT 11	California	California Department of Transportation	Temporary Pedestrian Access Routes Handbook	22	86	0	some	VRU specific	[unknown]	[unknown]	Jun-20	[unknown]	State-level Guidance Policy	don't remove any pages, whole document is useful	none
	Colorado	Colorado Department of Transportation	https://www.codot.gov/safety/traffic-safety/assets/work-zones/safety-mobility-program/policies-and-procedures/WZSM_Procedures.pdf https://www.codot.gov/safety/traffic-safety/assets/work-zones/safety-mobility-program/policies-and-procedures/CO_Guidelines_Positive_Protection_122809.pdf . VRU standard(s) - permanent only	92	20	20	none								
	Connecticut	Connecticut Department of Transportation	Safety reviews available but core document primarily refers to national guidance. VRU standard(s) - None available												
	Delaware	Delaware Department of Transportation	https://deldot.gov/Publications/manuals/de_mutcd/pdfs/final_rule_9_10_2007.pdf. VRU standard(s) - 2-page document but not containing any meaningful content on the subject	55	7	4	none								
AT 12	District of Columbia	District Department of Transportation	Pedestrian Safety and Work Zone Standards: Covered and Open Walkways	17	25	0	some	VRU specific	[unknown]	[unknown]	Jan-08	[unknown]	State-level Guidance Policy	don't remove any pages, whole document is useful	PDF pages 15, 16
	Florida	Florida Department of Transportation	https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/content2/roadway/ppmmanual/2017/volume1/chap10.pdf?sfvrsn=e84f8ef0_0 Also 4 VRU diagrams a part of wider TTM set of standard diagrams - https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/design/standardplans/2024/ser/rgeneralconstructionoperations.pdf?sfvrsn=5106f20c_2. VRU standard(s) -	76	36	12	none								
	Georgia	Georgia Department of Transportation	Outdated (broken link). VRU standard(s) - permanent only												
	Guam	Department of Public Works, Guam	None available. VRU standard(s) - None available												

	Hawaii	Hawaii Department of Transportation	None available. VRU standard(s) - None available												
	Idaho	Idaho Transportation Department	https://apps.itd.idaho.gov/apps/manuals/Work_Zone_Safety.pdf. VRU standard(s) - None available	21	4	4	none								
	Illinois	Illinois Department of Transportation	Outdated (broken link). VRU standard(s) - permanent only												
	Indiana	Indiana Department of Transportation	https://www.in.gov/indot/files/WorkZoneTCH.pdf. VRU standard(s) - Not separate from main TTM guidelines (Page 81 of main guidelines covers it)	87	20	0	lots	-							
	Iowa	Iowa Department of Transportation	Outdated (broken link). VRU standard(s) - None available												
	Kansas	Kansas Department of Transportation	https://www.ksdot.gov/PDF_Files/KANSAS%20WORK%20ZONE%20SAFETY%20AND%20MOBILITY%20POLICY%20MASTER.pdf. VRU standard(s) - None available	10	0	0	none								
	Kentucky	Kentucky Transportation Cabinet	https://transportation.ky.gov/Construction/Documents/workzonepolicy.pdf. VRU standard(s) - permanent only	15	0	0	none								
	Louisiana	Louisiana Department of Transportation	Two pages of content available but no material value. VRU standard(s) - permanent only												
	Maine	Maine Department of Transportation	None available. VRU standard(s) - None available												
	Maryland	Maryland Department of Transportation	Outdated (broken link). VRU standard(s) - None available												
	Massachusetts	Massachusetts Department of Transportation	http://www.neite.org/Resources/2010/MAITE%20Annual%20Meeting/MassDOT%27s%20Work%20Zone%20Transportation%20Management%20Procedures.pdf. VRU standard(s) - None available	27	4	1	none	Is a PPT presentation							
	Michigan	Michigan Department of Transportation	https://www.michigan.gov/mdot/-/media/Project/Websites/MDOT/Business/Work-Zone-Mobility/Maintenance-Work-Zone-Traffic-Control-Guidelines.pdf?rev=02e201af06f84d33a1d00ce6c3754398&hash=BBADED60F7370E516D9627B64F0DCC2C	74	3	1	lots		[unknown]	[unknown]	Apr-07	[unknown]	State-level Guidance Policy	no pages to be extracted, nothing relevant	none
AT 13	Michigan	Michigan Department of Transportation	Work Zone Safety and Mobility Manual	275	151	40	none		[unknown]	[unknown]	Oct-22	[unknown]	State-level Guidance Policy	PDF pages 21, 28, 36, 41, 44, 53, 54, 72, 73, 75, 79, 85, 87, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 122, 123,	none

													124, 128, 154, 182, 210, 222, 223, 225	
AT 14	Minnesota	Minnesota Department of Transportation	Minnesota Temporary Traffic Control Field Manual	200	67	25	none	Has traffic engineering manual too but link is broken	[unknown]	[unknown]	Jan-18	[unknown]	State-level Guidance Policy	PDF pages 6K-a, 6K-b, 6K-g, 6K-h, 6K-i, 6K-l, 6K-o, 6K-p, 6K-u, 6K-x, 6K-z, 6K-aa, 6K-cc, 6K-dd, 6K-ff, 6K-gg, 6K-19, 6K-35, 6K-66, 6K-78, 6K-87, 6K-89, 6K-90, 6K-91, 6K-92, 6K-93, 6K-117	none
AT 15	Minnesota	Minnesota Department of Transportation	Accommodating People On Bicycles Through Work Zones	28	31	193	some	only cycle-specific US guideline	[unknown]	[unknown]	Sep-21	[unknown]	State-level Guidance Policy	don’t remove any pages, whole document is useful	PDF Pages 14, 26
AT 16	Minnesota	Minnesota Department of Transportation	Pedestrian Accommodations through Work Zones Design Guidance	23	207	4	none		[unknown]	[unknown]	Nov-21	[unknown]	State-level Guidance Policy	don’t remove any pages, whole document is useful	none
	Mississippi	Mississippi Department of Transportation	None available. VRU standard(s) - None available												
AT 17	Missouri	Missouri Department of Transportation	Traffic Control for Non-Motorized Traffic	3	19	3	none	Uses a wiki rather than documents	[unknown]	[unknown]	Aug-20	[unknown]	State-level Guidance Policy	PDF pages 1, 2	none
	Montana	Montana Department of Transportation	Outdated (broken link). VRU standard(s) - Outdated (broken link)												
	Nebraska	Nebraska Department of Transportation	Outdated (broken link). VRU standard(s) - None available												
	Nevada	Nevada Department of Transportation	https://www.dot.nv.gov/home/showdocument?id=4756. VRU standard(s) - permanent only	63	28	6	none								

AT 18	New Hampshire	New Hampshire Department of Transportation	Work Zone Safety and Mobility Manual	107	78	10	none	No VRU doc - permanent only	[unknown]	[unknown]	May-22	[unknown]	State-level Guidance Policy	PDF pages 10, 16, 18, 19, 20, 49, 52, 53, 54, 55, 82	none
	New Jersey	New Jersey Department of Transportation	https://www.state.nj.us/transportation/eng/documents/BDC/pdf/TMG2014.pdf. VRU standard(s) - Table 7 on Page 62 of the permanent guidelines (https://www.state.nj.us/transportation/about/publicat/pdf/PedComp/pedintro.pdf) contains one page of temp guidelines (principles)	72	8	9	none								
	New Mexico	New Mexico Department of Transportation	https://realfilef260a66b364d453e91ff9b3fedd494dc.s3.amazonaws.com/07461f27-c74d-4416-9be4-d605d3d13ca1?AWSAccessKeyId=AKIAJBKPT2UF7EZ6B7YA&Expires=1692148522&Signature=H6qqKgKITr4%2FEwIbLqMzjInyB5o%3D&response-content-disposition=inline%3B%20filename%3D%22900%20Work%20Zone%20Safety.pdf%22&response-content-type=application%2Fpdf. VRU standard(s) - permanent only	106	77	25	none								
AT 19	New York	New York State Department of Transportation	Work Zone Traffic Control	159	128	97	some	No VRU doc available	[unknown]	[unknown]	May-23	[unknown]	State-level Guidance Policy	PDF pages 5, 6, 20, 21, 27, 33, 41, 46, 52, 56, 59, 61, 67, 69, 70, 71, 72, 73, 74, 75, 76, 84, 96, 104, 106, 115, 116, 119, 121, 122, 125, 126, 127, 130, 134, 139, 142, 143, 145	none
	North Carolina	North Carolina Department of Transportation	https://connect.ncdot.gov/projects/WZTC/Documents/TMP_Guidelines.pdf	74	20	6	none								
	North Carolina	North Carolina Department of Transportation	https://connect.ncdot.gov/projects/WZTC/Documents/WZSafetyAndMobilityGuidelines.pdf	26	5	1	none		[unknown]	[unknown]	Jul-18	[unknown]	State-level Guidance Policy	no pages to be extracted, nothing relevant	none
	North Dakota	North Dakota Department of Transportation	https://apps.nd.gov/itd/filenet/util/file/retrievePDF?objectstore=Department%20of%20Transportation&versionseriesid=%7BB4AB4E55-	37	unknown	unknown	none								

			D762-4669-A29E-87A036F76233%7D&type=C												
	Ohio	Ohio Department of Transportation													
	Oklahoma	Oklahoma Department of Transportation	No meaningful guidance												
AT 20	Oregon	Oregon Department of Transportation	Traffic Control Plans Design Manual	286	240	136	some		[unknown]	[unknown]	Jan-23	[unknown]	State-level Guidance Policy	PDF pages 14, 16, 17, 19, 20, 25, 29, 35, 52, 57, 59, 60, 71, 81, 85, 86, 87, 88, 90, 92, 93, 100, 109, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132-135, 136, 137, 138, 139, 140, 141, 172, 188, 202, 205, 208, 217, 221, 223, 224, 226, 231, 241, 250, 256, 259, 263, 264, 266, 268, 267, 279	PDF Pages 132-135, 141
AT 21	Oregon	Oregon Department of Transportation	Transportation Management Plan Project Level Guidance Manual	30	11	2	none		[unknown]	[unknown]	Jan-23	[unknown]	State-level Guidance Policy	PDF pages 5, 6, 9, 14, 18, 19, 22, 24, 25, 28	none
AT 22	Oregon	Oregon Department of Transportation	ODOT Temporary Pedestrian Accessible Routes (TPAR)	4	38	0	some		[unknown]	[unknown]	Oct-18	[unknown]	State-level Guidance Policy	don't remove any pages, whole document is useful	none
	Pennsylvania	Pennsylvania Department of Transportation	https://www.dot.state.pa.us/public/Bureaus/BOMO/Portal/WZSIP_Report.pdf. VRU standard(s) -	446	125	12	none								
	Puerto Rico	Puerto Rico Department of Transportation	https://act.dtop.pr.gov/fotos/transito/finalworkzonerule2015.pdf. VRU standard(s) -	9	unknown	unknown	none								
	Rhode Island	Rhode Island Department of Transportation	Outdated (broken link). VRU standard(s) -												
	South Carolina	South Carolina Department of Transportation	Outdated (broken link). VRU standard(s) -												
	South Dakota	South Dakota Department of Transportation	https://dot.sd.gov/media/documents/WorkZoneSafetyandMobilityPlan.pdf. VRU standard(s) -	9	9	2	none								

	Tennessee	Tennessee Department of Transportation	https://www.tn.gov/content/dam/tn/tdot/traffic-engineering/5-6-19-wz-manual/WZ%20Safety%20Mobility%20Manual%20Final%20-5-6-19.pdf. VRU standard(s) -	33	5	3	none								
	Texas	Texas Department of Transportation	Only one page of a wider document. VRU standard(s) -												
	Utah	Utah Department of Transportation	None available. VRU standard(s) -												
AT 23	Vermont	Vermont Agency of Transportation	Work Zone Safety and Mobility Policy and Guidance	124	318	266	some		[unknown]	[unknown]	Feb-21	[unknown]	State-level Guidance Policy	PDF pages 8, 10, 12, 16, 17, 19, 21, 23, 25, 26, 32, 33, 36, 37, 39, 40, 43, 46, 49, 63, 69, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95-96, 97, 98, 99, 100, 101, 102-109, 110, 111, 114, 123, 124	PDF Pages 87, 90, 91, 95-96, 102-109
AT 24	Vermont	Vermont Agency of Transportation	Vermont Bicycle and Pedestrian Work Zone Traffic Control Guide	48	286	235	some	VRU specific. VRU diagrams are duplicates of those held in the main Work Zone Safety and Mobility Policy and Guidance Document	[unknown]	[unknown]	Jul-18	[unknown]	State-level Guidance Policy	don't remove any pages, whole document is useful	PDF Pages 26-33
AT 25	Virginia	Virginia Department of Transportation	Virginia Department of Transportation Work Zone Pedestrian and Bicycle Guidance	36	132	57	some	VRU specific	[unknown]	[unknown]	Jan-16	[unknown]	State-level Guidance Policy	don't remove any pages, whole document is useful	PDF Pages 16-21, 25-30
AT 26	Washington	Washington State Department of Transportation	Work Zone Safety and Mobility	34	24	22	none		[unknown]	[unknown]	Sep-22	[unknown]	State-level Guidance Policy	PDF pages 4, 13, 14, 15, 17, 19, 20, 28, 29	none
	West Virginia	West Virginia Department of Transportation	None available. VRU standard(s) - None available												

AT 27	Wisconsin	Wisconsin Department of Transportation	Transportation Management Plan Process	67	208	27	none	-	2	2	Nov-22	3	State-level Guidance Policy	PDF pages 2, 4, 5, 7, 11, 12, 17, 18, 26, 27, 28, 30, 32, 51, 52, 53, 54, 55, 56, 57, 58, 59, 63, 65	none
	Wyoming	Wyoming Department of Transportation	None available. VRU standard(s) - None available												

Appendix E – Grey Literature – Consolidated Included Grey Literature List

Consolidated grey literature for inclusion in the integrative review		
ID	**Literature**	**Commentary and citation**
OGL1	Advanced Research on Road Work Zone Safety (ARROWS) Project	Focuses on technology-driven safety measures, mainly automated systems, to enhance road work zones' safety, emphasising the protection of road workers and users (National Technical University of Athens, 1998).
OGL2	Speed Management in Work Zones – The ASAP Project	It aims to develop methods to control vehicle speeds in construction areas, emphasizing its value in speed reduction and vulnerable road user safety (Thomson et al., 2014).
OGL3	WorkSafe NZ - Keeping healthy and safe while working on the road or roadside	It is a pivotal guide, with WorkSafe's regulatory role in NZ's workplace health and safety framework (WorkSafe NZ, 2022).
OGL4	Guidelines on Ensuring Positive Guidance in Work Zones	Focuses on standardising information for safe work zone navigation, addressing hazard visibility and consistency (The Roadway Safety Consortium, 2011).
OGL5	Accommodating Pedestrians in Work Zones Webinar (slides)	Sheds light on pedestrian treatment in work zones, emphasising the relevance and implementation of the associated guidance (Ullman et al., 2018).
OGL6	Waka Kotahi Cycling Safety Panel: Final Report	Offers insights into cycling safety innovations with transferable principles applicable to temporary settings (Cycling Safety Panel, 2014).
OGL7	Applying the Americans with Disabilities Act in Work Zones – A Practitioner Guide	Details the framework for accommodating individuals with disabilities in US work zones, aligning with ADA requirements (ATSSA, 2012).
OGL8	Pedestrian Considerations: Updated Checklist for Temporary Traffic Control Zones	Encapsulates pedestrian accommodation guidelines, especially for those with disabilities, in line with US regulations (ATSSA, 2021).
OGL9	Pedestrian Accommodation in Work Zones: A Field Guide	A field guide for pedestrian accommodations, emphasising federal regulations and compliance in the US. (Work Zone Safety Consortium, 2018)
OGL10	Everyone is a Pedestrian: For A Safe Path Through Work Zones	Educates the public on pedestrian safety in work zones (ATSSA, 2020).
OGL11	Guidelines for Work Zone Designers – Pedestrian and Bicycle Accommodation	Distills vulnerable road user treatment principles from various US jurisdictions (Shaw et al., 2023).

OGL12	Road works on cycle paths: knowledge compilation and problem description	A government-sponsored research project concerning treating cycle paths in TTM in Sweden (Niska & Eriksson, 2014).
OGL13	Research Report 708 - Research to support the application of a risk-based approach to temporary traffic management [in NZ]	Assesses a risk-based approach to TTM in NZ, incorporating a thorough literature review (Thomas et al., 2023).
OGL14	Good Practice Note: Environment & Social Framework for IPF Operations Road Safety	Published by the World Bank, this Good Practice Note is intended for deployment across World Bank activities, projects and initiatives and consolidates significant research around road safety that is valuable for this research (Bennett et al., 2019)
OGL15	Waka Kotahi Pedestrian Network Guidance (PNG): A Safe System for Walking	Permanent walking infrastructure guidance and principles published by Waka Kotahi (Waka Kotahi, 2023b, 2023c, 2023d).
OGL16	Waka Kotahi PNG: Principles of Safe, Obvious and Step-free (SOS)	
OGL17	Waka Kotahi PNG: Pedestrian network characteristics	
OGL18	Waka Kotahi Pedestrian Network Guidance – Implementation: Temporary Traffic Management (DRAFT)	An eventual part of Waka Kotahi's PNG will also be TTM guidance – linking permanent design principles to some exploration of temporary environments. This guidance is currently unpublished (Head, 2022).
OGL19	Waka Kotahi Cycling Network Guidance (CNG): Safety issues for people who cycle	Permanent cycling infrastructure guidance and principles published by Waka Kotahi (Waka Kotahi, 2014, 2023a, 2023e)
OGL20	Waka Kotahi CNG: Hierarchy of provision for cycling	
OGL21	Kiwirail - Design Guidance for Pedestrian & Cycle Rail Crossings	Presents human behaviour insights pertinent to TTM environments (Koorey et al., 2017).
OGL22	Research Report 621 - Regulations and safety for electric bicycles and other low-powered vehicles	Looks at the regulatory framework in New Zealand for these VRU modes, which helps inform the treatment of these users in the eventual TTM good practice guide (Lieswyn et al., 2017).
OGL23	Patterns in NZ Truck/Bike Crashes – Conference Paper	Analyses accidents between trucks and bicycles, offering insights into risk mitigation strategies for cyclists near heavy vehicles (Koorey & Mackie, 2018).
OGL24	Construction Logistics and Community Safety (CLOCS) Standard (UK)	Establishes standards for managing road risk, emphasising the protection of pedestrians, cyclists, and motorcyclists near construction sites (CLOCS, 2022).

OGL25	Transport for London TTM Handbook	Sets out good practices for those undertaking TTM on London's road network and contains prominent guidance relating to VRUs (TfL, 2018).
OGL26	Transport for London - Safer provisions for pedestrians at roadworks - A risk prioritisation framework	Specific guidance for managing the risk associated with pedestrians around roadworks on London's roads. A supplementary document to their TTM handbook (TfL, 2019).

Country TTM Standards (C)		
C1	Austroads Guide to Temporary Traffic Management (AGTTM)	Austroads
C2	ERF Towards Safer Works Zones	European Union Road Federation (ERF)
C3	IRIS Guidance Document on Temporary Traffic Management	Conference of European Directors of Roads
C4	TEM Guidelines on Workzone Safety	UNECE Trans-European Motorways Project
C5	Preventing Road Accidents and Injuries for the Safety of Employees (PRAISE): Road Safety at Work Zones	European Transport Safety Council
C6	Scoring Traffic at Roadworks (STARs) project	ERA-NET ROAD II
C7	Instruktion Råden over vejareal (Road Space Instructions for State Roads)	Danish Road Directorate
C8	Nõuded ajutisele liikluskorraldusele (Requirements for Temporary Traffic Management)	Republic of Estonia Transport Administration
C9	Tilapäiset liikennejärjestelyt katu- ja yleisillä alueilla (Temporary traffic arrangements in the street area)	Finnish Municipal Engineering Association
C10	Pyöräilijöiden tarpeet työnaikaisten tilapäisten liikennejärjestelyiden toteutuksessa (The needs of cyclists for temporary workers in the implementation of traffic arrangements)	Finnish Network of Cycling Municipalities
C11	Richtlinien für die verkehrsrechtliche Sicherung von Arbeitsstellen an Straßen (Guidelines for the traffic safety of work sites on roads)	Federal Ministry of Transport and Digital Infrastructure
C12	Temporary Traffic Measures and Signs for Road Works	Department of Transport (Ireland)
C13	Dėl automobilių kelių darbo vietų aptvėrimo ir eismo reguliavimo taisyklių	Ministry of Transport and Communications (Lithuania)

	(Order Regarding the Approval of Rules for Road Work Site Coverage and Traffic Regulation)	
C14	Code of Practice for Temporary Traffic Management (CoPTTM)	Waka Kotahi (NZ Transport Agency)
C15	New Zealand Guide to Temporary Traffic Management (NZGTTM)	Waka Kotahi (NZ Transport Agency)
C16	Technické Podmienky Používanie Dopravného Značenia A Dopravy Zariadenie Na Označovanie Pracoviskov (Technical Conditions Use Of Traffic Signs And Traffic Equipment For Marking Workplaces)	Slovak Road Administration
C17	도로안전시설 설치 및 관리지침 (Road Safety Facility Installation and Management Guidelines)	Ministry of Land, Infrastructure and Transport (South Korea)
C18	Trafikverkets tekniska krav för Arbete på väg (technical requirements for Work on the road)	Swedish Transport Authority
C19	Gatuarbete I Tätort: Handbok Till Stöd För Planering Och Genomförande (Street Work in Urban Areas: Hanbook to Support Pllanning and Implementation)	Swedish Association of Local Authorities and Regions (SALAR)
C20	Traffic Signs Manual: Chapter 8 - Traffic Safety Measures and Signs for Road Works and Temporary Situations	Department for Transport/Highways Agency (England) Department for Regional Development (Northern Ireland) Transport Scotland Welsh Assembly Government
C21	Work Zone Operations Best Practices Guidebook	Federal Highway Administration (FHWA) (United States)

Administrative Territory TTM Standards (AT)		
AT1	Traffic Management Manual for Work on Roadways (TMM)	British Columbia Ministry of Transportation and Infrastructure
AT2	Traffic Accommodation in Work Zones Manual	Transportation and Economic Corridors, Government of Alberta
AT3	Ontario Traffic Manual Book 7: Temporary Conditions	Ministry of Transportation, Ontario (MTO)
AT4	Temporary Workplace Traffic Control Manual	Department of Public Works, Nova Scotia

AT5	Traffic Control Manual	Department of Transportation & Works, Newfoundland & Labrador
AT6	Traffic Control Devices Manual for Work Zones	Ministry of Highways, Saskatchewan
AT7	Work Area Traffic Control Manual	New Brunswick Transportation and Infrastructure
AT8	Implementation Guidelines for Work Zone Safety Management	Arizona Department of Transportation
AT9	Pedestrian Accessibility Guidelines for Highway Projects	California Department of Transportation
AT10	Pedestrian Considerations For California Temporary Traffic Control Zones	California Department of Transportation
AT11	Temporary Pedestrian Access Routes Handbook	California Department of Transportation
AT12	Pedestrian Safety and Work Zone Standards: Covered and Open Walkways	District Department of Transportation
AT13	Work Zone Safety and Mobility Manual	Michigan Department of Transportation
AT14	Minnesota Temporary Traffic Control Field Manual	Minnesota Department of Transportation
AT15	Accommodating People On Bicycles Through Work Zones	Minnesota Department of Transportation
AT16	Pedestrian Accommodations through Work Zones Design Guidance	Minnesota Department of Transportation
AT17	Traffic Control for Non-Motorized Traffic	Missouri Department of Transportation
AT18	Work Zone Safety and Mobility Manual	New Hampshire Department of Transportation
AT19	Work Zone Traffic Control	New York State Department of Transportation
AT20	Traffic Control Plans Design Manual	Oregon Department of Transportation
AT21	Transportation Management Plan Project Level Guidance Manual	Oregon Department of Transportation
AT22	ODOT Temporary Pedestrian Accessible Routes (TPAR)	Oregon Department of Transportation
AT23	Work Zone Safety and Mobility Policy and Guidance	Vermont Agency of Transportation
AT24	Vermont Bicycle and Pedestrian Work Zone Traffic Control Guide	Vermont Agency of Transportation

AT25	Virginia Department of Transportation Work Zone Pedestrian and Bicycle Guidance	Virginia Department of Transportation
AT26	Work Zone Safety and Mobility	Washington State Department of Transportation
AT27	Transportation Management Plan Process	Wisconsin Department of Transportation

Appendix F – Terminology across different territories

Exhaustive list of TTM terminology across canvassed territories	
Primary Term	**Variations**
Temporary Traffic Management (TTM) *(20 items)*	Marking Of Road Works, Marking Of Workplaces, Road Safety Facilities, Road Traffic Control, Street Works, Technical Traffic Regulatory Measures, Temporary Signage, Temporary Signaling, Temporary Traffic Arrangements, Temporary Traffic Control, Temporary Traffic Management, Temporary Traffic Measures, Traffic Accommodation, Traffic Control, Traffic Control Person Zone, Traffic Control Systems, Traffic Guidance And Security, Traffic Management, Traffic Management And Control, Traffic Routing.
Traffic Management Plan (TMP) *(29 terms)*	Configuration Scheme, Control Plan, Explanatory Drawing, Geometric Layout, Internal Traffic Control Plan (ITCP), Marking Plan, Plan For Traffic Arrangements, Road Markings And Fencing Plans, Safety Facility Installation Plan, Schematic Plan, Sign Layout Diagram, Temporary Signaling Diagrams, Temporary Signalling Plan, Temporary Traffic Management Design, Temporary Traffic Management Plan, Traffic Accommodation Strategy Plans, Traffic Arrangement Plan, Traffic Control Layout, Traffic Control Plan (TCP), Traffic Guidance Scheme (TGS), Traffic Management Design, Traffic Management Plan, Traffic Management Plan (TMP), Traffic Management Scheme, Traffic Protection Plan (TPP), Transportation Management Plan (TMP), Transportation Operations Plan (TOP), TTM Plan, Workplace Equipment Scheme.
Traffic Management Personnel *(46 items)*	AFAD Operator, Designer, Entrepreneur, Flagger, Flagperson, Operator, Person Performing The Work, Person Responsible For Marking, Person Responsible For Traffic Management, Person Responsible For Traffic Safety, Person Working On The Road, Personnel, Personnel Supervising TTM, Qualified Person, Responsible Person, Road Manager, Road Worker, Site Traffic Management Specialist, Site Traffic Management Supervisor, TAS Certified Person, Temporary Workplace Signer, TMP Designer, Traffic Accommodation Supervisor (TAS), Traffic Control Implementer (TMI), Traffic Control Installer, Traffic Control Manager, Traffic Control Observer, Traffic Control Person (TCP), Traffic Control Persons (TCPS), Traffic Control Supervisor (TCS), Traffic Control Technician (TCT), Traffic Controller (TC), Traffic Guide, Traffic Management Guard, Traffic Management Operative, Traffic Observers, Traffic Operative, Traffic Professional, Traffic Safety Officer Person, Traffic Security Guide, Traffic Supervisor, TTM Designer, TTM Planner, TTM Worker, Work Zone Personnel, Workplace Personnel.
Vulnerable Road User Terms *(36 items)*	Alternate Pedestrian Routes (APR), Bicycle, Bicycle Path, Bicycles, Bicyclist, Bicyclists, Child, Cycle Path, Cyclist, Cyclists, Impaired Pedestrians, Mobility Impaired Pedestrians, Mobility-Assisted Pedestrians, Non-Motorized Traffic, Pedestrian, Pedestrian Access Route (PAR), Pedestrian Path, Persons With Disabilities, Pushchairs, Road Users With Impaired Vision, Mobility, Or Cognitive Limitations, Scooters, Senior Citizen, Special Needs Groups, Temporary Pedestrian Access Route (TPAR), Temporary Protective Facility, Those With Disabilities, Unprotected Personnel, Visually-Impaired Pedestrians, Vulnerable Highway Users, Vulnerable Transport User, Vulnerable Road Users, Vulnerable Work Operators, Walkers, Wheelchair Users, Wheelchairs.

Work Site *(33 items)*	Activity Area, Construction Site, Construction Work, Construction Zone, Controlled Area, Road Work, Road Workplaces, Road Works, Roadside Work, Roadwork Site, Roadwork Zone, Roadworks, Safety And Traffic Space, Shoulder Work, Temporary Traffic Control Zone, Temporary Work Area, Traffic Control Person Zone, Transportation Management Area (TMA), Utility Work, Work Activity, Work Activity Area, Work Area, Work Site, Work Site Identification, Work Zone, Working Area, Working Space, Workplace, Workplace Area, Workplaces On Roads, Works Area, Works On Roads, Worksite.

Appendix G – Compilation of unique legislative provisions for consideration with TTM

Acts of Parliament

Exhaustive exploration of relevant legislation to TTM		
Legislation	**Specific Provision(s)**	**Relevance/Expectations/Stipulations**
Biosecurity Act 1993	§6	§6 allows that any person authorised to implement a pest management plan that includes a road (as part of that plan) is, therefore, authorised to do so on that road
Building Act 2004	§133BS(2)(b)	§133BS(2)(b) requires that a responsible person must put in place measures to prevent or limit public access to buildings (and roads adjacent) that are earthquake prone.
Civil Defence Emergency Management Act 2002	§85(1)(f) §88	§85(1)(f) permits for the control of traffic within an area or district to the extent required to conduct civil defence emergency management when such an event is declared §88 permits the closure of public roads by authorised persons if required in an area under a declared state of emergency
Crimes Act 1961	§145(1) §270	§145(1) provides that criminal nuisance is committed when someone commits an act or omission that they knew would endanger someone else's life. §270 provides that anyone endangering (or interfering with) a transport facility (which includes vehicles used for transport, and any equipment used in service of transport facilities such as signs etc.) commits an offence.
Electricity Act 1992	§24(2) §24A(1)	§24(2) provides that any electricity operator has the power to undertake work in the road but must abide by any reasonable conditions prescribed by the local authority while doing so. §24A(1) sets the criteria for reasonable conditions from the local authority and includes consideration for the safe and efficient flow of traffic, the health and safety of anyone affected by the work, and the coordination with other work that may be occurring.
Fencing Act 1978	*Shortlisted due to its reference in the CoPTTM, but no specific provisions carried forward concerning this research.*	
Fire and Emergency New Zealand Act 2017	§12(3)(e) §44(1)(b)	§12(3)(e) establishes that Fire and Emergency New Zealand (FENZ) may, if capacity and capability allow, assist with transport accidents such as providing traffic control. §44(1)(b) provides that an authorised person (under this Act) may close any road in the vicinity of an emergency to people or traffic

Fire Service Act 1975	*Shortlisted due to its reference in the CoPTTM but has been repealed and replaced by the Fire and Emergency New Zealand Act 2017.*	
Gas Act 1992	§25	§25 Permits gas operators to conduct construction and maintenance activities on public roads, subject to local authority conditions
Government Roading Powers Act 1989	§48(3)(e) §61(4)(e) §61(4)(h) §61(4)(i)	§48(3)(e) provides that roads under the control of the Minister (and by extension, the Government) maintain roads in good repair and place devices in the road to control vehicle speeds where it is desirable for the safety of road workers or users of the road (or to protect part of the road). §61(4)(e) provides a similar requirement to be undertaken by the Agency (in relation to state highways) as outlined in §48(3)(e). §61(4)(h) grants the authority to temporarily control traffic on state highways for work, investigation, or structural protection. §62(4)(i) allows for the closure of any state highway for necessary repairs or obstruction removal.
Health and Safety at Work Act 2015 (HSWA)	§20 §28 §30 §31 §34 §36 §37	The act mandates everyone to be protected from workplace health and safety risks. It clarifies that all parties involved in TTM, from the client to the contractor, have obligations to workers and road users. §20 defines a workplace as any location where work is conducted for a business, including places a worker is likely to be, which in the context of TTM would include activity undertaken in a road reserve. §28 invalidates any contractual terms that seek to limit, exclude, or transfer any duty under the Act, ensuring that legal obligations for health and safety are non-negotiable and cannot be contractually avoided. §30 mandates the elimination of health and safety risks where reasonably practicable, and if not, minimising those risks. §31 clarifies that duties related to health and safety are non-transferable §34 requires PCBUs with the same duty regarding a matter to consult, cooperate, and coordinate activities, mandating collaborative risk management. §36 delineates the primary duty of care by a PCBU to ensure, as far as is reasonably practicable, the health and safety of workers and other persons, encompassing a range of responsibilities from providing a safe work environment to monitoring health conditions and providing sufficient training, instruction and supervision concerning risks arising from work tasks. In the context of TTM, this would include all workers present at a workplace in the road

		corridor, as well as all transient persons through that workplace (i.e. road users) §37 obliges a PCBU who manages or controls a workplace to ensure that the workplace and the means of entering and exiting it are without risks to health and safety.
Human Rights Act 1993	§21	§21 provides that discrimination on the grounds of physical disability, including reliance on disability assistance (i.e. a dog, or wheelchair) is prohibited. Furthermore, discrimination on the grounds of age is also prohibited.
Impounding Act 1955	*Shortlisted due to its reference in the CoPTTM, but no specific provisions carried forward concerning this research.*	
Land Transport Act 1998	§2 §22AB §113(3) §153 §157	§2 provides that a motor vehicle does not include any machine that is pedestrian controlled. §2 also provides that a mobility device is a vehicle design and constructed for use by persons who require mobility assistance and is powered by a motor with a power output not exceeding 1500W. §22AB provides that a road controlling authority may make bylaws relating to the use of roads under their jurisdiction §113(3) provides that enforcement officers may direct people (both those in vehicles, and pedestrians) to stop and/or proceed including crossing a road. §153 allows for the provision of rules concerning road user behaviour (including pedestrians and cyclists) §157 allows for the provision of rules (land transport rules) in relation to land transport such as the setting of speed limits rule and the traffic control devices rule (explored in the secondary legislation section).
Land Transport Management Act 2003 (LTMA)	§3 §5(3) §35 §94 §95(1)(g) §95(1)(h) §95(1)(n) §95(1)(p)	TTM is utilised by those who deliver work within the land transport funded umbrella as a mechanism to facilitate safe work and improve the safety of the land transport system in general. §3 establishes the act purpose to contribute to an effective, efficient, safe land transport system in the public interest. §94 mirrors this purpose with the objective of the Agency (Waka Kotahi, which is established under this Act). §5(3) provides the Agency (in this case, Waka Kotahi) the right to define the boundaries of all the parts of the road such as carriageway, footway etc. §35 requires those preparing any programme or plan to consider the needs of transport-disadvantaged persons. §95(1)(g) establishes the Agency's obligation to investigate and review accidents involving transport

		on its land in its capacity as the responsible safety authority. §95(1)(h) obliges the Agency to manage the State Highway network for New Zealand §95(1)(n) obliges the Agency to deliver or manage delivery of activities relating to research, education, and training concerning the land transport system §95(1)(p) obliges the Agency to issue reports and guidance and comment on any other matters relating to the land transport system and its participants
Litter Act 1979	*Shortlisted due to its reference in the CoPTTM, but no specific provisions carried forward concerning this research.*	
Local Government Act 2002 and 1974 (LGA)	§145 of LGA 2002 §353 of LGA 1974 Schedule 10 of the LGA 1974	§145 allows territorial authorities to make bylaws for public health and safety. §353 mandates that the council take public safety and traffic precautions during road construction or repair. Schedule 10 establishes the provisions for an RCA to temporarily prohibit traffic from a road or part of a road (i.e., a road closure).
Plain Language Act 2022	§4 §5 §6	§4 provides that a reporting agency is a crown agent, or public service agency (in the context of the applicability of this Act). §5 establishes that plain language is appropriate to the intended audience and clear, concise, and well organised. §6 requires that if a document is in English, and intended for the general public, and published by a reporting agency, then plain language must be used.
Policing Act 2008	§35(1)	§35(1) allows for sworn officers to temporarily close any road (including pedestrian traffic) if there is reasonable cause for public disorder, danger, or the discovery that a serious crime[2] may have been committed.
Public Works Act 1981	*Shortlisted due to its reference in the CoPTTM, but no specific provisions carried forward concerning this research. Many of the relevant clauses of the original Act have been repealed and replaced by the Government Roading Powers Act 1989 (which is explored separately)*	
Railways Act 2005	§7 §8 §9 §80(1)(a) §80(2)	The Railways Act primarily establishes obligations concerning the rail corridor and its operation. However, in all instances where there is road/rail interface[3], such provisions would have application. §7 outlines obligations for any rail participant or personnel[4] to ensure (so far as reasonably practicable) the safety of others.

[2] Defined as an offence punishable by 10 years or more imprisonment.
[3] New Zealand has over 3000 road/rail level crossings giving rise to these interfaces (Kiwirail, 2003).
[4] Rail participants, and by extension personnel, are any engaged in relevance to the rail corridor, such as operators or maintenance providers.

		§8 ensures this Act does nothing to limit the Health and Safety at Work Act 2015 §9 establishes expectations for anyone who interferes with parts of the rail network, including rail crossings and the infrastructure associated, such as signals and signage. §80(1)(a) establishes the right of way of all rail vehicles at level crossings. §80(2) establishes an expectation when warning devices at level crossings are being considered, that adjacent parties (such as RCAs) are consulted.
Resource Management Act 1991[5]	§2(1) §237C	§2(1), as related to §237C, defines an access and esplanade strip as areas that aim to, among other things, protect public access to water bodies, reserves, or crown/local authority owned land. §237C allows that an esplanade or strip may be closed to the public under a consent, and the local authority shall ensure such closure is adequately notified (including notice that it is an offence to enter the closed area) by the use of signs at all entry points (unless the easement indicates another party is responsible for such notification).
Summary Offences Act 1981	§12 §22(1)	§12 provides that any act endangering safety in any public place (such as placing any obstruction, leaving a hole, or removing a protective structure or warning sign or device) is an offence. §22(1) provides that any person obstructing (unreasonably impeding normal passage) a public way[6] and continues to do so after a warning from a police officer commits an offence.
Telecommunications Act 2001[7]	§119(1) §135	§119(1) sets the criteria for reasonable conditions from the local authority and includes consideration for the safe and efficient flow of traffic, the health and safety of anyone affected by the work, and the coordination with other work that may be occurring. §135 provides that any network operator has the power to undertake work in the road but must abide by any reasonable conditions prescribed by the local authority while doing so.
Transport Act 1962	*Shortlisted due to its reference in the CoPTTM but has been repealed. Specific bylaw provisions that remain in force are covered under the Land Transport Act 1998.*	

[5] The impending Natural and Built Environment Act 2023 was also canvassed however no relevant provisions were identified concerning this research.
[6] Public way means any street, road, path, mall, arcade or other way over which the public has the right to pass and repass.
[7] These provisions mirror those of the Electricity Act 1992 (§119(1) mirrors §24A(1), §135 mirrors §24(1))

Utilities Access Act 2010	§6 §9	§6 establishes the legislative stipulation that utility operators and corridor managers[8] must comply with the Code (defined separately as the National Code of Practice for Utility Operators Access to Transport Corridors). §9 establishes the purpose of the Code, which includes the assurance of access to roads for utility operators, ensures that disruption to roads by utility operators is minimised while maintaining safety, and ensures a nationally consistent approach to access to transport corridors (for utility operators).

Rules, Regulations, and other provisions

Exhaustive exploration of relevant second tier legislation and other instruments pertinent to TTM[9]		
Legislation	**Specific Provision(s)**	**Relevance/Expectations/Stipulations**
Health and Safety at Work (General Risk and Workplace Management) Regulations 2015.	§3 §6 §7 §8 §9	§3 outlines the definitions of administrative and engineering controls, emphasising methods of work and physical measures, respectively, to minimise risk. §6 mandates the hierarchy of controls – from elimination to engineering/substitution/isolation to administrative to PPE. §7 underscores the need for maintaining the effectiveness of control measures, a key aspect in the dynamic environment of TTM. §8 necessitates the periodic review and revision of control measures. §9 requires adequate training or supervision for workers in their tasks that may generate workplace risks.
Health and Safety at Work (Worker Engagement, Participation, and Representation) Regulations 2016	*Shortlisted, but no specific provisions carried forward concerning this research.*	
Land Transport (Road User) Rule 2004	§1.6 §2.13 §3.1 §6.14 §8.3	§1.6 defers to the Land Transport Rule: Traffic Control Devices (TCD) Rule 2004 for the definition of a pedestrian crossing (§8.2) which in turn describes a permanent fixture, meaning that provisions of this Rule that relate to pedestrian crossings are contained to such fixtures.

[8] As provided in §4, corridor managers include any local authority that has jurisdiction over any road.
[9] Targeted relevant provisions are distilled into the *Resultant legislative expectations for include* section

	§10.2 §11.1 §11.1A §11.11 §11.18 §11.3 §11.4	§1.6 also defines a pedestrian as a person on foot on a road, and a *“person in or on a contrivance equipped with wheels or revolving runners that is not a vehicle”*. §1.6 also defines a ‘wheeled recreation device’ meaning something of wheeled conveyance, excluding a cycle with wheels exceeding 355mm in diameter (including powered devices up to 300W). §2.13 prohibits drivers from driving on the footpath, excluding mopeds or motorcycles that are delivering newspapers or mail (with authorisation). §3.1 requires that road users obey traffic control devices, and where traffic control devices are installed near traffic signals (and they conflict), the traffic control devices take precedence. §6.14 outlines that drivers must not park on footpaths (or cycle paths). This does not include mobility devices, or recreational devices, provided they do not obstruct any other users. §8.3 provides that vehicle lighting must not be used in such a way that dazzles, confuses, or distracts so as to endanger the safety of other road users. §10.2 states a driver must give way to pedestrians in shared zones, but pedestrians must not unduly impede the passage of vehicles in those zones. §11.1 requires that pedestrians must use the footpath if provided and mobility device users must use the footpath (if practicable). It also stipulates that if these users do have to use the road, they must stay as close to the edge as possible. It also stipulates that any user of a wheeled recreational device must give way to pedestrians, and drivers of mobility devices. Furthermore, pedestrians must not unduly impede the passage of a mobility device or wheeled recreation device. §11.1A establishes use of a shared path – permitting pedestrians, cyclists, mobility device users, and wheeled recreation device users to use such a path. Users must use such a path in a careful and considerate manner, and not use it in a manner than constitutes a hazard to others using it. This provision also establishes that signs on the path may stipulate specific priorities of users (i.e. cyclists) and if so, such stipulations must be adhered to. §11.11 prohibits someone from riding a cycle on the footpath (unless delivering mail/newspapers etc.). Read in conjunction with §11.1 and §1.6, means that cyclists cannot ride on the footpath however wheeled recreational devices may (provided they give way to pedestrians, and their wheel diameters do not exceed 355mm). §11.18 requires that emergency vehicles, when using lights and sirens, must still comply with traffic control devices but may simply slow to no more than 20km/h and take due care to avoid collision with pedestrians or traffic. §11.3 requires that pedestrians must not cross a road within 20 metres of a formal pedestrian crossing, or traffic signals.

		§11.4 requires pedestrians or cyclists crossing the road (not at pedestrian crossings) to do so at right angles to the road edge, where practicable.
Land Transport Rule: Setting of Speed Limits Rule 2022	§7.1 §7.2 §7.4 §7.5 §7.6 §7.7 §7.8	Provisioned under the Land Transport Act 1998 (under land transport ordinary rules) §7.1: Road controlling authorities must consider setting temporary speed limits in cases of work on roads, unsafe surfaces, special events, or emergencies. §7.2: Temporary speed limits are enforced through signage, must be at least 10 km/h less than any existing speed limit and must be approved in writing via a traffic management plan by the RCA. §7.4: Before setting a temporary speed limit due to work, the road controlling authority must assess the risk to workers and the public. §7.5: Temporary speed limits due to unsafe road surfaces must be set after evaluating the risk to the public. §7.6: For special events, the road controlling authority must set a temporary speed limit considering the nature of the event and the risk to the public. §7.7: In emergencies, the speed limit must be set considering the circumstances and the risk to the community and the public. §7.8: The reasons for setting an emergency speed limit must be recorded in writing. §7.9: Emergency speed limits must be removed when they are no longer necessary
Land Transport Rule: Traffic Control Devices (TCD) Rule 2004	Part 2 - Definitions[10] §2.1(1) §3.2(2) §4.2(5) §4.2(6) §4.2(7) §4.3(1)(b) §4.3(2) §4.4(19) §4.4(20) §7.9 §8.1(2)	Provisioned under the Land Transport Act 1998 (under land transport ordinary rules) Part 2 Definitions defines a Cycle (*“a vehicle having at least two wheels and that is designed primarily to be propelled by the muscular energy of the rider and includes a power-assisted cycle.”)*; and a Cycle Lane *(“a longitudinal strip within a roadway designed for the passage of cycles”)*; and a Cycle Path *(“means part of the road that is physically separated from the roadway that is intended for the use of cyclists, but which may be used also by pedestrians; and (b) includes a cycle track[11]”)* §2.1(1) states that an RCA is responsible for authorising the installation, operation, and removal of traffic control devices (for reasons such as instructing road users, or warning road users of hazards). §3.2(2) states that a person must not provide or operate a traffic control device on a road without obtaining approval from the RCA first (except in specific circumstances such as emergency services, or accident triangles etc.).

[10] These definitions are utilised in the exploration of Vulnerable Road User types in Appendix B.
[11] As referenced in §332 of the Local Government Act 1974

		§4.2(5) mandates road controlling authorities to install temporary warning signs if there is a temporary danger to the public or road workers or damage to the road. §4.2(6) allows emergency services personnel or workers involved in hazard removal to erect appropriate temporary warning signs. §4.2(7) and 4.2(8) stipulate the conditions for removing temporary warning signs. §4.3(1)(b) and 4.3(2) describe the types of traffic signs that can be used for temporary hazards or risks. §4.4(19) and 4.4(20) allow for variable traffic signs to be mounted on a motor vehicle for temporary traffic management, provided they operate following a traffic management plan. §7.9 provides that a road controlling authority may provide a TCD to channel traffic, restrict the speed of traffic, or discourage the through use of a road. That RCA may use signs, markings, or delineators. If such treatment involves a slow point or a chicane (intended to reduce speed) then it must be illuminated or have reflective delineators or reflective signs installed so that it is visible. §8.1(2) provides options for road controlling authorities to assist pedestrians in crossing roadways without necessarily requiring drivers to stop. This encompasses using devices such as signs and markings.
National Code of Practice for Utility Operators' Access to Transport Corridors[12]	Definitions §2.5(1)(b) §4.3.3(1) §5.3 §5.4(1)(c) §5.5.1(a) §5.6.6(2) Schedule B (1)(u) Schedule C – Supporting Processes – Risk management process	Definitions – defines a Traffic Management Plan (TMP), which is *"An approved site-specific plan, which addresses the management of movement of vehicles, cyclists and pedestrians through or past the Work Site and the safety needs of both the Public, the Contractors and (for Railway Corridors) persons who access the Railway Land. For Road Corridors, the TMP must be in accordance with the Code of Practice for Temporary Traffic Management or other approved local standards."* §2.5(1)(b) requires that the utility operator must develop, obtain approval, and implement a site traffic management plan (TMP). §4.3.3(1) requires the utility operator to supply a traffic management plan that is site-specific and designed by a suitably qualified person or generic but matches the road layout it is to be used for and complies with CoPTTM (or other approved local standards) §5.3 requires utility operators to implement the approved TMP, remedy non-compliance from a worksite audit (or cease work until they can), and follow instructions from any police officer concerning traffic management. §5.4(1)(c) requires any emergency works to facilitate a safe working area (by provision of safety measures) before starting work

[12] Whilst this instrument is not itself a piece of legislation, it is legislated under the Utilities Access Act 2010 and as such as been added to the table.

		§5.5.1(a) requires the protection of public safety at all times at worksites with trenches §5.6.6(2) requires Utility Operators to ensure any temporary road markings used are of an approved type and suitable (as specified by the corridor manager) Schedule B (1)(u) – as a template for general conditions, requires utility operators to follow instructions from a road corridor manager concerning traffic management and safety. Schedule C – Supporting Processes – Risk management process – outlines a non-prescriptive risk management framework for devising approaches to above-ground utility structures. This process mirrors that found in ISO31000 but applies the process to the context of utility operators working on the road. It establishes the expectation that road users and workers' safety. It also introduces the concept of lowest total risk, risk transfer, and reasonably practicable – mirroring the Health and Safety at Work Act 2015 expectations and its subordinate legislation.
Transport (Vehicular Traffic Road Closure) Regulations 1965	§3 §8	Provisioned under the Transport Act 1962 §3 allows for a controlling authority to close a road to ordinary vehicular traffic (specifically for event-like activities) §8 allows a controlling authority to issue permits for the use of closed roads

Appendix H – Consolidated NZ legislative provisions relevant to the treatment of vulnerable road users in TTM

<table>
<tr><th colspan="8">New Zealand legislative provisions relevant to the treatment of vulnerable road users in TTM[13][14][15]</th></tr>
<tr><th>Provisions relating to definitions</th><th>Provisions relating to those setting standards[16]</th><th>Provisions relating to Road Controlling Authorities</th><th>Provisions relating to other agencies</th><th>Provisions relating to Clients</th><th>Provisions relating to Contractors</th><th>Provisions Relating to Road Users</th><th>Provisions relating to Enforcement or Emergencies</th></tr>
<tr><td rowspan="3">Pedestrians are those on foot in a roadway or anyone in or on a contrivance equipped with wheels that is not a vehicle. Separately, such devices are defined as a 'wheeled recreational device' which may use a footpath but must give way to pedestrians and mobility devices[17].</td><td rowspan="3">Subordinate rules may govern road user behaviour or the design and use of traffic control devices – which would be legally enforceable and applicable to TTM environments and vulnerable road users. Such rules may subsequently be updated/provisioned at the ministerial level, meaning standards conditional on such rules must adhere to such changes.</td><td colspan="4">All entities (PCBUs) must, so far as reasonably practicable, ensure the health and safety of all workers and other persons[20] who come into contact with their workplaces, including safe entry and exit. Where more than one party is involved, they must coordinate, cooperate, and communicate on the best methods to manage risk[18]. Parties must manage risks to health and safety according to the hierarchy of controls – mandating elimination first, and then other engineering-like controls (such as isolation) before administrative and then personal protective controls last. They must also ensure that any control measures used are reviewed and remain effective. They must also provide adequate training, instruction or supervision for workers in their tasks that give rise to risks[19].</td><td>All road users must conform to instructions given by enforcement officers relating to their movement in the road corridor[17], and any person obstructing a public way commits to an office if they continue to do so after a warning from a police officer[20].</td><td rowspan="3">Traffic control, including closing roads, may be undertaken by civil defence authorised persons[21], FENZ personnel[22], and police officers[23] under their respective Acts. Any entities undertaking TTM on the road would be required to conform with instructions given by such personnel under such circumstances.</td></tr>
<tr><td colspan="4">In any event where a public esplanade or strip (that is, for public access to natural resources/environments) is to be closed (under consent), then this must be notified to the public through signage at all entry points, including that it is an offence to enter the area[24].</td><td>Cyclists must not ride on the footpath, and shared paths must give way to pedestrians unless signposted priorities apply[17].</td></tr>
<tr><td colspan="4">Temporary speed limits (TSLs) may be used where there is a risk to road users, the public, or road workers, unsafe road surfaces, public events, or emergencies. A risk assessment must precede any use of a TSL. Any TSLs must be approved in writing via a TMP by the RCA, and a record of the time and location of any installation must be kept. The reason for any TSL must be evident to the road user.</td><td>Drivers must obey traffic control devices, not park or drive on footpaths, and give way to pedestrians in shared zones[17].</td></tr>
<tr><td rowspan="2">A cycle is designed to be propelled primarily by muscular energy and includes a power-assisted cycle. A cycle lane is a longitudinal strip primarily designed for the passage of such cycles, while a cycle path is a segregated provision[25].</td><td rowspan="2">Plain language must be used for documents intended for the general public if produced by a crown agent or public agency[26].</td><td colspan="4">Persons may not be discriminated against due to their age or the presence of a disability, including where such persons may rely on aides for such disability (such as dogs, walkers, or wheelchairs)[27].</td><td rowspan="2">Pedestrians (mobility and wheeled recreational devices) must use the footpath if available, and if not, must be as far to the edge of the road as possible. They must also, if crossing the road not at a pedestrian crossing, do so at right angles to the road edge[17].</td><td>Emergency services may erect temporary warning devices/signs[25].</td></tr>
<tr><td>An RCA is responsible for authorising the installation, operation, and removal of traffic control devices (for reasons such as instructing or warning road users of hazards). Such devices must be installed if there is a temporary danger to the public or road workers or damage to the road. RCAs may assist pedestrians in crossing the road without a formal pedestrian crossing by using signs and markings (other traffic control devices)[25].</td><td colspan="3">Electricity[28], Telecommunications[29], or Gas[30] operators have the power to undertake work in the road corridor but may have reasonable conditions imposed on them by the road controlling authority to ensure safety, the efficient flow of traffic, and coordination with other works. They must also comply with the 'Code'[31], which requires TMPs to be fit-for-purpose, prepared by a suitably qualified person, be implemented (following approval), and facilitate the protection of public safety.</td><td>Earthquake-prone buildings require responsible persons to prevent or limit public access if required (including adjacent roads). Such requirements would then need to be enacted, complying with the HSWA 2015[32].</td></tr>
<tr><td colspan="2">Waka Kotahi has the right to define the boundaries of all of the parts of a road (such as carriageway, footway, etc.). Depending on the context, such definitions would affect how and where vulnerable road users may operate and thus require TTM treatment[33].</td><td colspan="3">Roads must be maintained in good condition, and to do so, devices may be placed to control speeds where it is desirable for the safety of road workers or users (or protection of the road itself). This extends to the use of road closures and the temporary control of traffic where necessary[34]. Local Councils must also take public safety and traffic precautions during road construction and repair[35].</td><td colspan="2" rowspan="2">It is an offence to tamper with or compromise the effectiveness of measures at level crossings. In the context of TTM, such measures must remain effective at all times[38].</td><td rowspan="4">Emergency vehicles must comply with traffic control devices (specifically concerning pedestrians) but can be considered 'compliant' if they drop to 20km/h and avoid collision with pedestrians or traffic[25].</td></tr>
<tr><td rowspan="3">Mobility devices may be motorised, not exceeding 1500W, and may be pedestrian controlled – and these are not classed as motor vehicles[36].</td><td colspan="4">Those preparing any programme or plan (concerning Land Transport) must consider the needs of disadvantaged persons[33]. This establishes an explicit obligation for such persons to be considered holistically in the land transport system, including during the construction and maintenance of land transport facilities.</td></tr>
<tr><td>Waka Kotahi must manage the State Highway Network[33].</td><td>RCAs may make bylaws for the roads under their jurisdiction or public health and safety[37], which could give rise to jurisdiction-specific requirements for vulnerable road users.</td><td rowspan="2">Rail participants must ensure (so far as reasonably practicable) the safety of others[38].</td><td colspan="3">Rail vehicles have the right of way at all level crossings. Such a requirement would have to be adhered to in any TTM-related guidance where there is a road/rail interface and would also apply to road users of the corridor[38].</td></tr>
<tr><td colspan="2">Waka Kotahi delivers or manages activities relating to training, education, or research and issue reports and provides guidance or comment concerning the land transport system (and its participants)[33].</td><td>Any signs installed with the purpose of TTM must comply with the TCD Rule and be approved by the RCA[25]. Any devices must be illuminated or reflective in nature[33] if traffic slowing is intended.</td><td colspan="2">Someone may not undertake an act (or omission) they know would endanger someone's life[39] or interfere with a transport facility (including signs or equipment)[39]</td></tr>
</table>

13 The term 'relating to' is used for the headings of this table –many provisions extend to other parties as well. This table simply outlines the most relevant party(ies) for each provision.
1414 The legislation explored in this table is in no particular hierarchical order.
1515 This page is intended to be viewed or printed in A3 size.
16 For example, the resultant good practice guide that this research is intending to inform.
17 Land Transport (Road User) Rule 2004
18 Health and Safety at Work Act 2015 (HSWA 2015)
19 Health and Safety at Work (General Risk and Workplace Management) Regulations 2015.
20 Summary Offences Act 1981.
21 Civil Defence Emergency Management Act 2002
22 Fire and Emergency New Zealand Act 2017
23 Policing Act 2008
24 Resource Management Act 1991
25 Land Transport Rule: Traffic Control Devices (TCD) Rule 2004
26 Plain Language Act 2022
27 Human Rights Act 1993
28 Electricity Act 1992
29 Telecommunications Act 2001
30 Gas Act 1992
31 National Code of Practice for Utility Operators' Access to Transport Corridors
32 Building Act 2004
33 Land Transport Management Act 2003 (LTMA 2003)
34 Government Roading Powers Act 1989
35 Local Government Act 1974
36 Land Transport Act 1998
37 Local Government Act 2002
38 Railways Act 2005
39 Crimes Act 1961

Appendix I – Catalogue of Academic Database Searches Conducted

Search No.	Avenue	Search Description	Search String	Database	Additional Search parameters (after hitting 'search' - select these options on the left	Number of results after filters applied	Date of Search	Search URL
1	Vulnerable Road Users (VRU) Treatment in Temporary Traffic Management (TTM)	VRU Terms + Traffic Management (and NOT air, rail, telecommunication)	(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND "Traffic Management" NOT (air OR rail OR telecommunication*)	Scopus	2014 - 2023 Keywords - Traffic Management Traffic Assignment Pedestrianization Subject area: Excluded Computer Science Excluded Environmental Science Excluded Mathematics Excluded Medicine kept Social Sciences	1	11-Sep-23	
2	Vulnerable Road Users (VRU) Treatment in Temporary Traffic Management (TTM)	VRU Terms + Traffic Control (and NOT air, rail, telecommunication)	(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND "Traffic Control*" NOT (air OR rail OR telecommunication*)	Scopus	2014-2023 Excluded computer science Excluded Information Technology Excluded Information Security Excluded Intelligent Computing Excluded Firmware Excluded Access Control Excluded Trusted Computing	3	11-Sep-23	
3	Vulnerable Road Users (VRU) Treatment in Temporary Traffic Management (TTM)	VRU Terms + Traffic Guidance (and NOT air, rail, telecommunication)	("Traffic Management" OR "Traffic Guid*" OR "Traffic Control*" OR "Work Zone" OR "Road Work") AND method* AND NOT (air OR rail OR telecommunication*)	Scopus		7	13-Sep-23	https://shorturl.at/diA36
4	TTM Principles and Philosophies	TTM Terms + Method (and NOT air, rail, telecommunication)	("Traffic Management" OR "Traffic Guid*" OR "Traffic Control*" OR "Work Zone" OR "Road Work") AND (method* OR approach* OR guide* OR principl* OR philosoph* OR strateg*)	Scopus		25	12-Sep-23	Scopus - Document search results | Signed in
5	VRU Psychology, Compliance, Behaviour, or Needs Relevant to TTM	VRU Terms + Behaviour	(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND (behavio* OR respon* OR attitude* OR perception* OR psycholog*)	Scopus		169	13-Sep-23	https://shorturl.at/cfv09
6	Compilation and Presentation of Good Practice Guides in TTM and Comparable Disciplines	Health and Safety + Guide or Protocol or Practice or Standard AND Produce	"safety" AND (guide* OR protocol* OR practice* OR standard*) AND NOT (auto* OR food OR china OR patient OR agric* OR robo* OR covid OR nurs*)	Scopus		32	14-Sep-23	https://shorturl.at/brt38
7	Vulnerable Road Users (VRU) Treatment in Temporary Traffic Management (TTM)	VRU Terms + Traffic Management (and NOT air, rail, telecommunication)	(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND "Traffic Management" NOT (air OR rail* OR telecommunication*)	TRID		2	12-Sep-23	https://shorturl.at/uEGL5

8	Vulnerable Road Users (VRU) Treatment in Temporary Traffic Management (TTM)	VRU Terms + Traffic Control (and NOT air, rail, telecommunication)	(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND "Traffic Control*" NOT (air OR rail OR telecommunication*)	TRID	2014-2023 English only	4	12-Sep-23	https://shorturl.at/jOQ23
9	Vulnerable Road Users (VRU) Treatment in Temporary Traffic Management (TTM)	VRU Terms + Traffic Guidance (and NOT air, rail, telecommunication)	("Traffic Management" OR "Traffic Guid*" OR "Traffic Control*" OR "Work Zone" OR "Road Work") AND method* NOT (air OR rail* OR telecommunication*)	TRID	2014-2023 English only Articles and papers	46	12-Sep-23	https://shorturl.at/hsvN7
10	TTM Principles and Philosophies	TTM Terms + Method (and NOT air, rail, telecommunication)	("Traffic Management" OR "Traffic Guid*" OR "Traffic Control*" OR "Work Zone" OR "Road Work") AND (method* OR approach* OR guide* OR principl* OR philosoph* OR strateg*) NOT rail* NOT Train NOT air* NOT intelligent NOT licence NOT autono* NOT automa* NOT adaptive NOT network NOT simulat* NOT model NOT software NOT learning NOT capacity NOT virtual NOT real-time NOT efficien*	TRID	2014-2023 English only Articles and papers	60	12-Sep-23	https://shorturl.at/dimpx
11	VRU Psychology, Compliance, Behaviour, or Needs Relevant to TTM	VRU Terms + Behaviour	(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND (behavio* OR respon* OR attitude* OR perception* OR psycholog*)	TRID	2014-2023 English only Articles and papers Pedestrian and Cyclist subject area only	230	14-Sep-23	https://shorturl.at/hloAG
12	Compilation and Presentation of Good Practice Guides in TTM and Comparable Disciplines	Health and Safety + Guide or Protocol or Practice or Standard AND Produce	"safety" AND (guide* OR protocol* OR practice* OR standard*) NOT auto*	TRID		98	13-Sep-23	https://shorturl.at/sxHIR
13	Vulnerable Road Users (VRU) Treatment in Temporary Traffic Management (TTM)	VRU Terms + Traffic Management (and NOT air, rail, telecommunication)	(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND "Traffic Management" NOT (air OR rail OR telecommunication*)	IEEE		90	12-Sep-23	IEEE Xplore Search Results
14	Vulnerable Road Users (VRU) Treatment in Temporary Traffic Management (TTM)	VRU Terms + Traffic Control (and NOT air, rail, telecommunication)	(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND "Traffic Control*" NOT (air OR rail* OR telecommunication*)	IEEE		64	14-Sep-23	IEEE Xplore Search Results
15	Vulnerable Road Users (VRU) Treatment in Temporary Traffic Management (TTM)	VRU Terms + Traffic Guidance (and NOT air, rail, telecommunication)	("Traffic Management" OR "Traffic Guid*" OR "Traffic Control*" OR "Work Zone" OR "Road Work") AND method* NOT (air OR rail* OR telecommunication*)	IEEE		51	12-Sep-23	IEEE Xplore Search Results
16	TTM Principles and Philosophies	TTM Terms + Method (and NOT air, rail, telecommunication)	("Traffic Management" OR "Traffic Guid*" OR "Traffic Control*" OR "Work Zone" OR "Road Work") AND (method* OR approach* OR guide* OR principl* OR philosoph* OR strateg*)	IEEE		87	12-Sep-23	IEEE Xplore Search Results
17	VRU Psychology, Compliance, Behaviour, or Needs Relevant to TTM	VRU Terms + Behaviour	(pedestrian* OR *ycl* OR wheelchair* OR disabilit* OR vulnerab*) AND (behavio* OR respon* OR attitude* OR perception* OR psycholog*)	IEEE		89	12-Sep-23	IEEE Xplore Search Results
18	Compilation and Presentation of Good Practice Guides in TTM and Comparable Disciplines	Health and Safety + Guide or Protocol or Practice or Standard AND Produce	"safety" AND (guide* OR protocol* OR practice* OR standard*) NOT auto*	IEEE		64	12-Sep-23	IEEE Xplore Search Results
Total						**1122**		

Appendix J – Keywords extracted from academic search results for inclusion

Accident prevention
Activity centers
Age groups
Aged
Aged drivers
Aggression
Alertness
Algorithms
American National Standards Institute
Analysis
Analysis of variance
Attention
Attitudes
Barriers (Roads)
Before and after studies
Behavior
behavior model
Behavioral research
Best practices
Bicycle travel
Bicycles
Bicycling
Bike-sharing system
Blindness
Booster seats
Case studies
choice behavior
Cities
Cluster analysis
Cognition
Color
Comfort
complex environment
consensus
Convenience
Cooperation
cooperative traffic control
Correlation analysis
Crash characteristics
Crash injuries
Crash rates
Crashes
Crosswalks
Decision making
Delays
Diagnostic tests
Distraction
Diverging traffic
Drivers
driving behaviors
driving cycle prediction
E-bike crossing behaviors
Errors
Europe
Evaluation
Evaluation and assessment
Experiments
Eye movements
failure probability
Footbridges
Forecasting
Game theory
Groups
Guidelines
Hazard analysis
Hazard perception
Hazards
heterogeneous corridors
Highway capacity
Highway engineering
Highway maintenance
Highway safety
Highway traffic control
Highway work zone
Human factors
Implementation
Information dissemination
Infrastructure
Injuries
Injury severity
International Organization for Standardization
Intervention
Japan

Laws and legislation
Legislation
Location
Maintenance
Management
Measurement
Mobility
Monitoring
Motor vehicles
Multimodal traffic speed
Nagoya (Japan)
New York (New York)
Nova Scotia
Ohio
Operating speed
Operations
Pedestrian
Pedestrian density
pedestrian dynamics
Pedestrian lane detection
Pedestrian movement
Pedestrian safety
Pedestrian traffic
Pedestrian vehicle crashes
Pedestrian vehicle interface
Pedestrians
Perception
Physiological aspects
Psychological aspects
Quantitative analysis
questionnaire survey
Regulation
Regulations
Research
Reviews
Risk
Risk analysis
Risk assessment
Risk taking
road accidents
Road construction
shared bicycle
Sidewalks
South Korea
Speed
Standards
State departments of transportation
State highway departments
State of the practice
Surveys
Traffic control
Traffic control devices
Traffic crashes
traffic mode identification
Traffic safety
Traffic signal timing
Trust (Psychology)
United Nations
United States
Unsignalized intersections
Urban areas
Urban highways
Urban transportation
Validation
vehicle-pedestrian conflicts
Vertical walking facilities
Virginia
Walkability
Walking
Warrants (Traffic control devices)
Work zone safety
Work zone traffic control
Work zones
Yielding

Appendix K –Shortlisted academic literature catalogue

Assigned Final Literature ID	Incl/Excl	Incl/Excl Commentary	Database	Authors	Title	Year	Source title	DOI	Document Type
L1	Included - Good relevance	Exactly the topic of this research	TRID	Shaw, John L; Oneyear, Nicole L	Pedestrian Accommodations in Work Zones: Systematic Literature Review and Research Needs	2021	Smart Work Zone Deployment Initiative	N/A	Article
L2	Included - Good relevance	Insights into TTM device safety for cyclists	Scopus	Anna Niska, Jan Wenall, J. Karlstrom	Crash tests to evaluate the design of temporary traffic control devices for increased safety of cyclists at road works.	2022	Accident Analysis & Prevention	10.1016/j.aap.2021.106529	Article
L3	Included - Good relevance	Exactly the topic of this research	TRID	Alessio Moricca, Vedrana Ikalovic	Pedestrian mobility in the Proximity of Construction Sites - An Approach to Analyse and Improve the Experience	2022	Risk Analysis, Hazard Mitigation and Safety and Security Engineering XIII	10.2495/SSR220051	Book Section
L4	Included - Good relevance	Exactly the topic of this research	TRID	Mazumder, Abul; Sahi, Wjdan; Black, Dustin; Attanayake, Upul	Enhancing Non-motorized Mobility within Construction Zones	2017	Western Michigan University. Transportation Research Center for Livable Communities; National Research Council (U.S.). Transportation Research Board	N/A	Presentations
L5	Included - Good relevance	Focussed on permanent infrastructure but highly relevant - including the fact it is from NZ	TRID	Ajjima Soathong; Douglas Wilson; Prakash Ranjitkar; Subeh Chowdhury	A Critical Review of Policies on Pedestrian Safety and a Case Study of New Zealand	2019	Sustainability	https://doi.org/10.3390/su11195274	Article
L6	Included - Good relevance	Exactly the topic of this research	TRID	Shaw, John; Chitturi, Madhav; Han, Youngjun; Bremer, William; Noyce, David	Bicyclist and Pedestrian Safety in Work Zones: Recent Advances and Future Directions	2016	Transportation Research Board 95th Annual Meeting	N/A	Conference Procedings
L7	Included - Good relevance	Provides insightful information on behaviours of cyclists which can inform TTM practitioners on how to interpret cyclist actions (or inactions)	Scopus	Frank Westerhuis,Dick de Waard	Reading cyclist intentions: Can a lead cyclist's behaviour be predicted?	2017	Accident Analysis & Prevention	10.1016/j.aap.2016.06.026	Article
L8	Included - Good relevance	Provides insight to pedestrian decision making in urban areas	TRID	Jing Xu,Yan Ge,Weina Qu,Xianghong Sun,Kan Zhang	The mediating effect of traffic safety climate between pedestrian inconvenience and pedestrian behavior.	2018	Accident Analysis & Prevention	10.1016/j.aap.2018.07.020	Article
L9	Included - Good relevance	Provides insight into how pedestrians behave and has transferability to TTM environments	Scopus	Mathilde, Jay; Anne, Régnier; Anaïs, Dasnon; Killian, Brunet; Marie, Pelé	The light is red: Uncertainty behaviours displayed by pedestrians during illegal road crossing.	2020	Accident Analysis & Prevention	10.1016/j.aap.2019.105369	Article
L10	Included - Good relevance	Provides good insight into key risks for VRUs (in different environments/risk factors)	TRID	Tanishita, Masayoshi, Sekiguchi, Yuta, Sunaga, Daisuke	Impact analysis of road infrastructure and traffic control on severity of pedestrian–vehicle crashes at intersections and non-intersections using bias-reduced logistic regression	2023	IATSS Research	10.1016/j.iatssr.2023.03.004	
L11	Included - Good relevance	Provides insight into how cyclists decide to use certain facilities - highly transferable to TTM	Scopus	Athena Ng,Ashim Kumar Debnath,Kristiann C. Heesch	Cyclist' safety perceptions of cycling infrastructure at un-signalised intersections: Cross-sectional survey of Queensland cyclists	2017	Journal of transport and health	10.1016/j.jth.2017.03.001	Article
L12	Included - Good relevance	Provides insight into how pedestrians decide to use certain facilities - highly transferable to TTM. Pedestrian version (similar) of 50088	TRID	Meesung Lee,Heerim Lee,Sungjoo Hwang,Minji Choi	Understanding the impact of the walking environment on pedestrian perception and comprehension of the situation	2021	Journal of transport and health	10.1016/j.jth.2021.101267	
L13	Included - Good relevance	Provides insight into how cyclists behave and make decisions - highly transferable to TTM	Scopus	Víctor Marín Puchades, Filippo Fassina, Federico	The role of perceived competence and risk perception in cycling near misses	2018	Safety Science	10.1016/j.ssci.2018.02.013	Article

				Fraboni, Marco De Angelis, Gabriele Prati, Dick de Waard, Luca Pietrantoni					
L14	**Included - Good relevance**	**Provides insight into cognitive load capability of pedestrians (relevant for TTM where cognitive load is increased due to changed environments)**	**TRID**	**Huarong Wang,Dongqian Li,Qiushuang Wang,David C Schwebel,Lvqing Miao,Yongjiang Shen**	**How distraction affects pedestrian response: Evidence from behavior patterns and cortex oxyhemoglobin changes**	**2022**	**Transportation Research Part F-traffic Psychology and Behaviour**	**10.1016/j.trf.2022.10.026**	
L15	**Included - Good relevance**	**Made more relevant due to recent site entry fatality (CHCH, 2018) and is valuable in TTM for site access scenarios**	**Scopus**	**Berghoefer F.L.; Huemer A.K.; Vollrath M.**	**Look right! The influence of bicycle crossing design on drivers' approaching behavior**	**2023**	**Transportation Research Part F: Traffic Psychology and Behaviour**	**10.1016/j.trf.2023.03.017**	**Article**
L16	**Included - Good relevance**	**Speaks to compliance of VRUs and how they behave together (incl sign compliance). Highly transferable.**	**Scopus**	**Essa M.; Hussein M.; Sayed T.**	**Road users' behavior and safety analysis of pedestrian–bike shared space: case study of robson street in vancouver**	**2018**	**Canadian Journal of Civil Engineering**	**10.1139/cjce-2017-0683**	**Article**
L17	Included - moderate relevance	Not specific to VRUs but is specific to TTM design (TMPs) and is likely to have some flow over relevance	TRID	John Gambatese, Michael Johnson	Impact of Design and Construction on Quality, Consistency, and Safety of Traffic Control Plans	2014	Journal of the Transportation Research Board	https://doi.org/10.3141/2458-06	Article
L18	Included - moderate relevance	Explores one specific risk factor (mobile phone use) for cyclists which is admissable, but highly specific and therefore will have limited contribution	Scopus	Dick de Waard,Frank Westerhuis,Ben Lewis-Evans	More screen operation than calling: The results of observing cyclists' behaviour while using mobile phones	2015	Accident Analysis & Prevention	10.1016/j.aap.2015.01.004	Article
L19	Included - moderate relevance	Speaks to psychological behaviours at level crossings by VRU which has appropriate transferability to TTM	Scopus	Teodora Stanimirova Stefanova, Jean-Marie Burkhardt,Ashleigh J. Filtness,Christian Wullems,Andry Rakotonirainy,Patricia Delhomme	Systems-based approach to investigate unsafe pedestrian behaviour at level crossings	2015	Accident Analysis & Prevention	10.1016/j.aap.2015.04.001	Article
L20	Included - moderate relevance	Explores one risk are - child pedestrians - however there is likely valuable content to be gleaned that is transferable and important for this context	Scopus	Jiabin Shen,Leslie A. McClure,David C. Schwebel	Relations between temperamental fear and risky pedestrian behavior	2015	Accident Analysis & Prevention	10.1016/j.aap.2015.04.011	Article
L21	Included - moderate relevance	Some relevance in relation to driver behaviour toward crossing pedestrians which may have some relevant findings transferable to TTM environments	Scopus	Laura Sandt,Stephen W. Marshall,Daniel A. Rodriguez,Kelly R. Evenson,Susan T. Ennett,Whitney R. Robinson	Effect of a community-based pedestrian injury prevention program on driver yielding behavior at marked crosswalks	2016	Accident Analysis & Prevention	10.1016/j.aap.2016.05.004	Article
L22	Included - moderate relevance	Explores one specific risk factor (mobile phone use) for pedestrians which is admissable, but highly specific and therefore will have limited contribution	Scopus	Alexia J. Lennon,Oscar Oviedo-Trespalacios,Sarah Matthews	Pedestrian self-reported use of smart phones: Positive attitudes and high exposure influence intentions to cross the road while distracted.	2017	Accident Analysis & Prevention	10.1016/j.aap.2016.10.028	Article
L23	Included - moderate relevance	Some insight into risky cyclist behaviours	Scopus	Sergio A. Useche, Francisco Alonso, Luis Montoro, Cristina Esteban	Explaining self-reported traffic crashes of cyclists: An empirical study based on age and road risky behaviors	2019	Safety Science	10.1016/j.ssci.2018.11.021	Article
L24	Included - moderate relevance	Generally speaks to the generation of safety standards (in the context of adventure industry but likely transferability to TTM)	Scopus	Tony Carden, Natassia Goode, Paul M. Salmon	Simplifying safety standards: using work domain analysis to guide regulatory restructure	2020	Safety Science	10.1016/j.ssci.2020.105096	Article
L25	Included - moderate relevance	Relevance of cycling surfaces on behaviours of cyclists	Scopus	Pieter Vansteenkiste, Linus Zeuwts, Greet Cardon, Renaat	The implications of low quality bicycle paths on gaze behavior of cyclists: A field test	2014	Transportation Research Part F-traffic Psychology and Behaviour	10.1016/j.trf.2013.12.019	Article

				Philippaerts, Matthieu Lenoir					
L26	Included - moderate relevance	Relevance may come from the intra-relationships with VRUs (shared spaces)	Scopus	Ioannis Kaparias, Michael G H Bell, Thomas Biagioli, L. Bellezza, Bill Mount	Behavioural analysis of interactions between pedestrians and vehicles in street designs with elements of shared space	2015	Transportation Research Part F-traffic Psychology and Behaviour	10.1016/j.trf.2015.02.009	Article
L27	Included - moderate relevance	Possibly provides some insight into behavioural differences between VRU types - especially micro-mobility	Scopus	Sergio A. Useche,Steve O'Hern,Adela Gonzalez-Marin,Javier Gene-Morales,Francisco Alonso,Amanda N. Stephens	Unsafety on two wheels, or social prejudice? Proxying behavioral reports on bicycle and e-scooter riding safety: A mixed-methods study		Transportation Research Part F-traffic Psychology and Behaviour	10.1016/j.trf.2022.06.015	Article
L28	Included - moderate relevance	May speak to specific intergventions that are effective for improving driver decisions related to VRUs	TRID	Mehrotra, Shashank, Roberts, Shannon C	Identifying And Improving Young Drivers' Perceptions Towards Vulnerable Road Users	2022	Human Factors and Ergonomics Society Annual Meeting	10.1177/1071181322661427	Conference Procedings
L29	Included - moderate relevance	May speak to driver decisions around cyclists being present (and how they make decisions)	Scopus	Ary P. Silvano,Ary P. Silvano,Xiaoliang Ma,Haris N. Koutsopoulos	When Do Drivers Yield to Cyclists at Unsignalized Roundabouts?: Empirical Evidence and Behavioral Analysis	2015	Transportation Research Record	10.3141/2520-04	Article
L30	Included - moderate relevance	May speak to the safety level of different TTM solutions (not specific to VRU but may be relevant)	Scopus	Emira Rista,Timothy P. Barrette,Raha Hamzeie,Peter T. Savolainen,Timothy J. Gates	Work Zone Safety Performance	2017	Transportation Research Record	10.3141/2617-11	Article
L31	Included - moderate relevance	Speaks to the creation of cyclist enbvironemtns and itneraction of drivers for safety. Some transferability to TTM	Scopus	Matus Sucha	Bicycle Traffic in the Czech Republic: The Ways of Influencing the Behaviour of People Involved in It	2017	Transactions on Transport Sciences	10.5507/tots.2017.005	Article
L32	Included - moderate relevance	Some insight in relation to the speciofic behavioural characteristics of elderly VRUs	TRID	Yeon-Hong, Ji, Choi, Ji-Hye, Lee, Soo-Beom, Lim, Jun-Beom	Study on Measures to Reduce Car Accidents of Elderly Pedestrians by Analyzing Their Behavior	2015	25th World Road Congress, Location: Seoul , South Korea	N/A	Conference Procedings
	Excluded	**Relevant context but specific to curb extension effectiveness**	Scopus	Francesco Bella,Manuel Silvestri	Driver's braking behavior approaching pedestrian crossings: a parametric duration model of the speed reduction times	2016	Journal of Advanced Transportation	10.1002/atr.1366	Article
	Excluded	**Overarching relevant area but specific to industrial context**	Scopus	Trish Kerin	The evolution of process safety standards and legislation following landmark events: what have we learnt?	2016	Process Safety Progress	10.1002/prs.11762	Article
	Excluded	**Specific to mental health in canadian workplaces**	Scopus	Laura Kalef,Courtney Rubin,Cindy Malachowski,Bonnie Kirsh	Employers' Perspectives on the Canadian National Standard for Psychological Health and Safety in the Workplace	2016	Employee Responsibilities and Rights Journal	10.1007/s10672-015-9270-9	Article
	Excluded	**Relevant context but specific to curb extension effectiveness and a revision/extension of article 50051**	Scopus	Francesco Bella,Manuel Silvestri	Effects of safety measures on driver's speed behavior at pedestrian crossings.	2015	Accident Analysis & Prevention	10.1016/j.aap.2015.07.016	Article
	Excluded	**Some relevance to the relationship between cyclists and drivers - but squarely centrred on clothing and interpretation of behaviour and therefore no transferability to VRU in TTM**	Scopus	Laura Fruhen,Isabel Rossen,Mark A. Griffin	The factors shaping car drivers' attitudes towards cyclist and their impact on behaviour.	2019	Accident Analysis & Prevention	10.1016/j.aap.2018.11.006	Article
	Excluded	**Highly relevant topic, but as a scoping study this is merely evaluating how much VRU behaviours have been studied - rather than what the results of those studies are.**	Scopus	Wouter van Haperen,Malik Sarmad Riaz,Stijn Daniels,Stijn Daniels,Stijn Daniels,Nicolas	Observing the observation of (vulnerable) road user behaviour and traffic safety: A scoping review.	2019	Accident Analysis & Prevention	10.1016/j.aap.2018.11.021	Article

			Saunier,Tom Brijs,Geert Wets					
Excluded	**Targeted specifically toward infrastructure building**	TRID	Hauer Ezra	On the relationship between road safety research and the practice of road design and operation.	2019	Accident Analysis & Prevention	10.1016/j.aap.2019.03.016	
Excluded	**Discusses attitudes to VRU behaviour by VRU themselves**	Scopus	Rich C. McIlroy,Sergio A. Useche,Adela Gonzalez-Marin	To what extent do our walking and cycling behaviours relate to each other, and do we cycle as well as we think we do? Piloting the walking and cycling behaviour questionnaires in the UK	2022	Accident Analysis & Prevention	10.1016/j.aap.2022.106597	Article
Excluded	**Some relevant factors however speaks specifically to the competency of cyclists and their perceptions, incouding subsequent interventions**	Scopus	Divera Twisk, Simone Wesseling, W P Vlakveld, Jan Vissers, Geertje Hegeman, Nikki Hukker, Erik Roelofs, Wilma Slinger	Higher-order cycling skills among 11- to 13-year-old cyclists and relationships with cycling experience, risky behavior, crashes and self-assessed skill.	2018	Journal of Safety Research	10.1016/j.jsr.2018.10.003	Article
Excluded	**Speaks to the choices to ride bikes, nothing relevant.**	Scopus	Calvin Thigpen	Do bicycling experiences and exposure influence bicycling skills and attitudes? Evidence from a bicycle-friendly university	2019	Transportation Research Part A-policy and Practice	10.1016/j.tra.2018.05.017	Article
Excluded	**Specifically around cyclists being compromised due to music but study terminated so limited value**	Scopus	A. Stelling-Konczak,W P Vlakveld,P. van Gent,P. van Gent,Jacques J.F. Commandeur,G.P. van Wee,B. van Wee,Marjan Hagenzieker	A study in real traffic examining glance behaviour of teenage cyclists when listening to music: Results and ethical considerations	2018	Transportation Research Part F-traffic Psychology and Behaviour	10.1016/j.trf.2018.02.031	Article
Excluded	**Specifically about how to improve cyclist humanisation**	Scopus	Alexa Delbosc,Farhana Naznin,Nick Haslam,Narelle Haworth	Dehumanization of cyclists predicts self-reported aggressive behaviour toward them: A pilot study	2019	Transportation Research Part F-traffic Psychology and Behaviour	10.1016/j.trf.2019.03.005	Article
Excluded	**Speaks only to daylight saving impacts on cycle volumes**	TRID	Wessel, Jan	Cycling in the dark – the impact of Standard Time and Daylight Saving Time on bicycle ridership	2022	PNAS Nexus	10.1093/pnasnexus/pgab006	Article
Excluded	**Specific to case-control stidues and is a meta-analysis of sorts**	TRID	Louis-Rachid Salmi, L. Rachid Salmi, Ludivine Orriols, Emmanuel Lagarde	Comparing responsible and non-responsible drivers to assess determinants of road traffic collisions: time to standardise and revisit	2014	Injury Prevention	10.1136/injuryprev-2013-041143	
Excluded	**Behind paywall and abstract explores more holistic commercial road corridor intentions.**	TRID	Hammerschmidt, Sara	Better Corridors for Healthier Communities: Project Investigates Best Practices	2015	Transport Research News: Public Health and Transportation: Innovation, Intervention, and Improvements	10.17226/23612	Article
Excluded	**Specifically regarding tourist pedestrian behaviour in Italy - thus quite nuanced and targetted at a specific problem unrelated to VRU in TTM**	Scopus	Antonio Pratelli,Marino Lupi,Daniele Razzuoli	Illegal pedestrian crossing at a traffic light: A study on tourist behaviour	2017	International Journal of Transport Development and Integration	10.2495/TDI-V1-N4-633-639	Article
Excluded	**specifically related to TTM disruption and on multi-lane freeways**	TRID	Ossama E. Ramadan,Virginia P Sisiopiku	Bottleneck Merge Control Strategies for Work Zones: Available Options and Current Practices	2015	Open Journal of Civil Engineering	10.4236/ojce.2015.54043	Article
Excluded	**Focussed on who cycles and why**	Scopus	Vit Gabrhel	Feeling like cycling? Psychological factors related to cycling as a mode choice	2019	Transactions on Transport Sciences	10.5507/tots.2019.006	Article
Excluded	**TTM related, but specific to road safety barriers and no substance related to VRU**	TRID	Harris, P	Better than nothing? Safety barriers in construction zones: principles and practice	2016	Australasian Road Safety Conference, 2016, Canberra, ACT, Australia	N/A	Conference Procedings

Appendix L –Included Academic Literature Summary Table

ID	Author, Title, Journal & Year	Standing[40]	Findings	Limitations	Sample Size	Study Type	VRU Implications	Methodology	Practical Applications
L1	Shaw, J., & Oneyear, N. Pedestrian Accommodations in Work Zones: Systematic Literature Review and Research Needs Smart Work Zone Deployment Initiative, Federal Highway Administration 2021	Journal Ranking: not applicable Article Citations: not available Article Impact: not available Author Citations: not available	9 studies on work zone pedestrian safety. Focus on design and aids for visually impaired. No quantitative evaluations. High risk of bias.	Limitations include small number of studies, qualitative nature, subjective findings, risk of bias, lack of robust methodologies, and quantitative analysis.	N/A	Systematic literature review	Study highlights need for improved pedestrian accommodations in work zones, particularly for vulnerable road users.	Systematic literature review on work zone pedestrian safety, studies from 2004-2021, supplemental grey literature review.	Improving pedestrian safety and mobility in work zones through effective design solutions.
L2	Niska, A., Wenall, J., & Karlstrom, J. Crash tests to evaluate the design of temporary traffic control devices for increased safety of cyclists at road works Accident Analysis & Prevention 2022	Journal Ranking: A* Article Citations: 1 Article Impact: 0.36 Author Citations: 117	Bicycle crashes into road equipment cause injuries. Avoid unnecessary traffic control devices. Barriers must be 1.4m high and anchored. No financial interests affecting study.	Crash test dummy designed for car crashes, qualitative method, lack of sensor data, wooden boards used, no repeated tests.	N/A	Research report	Importance of considering safety of vulnerable road users in work zones; bicycle crashes can lead to severe injuries.	Simulated single-bicycle crashes in VTI lab, Hybrid II 50th percentile dummy, video documentation, standard crash testing procedures.	Informing the design of temporary traffic control devices to increase cyclist safety.
L3	Moricca, A., & Ikalovic, V. Pedestrian mobility in the proximity of construction sites: an approach to analyse and improve the pedestrian experience WIT Transactions on the Built Environment 2022	Journal Ranking: not applicable Article Citations: not available Article Impact: not available Author Citations: not available	Residents accept construction sites. Interested in projects. Better stakeholder communication can improve sidewalks. No specific findings mentioned.	Document does not explicitly mention limitations.	204 survey responses	Research report	Importance of considering vulnerable road users in construction sites; better communication and real-time plans can improve safety.	Three-step methodology: GIS analysis, CAWI survey, sidewalk observations near construction sites. Goal to improve pedestrian mobility.	Analyzing comfort and behavior of pedestrians near construction sites.
L4	Mazumder, A., Sahi, W., Black, D., & Attanayake, U. Enhancing Non-motorized Mobility within Construction Zones Transportation Research Center for Livable Communities 2017	Journal Ranking: not available Article Citations: not available Article Impact: not available Author Citations: not available	Not really provided	Limitations not mentioned in provided context.	Not provided	Technical report	Lack of specific instructions to contractors leads to closure of access for non-motorized traffic.	No explicit methodology stated.	Developing policies and infrastructure for non-motorized mobility within construction zones.
L5	Soathong, A., Wilson, D., Ranjitkar, P., & Chowdhury, S. A Critical Review of Policies on Pedestrian Safety and a Case Study of New Zealand Sustainability (Switzerland) 2019	Journal Ranking: not available Article Citations: 12 Article Impact: 0.83 Author Citations: 31	Not really provided	Focus on macro level, specific to New Zealand.	Five years of crash data from CAS and the amount of walking from 2012 to 2015 from NZHTS	Critical review & case study	Need for effective road safety policies to protect vulnerable road users like pedestrians.	Analysis of 5 years of NZ crash data, CAS and NZHTS databases, comparison with international road safety policies.	Providing insights for policymakers on pedestrian safety and road safety strategies.

[40] Journal ranking taken from Australian Business Deans Council (ABDC), Article Citations & Impact (Field-Weighted Citation Impact (FWCI)), and Author Citations taken from Scopus.

L6	Shaw, J., Chitturi, M., Han, Y., Bremer, W., & Noyce, D. A. Bicyclist and Pedestrian Safety in Work Zones: Recent Advances and Future Directions Smart Work Zone Deployment Initiative, Issue. Federal Highway Administration 2016	Journal Ranking: not applicable Article Citations: not available Article Impact: not available Author Citations: not available	219 bike/pedestrian crashes in Wisconsin work zones. Common issues: worker-on-foot crashes, inadequate accommodations, visual obstructions. 17% of crashes involve pedestrians/bicyclists.	Document does not explicitly state limitations.	The study analyzed narrative crash reports for 219 bicycle and pedestrian crashes that occurred in Wisconsin work zones over a 10-year period (2004-2013).	Research report	Safety and mobility challenges for pedestrians and cyclists in work zones; need for better project design.	No specific methodology information provided.	Development of work zone design guidelines for pedestrians and bicyclists.
L7	Westerhuis, F., & De Waard, D. Reading cyclist intentions: Can a lead cyclist's behaviour be predicted? Accident Analysis & Prevention 2017	Journal Ranking: A* Article Citations: 14 Article Impact: 0.98 Author Citations: 91	Not really provided	Online survey, real traffic in Netherlands, cue availability varies, no cyclist info.	The study had a total of 158 participants who started the survey, and 108 participants answered all the questions.	Qualitative study	Cyclists may have difficulty predicting intentions of other cyclists; need for explicit communication.	Online survey, predict cyclist turn, 24 trials, IBM SPSS and MLwiN for statistical analysis.	Importance of explicit communication for cyclists in traffic.
L8	Xu, J., Ge, Y., Qu, W., Sun, X., & Zhang, K. The mediating effect of traffic safety climate between pedestrian inconvenience and pedestrian behavior Accident Analysis & Prevention 2018	Journal Ranking: A* Article Citations: 16 Article Impact: 1.33 Author Citations: 94	Pedestrian inconvenience in city traffic affects behavior. Traffic safety climate mediates this relationship. Fewer inconveniences lead to safer climate and behavior.	Reliance on self-report, sample not representative, weak correlations.	The sample size for this study is 311 participants.	Observational and qualitative study	Pedestrian safety should be a priority in transportation research and planning.	Observations and self-reported questionnaires, Pedestrian Behavior Scale (PBS).	Understanding pedestrian inconvenience, traffic safety climate, and behavior.
L9	Jay, M., Regnier, A., Dasnon, A., Brunet, K., & Pele, M. The light is red: Uncertainty behaviours displayed by pedestrians during illegal road crossing Accident Analysis & Prevention 2020	Journal Ranking: A* Article Citations: 14 Article Impact: 1.16 Author Citations: 17	Pedestrians hesitate to cross when complex environments are present. Number of lanes affects behavior. No decrease in attention when using phones	Document does not explicitly state limitations.	118 pedestrians who showed uncertainty behaviors while crossing at a red light Random sample of 1278 pedestrians was used for assessing the effect of age on uncertainty behaviors	Behavioural sampling / quantitative study	Pedestrians displaying uncertainty behaviors are more vulnerable to accidents.	Behavioral sampling, France & Japan, 6-day data collection, BORIS software, GLM.	Preventing illegal and dangerous road-crossing behaviors by pedestrians.

L10	Tanishita, M., Sekiguchi, Y., & Sunaga, D. Impact analysis of road infrastructure and traffic control on severity of pedestrian–vehicle crashes at intersections and non-intersections using bias-reduced logistic regression IATSS Research 2023	Journal Ranking: C Article Citations: 1 Article Impact: not available Author Citations: 70	Not really provided	Limited injury severity definition, no pedestrian and driver characteristics, no interaction terms, missing variables like jaywalking.	86,406 pedestrian-vehicle crashes.	Research report / Quantitative study	Impact of road infrastructure and traffic control on severity of pedestrian-vehicle crashes.	Bias-reduced logistic regression, crash data, brglm package in R, BIC for model selection.	Reducing severity of pedestrian-vehicle crashes through infrastructure and control measures.
L11	Ng, A., Debnath, A. K., & Heesch, K. C. Cyclist' safety perceptions of cycling infrastructure at un-signalised intersections: Cross-sectional survey of Queensland cyclists Journal of Transport and Health 2017	Journal Ranking: B Article Citations: 18 Article Impact: 0.7 Author Citations: 18	Not really provided	Reporting bias, 2D illustrations, selection bias, focus on four-way intersections, response rate ambiguity.	264 participants.	Cross-sectional survey	Cyclists feel safer using cycling infrastructure where they give way to turning motorists.	Cross-sectional survey, cycling infrastructure, close-ended questions, online.	Informing cycling infrastructure design at un-signalised intersections.
L12	Lee, M., Lee, H., Hwang, S., & Choi, M. Understanding the impact of the walking environment on pedestrian perception and comprehension of the situation Journal of Transport and Health 2021	Journal Ranking: B Article Citations: 3 Article Impact: 0.29 Author Citations: 16	Pedestrian awareness affected by information type and walking environment complexity. High awareness for safety-related objects. Less complex areas have better awareness.	Not mentioned.	15 participants.	Reearch report	Importance of pedestrian awareness of walking environment.	Real-world experiments, 15 participants, Situation Awareness Global Assessment Technique (SAGAT), ANOVA.	Enhancing pedestrian awareness and walking safety.
L13	Puchades, V. M., Fassina, F., Fraboni, F., De Angelis, M., Prati, G., de Waard, D., & Pietrantoni, L. The role of perceived competence and risk perception in cycling near misses Safety Science 2018	Journal Ranking: A Article Citations: 19 Article Impact: 1.29 Author Citations: 301	Not really provided	Self-assessment, memory decay, unexplored nuances of perceived control.	455 participants.	Quantitative study	Improving cycling infrastructure can reduce interaction between cyclists and motorized vehicles.	Questionnaire-based, path analysis, Bayesian estimation.	Understanding behavioral adaptation in cycling and its safety implications.
L14	Wang, H., Li, D., Wang, Q., Schwebel, D. C., Miao, L., & Shen, Y. How distraction affects pedestrian response: Evidence from behavior patterns and cortex oxyhemoglobin changes Transportation Research Part F: Traffic Psychology and Behaviour 2022	Journal Ranking: A Article Citations: 1 Article Impact: 0.28 Author Citations: 128	Pedestrian awareness affected by information type and walking environment complexity. High awareness for safety-related objects. Less complex areas have better awareness.	fNIRs tech limits, seated tasks, uncontrolled music type, ecological validity, imperfect lab settings.	30 participants.	Quantitative study	Distraction from mobile phone use impacts safety of vulnerable road users.	Within-subjects design, response time, walking speed, oxyhemoglobin concentration.	Development of pedestrian safety training programs.
L15	Berghoefer, F. L., Huemer, A. K., & Vollrath, M. Look right! The influence of bicycle crossing design on drivers' approaching behavior Transportation Research Part F: Traffic Psychology and Behaviour 2023	Journal Ranking: A Article Citations: not available Article Impact: not available Author Citations: 16	Junction view affects driver behavior. Colored bicycle crossings slow drivers. Right-turning drivers look left; left-turning drivers check both sides. Peripheral vs central view affects crossing design.	Driving simulator, young drivers, no interactions with oncoming cyclists.	81 participants.	Quantitative study	Drivers often fail to include cyclists in their visual scanning strategy.	Experimental design, driving simulator, SILAB 5.0, Dikablis Eye Tracking Glasses, 81 participants.	Design and planning of bicycle crossings at T-junctions.

L16	Essa, M., Hussein, M., & Sayed, T. Road users' behavior and safety analysis of pedestrian–bike shared space: case study of Robson Street in Vancouver Canadian Journal of Civil Engineering 2018	Journal Ranking: not available Article Citations: 9 Article Impact: 0.25 Author Citations: 843	Bike dismount sign reduces conflicts. Speed distribution analyzed. Conflicts highest during weekends and in dense areas. Reduction factor after sign placement is 34%.	Limited sample size, one conflict indicator, need for validation.	N/A	Reearch report	Behavior and safety of road users in pedestrian-bike shared space.	Automated video processing, road user trajectories.	Behavior of road users in pedestrian-bike shared spaces.
L17	Gambatese, J., & Johnson, M. Impact of Design and Construction on Quality, Consistency, and Safety of Traffic Control Plans Journal of the Transportation Research Board 2014	Journal Ranking: not available Article Citations: not available Article Impact: not available Author Citations: not available	Constructability reviews improve TCP quality and safety. Lack of performance data collection. Complexity assessed via survey. Ambiguous TCP design review process.	Document does not explicitly state limitations.	39 projects in Oregon.	Research study	Study does not mention vulnerable road users.	Mixed methods, survey, traffic control plan evaluation, work zone evaluation.	Improving traffic control plans for highway construction projects.
L18	de Waard, D., Westerhuis, F., & Lewis-Evans, B. More screen operation than calling: The results of observing cyclists' behaviour while using mobile phones Accident Analysis & Prevention 2015	Journal Ranking: A* Article Citations: 44 Article Impact: 2.33 Author Citations: 4756	Mobile phone use affects cyclist distance from curb and head movements. Similar effects observed in experimental studies. Age distribution varies between phone users and non-users.	No eye movements, age estimation, low observed calling cyclists, no reliable accident data.	37 hours of video footage.	Observational study	Mobile phone use while cycling affects lane position and head movement.	On-road observation, mobile phone use by cyclists, lateral position, head movements.	Raising awareness about mobile phone use while cycling.
L19	Stefanova, T., Burkhardt, J. M., Filtness, A., Wullems, C., Rakotonirainy, A., & Delhomme, P. Systems-based approach to investigate unsafe pedestrian behaviour at level crossings Accident Analysis & Prevention 2015	Journal Ranking: A* Article Citations: 37 Article Impact: 2.47 Author Citations: 66	Multiple risk factors for unsafe pedestrian behavior at level crossings. PULC framework applied. Pedestrian level most associated with unsafe behavior.	Lack of empirical research, inconsistent data, focus on frequencies, biases in reported violations.	12 pedestrians who regularly crossed the same level crossing.	Research Report	Need for more research on factors contributing to unsafe behavior among vulnerable road users.	Focus group, level crossing, Rasmussen's AcciMap.	Identifying factors for unsafe pedestrian behavior at level crossings.
L20	Shen, J., McClure, L. A., & Schwebel, D. C. Relations between temperamental fear and risky pedestrian behavior Accident Analysis & Prevention 2015	Journal Ranking: A* Article Citations: 9 Article Impact: 0.29 Author Citations: 22333	Emotion-based traits like fear affect children's pedestrian risks. Fear more relevant for girls. Start gap and TTC mediate fear and risky behavior.	Parent report, virtual reality limits, mid-block focus, no risky behaviors at signaled intersections.	240 children ages 7-8 recruited from community sources in the Birmingham, Alabama area.	Empirical Study	Temperamental fear and gender influence risk of pedestrian injuries in children.	Virtual reality, parent-report measures, Child Behavior Questionnaire.	Considering children's emotions in pedestrian safety interventions.
L21	Sandt, L. S., Marshall, S. W., Rodriguez, D. A., Evenson, K. R., Ennett, S. T., & Robinson, W. R. Effect of a community-based pedestrian injury prevention program on driver yielding behavior at marked crosswalks Accident Analysis & Prevention 2016	Journal Ranking: A* Article Citations: 16 Article Impact: 0.8 Author Citations: 203	Multi-faceted safety program increases driver yielding at crosswalks. Spill-over effects observed. 4-7% point improvements in yielding.	Unmeasured confounders, no randomization, selection bias, data collection bias, limited locations, short monitoring, spill-over effects, variable uncertainty.	24,941 drivers in 11,817 attempted crossing events at 16 crosswalks in five municipalities.	Pre-post design study	Study does not address other vulnerable road users such as cyclists.	Pre-post design, driver yielding behavior, GEE model.	Implementing community-based pedestrian safety programs.

L22	Lennon, A., Oviedo-Trespalacios, O., & Matthews, S. Pedestrian self-reported use of smart phones: Positive attitudes and high exposure influence intentions to cross the road while distracted Accident Analysis & Prevention 2017	Journal Ranking: A* Article Citations: 74 Article Impact: 4.38 Author Citations: 648	Automated vision techniques for cyclist data collection. High exposure to traffic conflicts. Countermeasures needed. Traffic conflicts as collision data surrogate.	Need for further research, "proof of concept" phase, further development needed.	N/A	Research Report	Need for innovative methods to analyze and improve safety of vulnerable road users.	Automated video analysis, vehicle-bicycle interactions.	Automated safety diagnosis of vehicle-bicycle interactions.
L23	Useche, S. A., Alonso, F., Montoro, L., & Esteban, C. Explaining self-reported traffic crashes of cyclists: An empirical study based on age and road risky behaviors Safety Science 2019	Journal Ranking: A Article Citations: 45 Article Impact: 4.92 Author Citations: 1533	Risky behaviors mediate individual factors and cyclist crash rates. Age affects model. Lack of data outside Europe and North America. Risk perception varies between American and European cyclists.	Variation in traffic dynamics, convenience sample, demographic influence, self-reported data.	1064 cyclists from 20 different countries.	Empirical Study	Importance of understanding behavioral issues contributing to crashes among vulnerable road users.	Cross-sectional design, electronic questionnaire, path analysis, multi-group analysis.	Promoting avoidance of risky behaviors among cyclists.
L24	Carden, T., Goode, N., & Salmon, P. M. Simplifying safety standards: Using work domain analysis to guide regulatory restructure Safety Science 2021	Journal Ranking: A Article Citations: 2 Article Impact: 0.16 Author Citations: 83	WDA useful for redesigning adventure activity standard. Reduced elements from 111 to 25. Integration of human factors and regulatory guidance.	Need for further methods testing, stakeholder concerns, regulatory system effectiveness.	N/A	Research study	Study does not mention vulnerable road users.	Work Domain Analysis, abstraction hierarchy model, regulatory design principles.	Redesigning safety standards for adventure activities in Australia.
L25	Vansteenkiste, P., Zeuwts, L., Cardon, G., Philippaerts, R., & Lenoir, M. The implications of low quality bicycle paths on gaze behavior of cyclists: A field test Transportation Research Part F: Traffic Psychology and Behaviour 2014	Journal Ranking: A Article Citations: 40 Article Impact: 2.61 Author Citations: 528	Cyclists' visual behavior differs on low vs high quality tracks. Attention shifts more towards road on low quality tracks. Cycling speed unaffected.	Low participants, sunlight data loss, no gazing distance, non-identical traffic situations.	ten participants.	Quantitative study	Poor road conditions can increase risk of accidents for cyclists.	Eye movements, IviewX Head mounted Eye tracking Device.	Improving bicycle safety through visual behavior understanding.
L26	Kaparias, I., Bell, M. G. H., Biagioli, T., Bellezza, L., & Mount, B. Behavioural analysis of interactions between pedestrians and vehicles in street designs with elements of shared space Transportation Research Part F: Traffic Psychology and Behaviour 2015	Journal Ranking: A Article Citations: 32 Article Impact: 0.92 Author Citations: 619	30% reduction in interaction events post-redevelopment. SC-P interactions reduced, ESS constant. Pedestrians give way to vehicles more.	External factors, no before-study, "safety-in-numbers" not investigated, non-linear relationships not explored.	N/A	Research report	Study does not mention vulnerable road users.	Qualitative behavioural analysis, video observation, Exhibition Road site.	Planning and design of streetscape schemes with shared space elements.
L27	Useche, S. A., O'Hern, S., Gonzalez-Marin, A., Gene-Morales, J., Alonso, F., & Stephens, A. N. Unsafety on two wheels, or social prejudice? Proxying behavioral reports on bicycle and e-scooter riding safety – A mixed-methods study Transportation Research Part F: Traffic Psychology and Behaviour 2022	Journal Ranking: A Article Citations: 4 Article Impact: 0.56 Author Citations: 1533	Not really provided	Sample of non-riders, geographical bias, subjective ratings, no demographic factors, regional differences not accounted.	950 completed questionnaires	Cross-sectional survey	E-scooter riders perceived as riskier compared to cyclists.	Cross-sectional external-rated design, rapid assessment procedure interviews.	Enhancing policymaking for e-scooter and other two-wheeled riders.

L28	Mehrotra, S., & Roberts, S. C. Identifying And Improving Young Drivers' Perceptions Towards Vulnerable Road Users Proceedings of the Human Factors and Ergonomics Society Annual Meeting 2022	Journal Ranking: not applicable Article Citations: not available Article Impact: not available Author Citations: not available	Young drivers learn from parents and other drivers. Intervention reduces violations. Sensation-seeking behavior influences violations. Study conducted during COVID-19.	Conducted during COVID-19, self-reported data, no driving behavior tracking, no confounding factors, small sample size, short-term effects, no comparison group.	23 participants between the ages of 18 to 21 years old.	Research Report	Young drivers' perceptions towards vulnerable road users can be improved through intervention.	Qualitative interviews, young drivers, grounded theory approach.	Improving young drivers' perceptions towards vulnerable road users.
L30	Rista, E., Barrette, T., Hamzeie, R., Savolainen, P., & Gates, T. J. Work Zone Safety Performance: Comparison of Alternative Traffic Control Strategies Transportation Research Record 2017	Journal Ranking: B Article Citations: 4 Article Impact: 0.1 Author Citations: 24	Crashes increase with work zone length and duration. Different traffic control strategies have varying effects. Need for further research on work zone safety.	Data from Michigan DOT, lack of traffic volume data, no specific factors, no geometric characteristics, no work activity details, no traffic control device info.	790 segments or work zones.	Research Report	Study does not provide implications for vulnerable road users.	Statistical analyses, Poisson and negative binomial models, random parameter framework.	Estimating impacts of traffic control strategies on work zone safety.
L31	Šucha, M. Bicycle Traffic in the Czech Republic: The Ways of Influencing the Behaviour of People Involved in It Transactions on Transport Sciences 2017	Journal Ranking: not available Article Citations: not available Article Impact: not available Author Citations: not available	Not really provided			Research Report	Importance of promoting and improving conditions for vulnerable road users.		Enhancing cycling and cyclist safety in the Czech Republic.
L32	Yeon-Hong, J., Choi, J., Lee, S.B., Lim, J.B. Study on measures to reduce car accidents of elderly pedestrians by analysing their behavior 25th World Road Congress 2015	Journal Ranking: not applicable Article Citations: not available Article Impact: not available Author Citations: not available	Elderly pedestrians generally safe at crosswalks. Lack safety awareness when green light blinks. Some deviate from crosswalk. Lack knowledge of traffic safety signs.	The document does not explicitly mention the limitations of the study.	54 elderly people over 65 years old.	Qualitative & quantitative study	Focus on elderly pedestrians to provide measures for reducing car accidents.		Developing traffic safety measures for elderly pedestrians.

Appendix M –NVivo Codebook

Name	Files	References
Controls	1	2
Accomodation of Bus Stops	6	6
Advanced Technologies	1	1
Advanced Warning and Signage	26	50
Audible Messaging	7	8
Communication with public	14	19
Cone Bars	3	6
Construction methodology, staging and design	4	6
Detours	22	41
Dismount	4	5
Escorting or Temporary Removal of Hazards	6	8
Fencing	30	65
Kerb Ramps	18	46
Lighting	9	15
Reconnaissance & Trials or Testing	14	21
Road marking or Tape	3	4
Safety Zones	5	6
Sharing the road	18	25
Shuttle transport	7	7
Speed Limits and Enforcement	17	23
Tactile Pavers	3	5
Temp Walkway Bridges	4	6
Temporary Crossing	9	13
Temporary Cycleways	9	19
Temporary Ped or Cycle StopGo or Signals	1	2
Temporary Walkways	26	70
Trench covers	1	1

TRSBS	7	10
Walkway covering	7	8
Definitions	28	67
Design	0	0
Design philosophy	36	83
Design Process & Construction integration	26	61
Design shortfalls	5	17
International design or planning contexts	2	4
Report-specific	1	1
Additional stuff for other parts	14	16
Ideas for presentation of data	8	11
Structure or content of findings	2	10
Future Research	1	1
Good Practice Guide itself	3	9
Content	4	7
Presentation of content	2	2
Structure	3	5
Must, Should, Optional	0	0
Must	86	10284
Optional	41	970
Should (Shall)	73	4139
Overarching TTM Context	1	42
The importance of effective TTM	1	16
Quotes	4	5
Regulatory Framework	15	288
3C's	3	23
International regulatory framework	6	11
Must	6	17
PCBU Responsibilities	1	22

Planning	2	20
Practical Tools	1	27
Procurement	1	3
Risk Management Process	4	63
Setting legislation or standards	4	8
Should	5	32
The design of standards	1	22
Training & Competency	1	20
Workers & Worker Engagement	1	15
RISKS	0	0
Conflict Methods	2	2
Risk Moderators	0	0
Children attracted to construction	1	1
Complex road environments	2	3
Compliance or decision making or risk taking by VRU	21	43
Darkness or Nighttime	10	12
Impairment	4	5
Inadequate or innapropriate TTM	1	1
Lighting	4	4
Noise	1	1
Rail Crossings	2	2
Road environment type or factors	1	1
Space constraints	4	5
Surface Condition	6	7
Time or Duration	7	8
Visibility	4	4
Volume of VRUs	7	7
Weather	2	2
Risks arising from deployment of controls	1	1

Control deterioriation	4	5
Cyclists using different standard facilities	3	4
Diverted attention, modified behaviours or confusion	19	31
Dynamic environments	1	1
Lighting	6	9
Loss or impact of access to properties	2	2
New points or places of conflict or interaction	1	1
Redundant materials or plant or hazards	3	3
Sign placement	16	19
Site Access or Exit	2	2
Standard or capacity of diversion routes	2	5
Subjectivity or competency	4	6
Surface Condition & Trip Hazards	17	23
Visibility	3	5
Water pooling	2	3
Specific Risks	15	37
Existing infrastructure and facilities	1	1
Falling object risk	7	8
Materials and Plant	2	4
Open trenches or manholes	6	6
Trip Hazards or Poor Surface Condition	7	17
Stuff across the walk or cycle way	1	2
Rule Layers	2	2
Outcome Rules	8	10
Prescription	6	9
Process or Procedure Rules	9	12
Specific VRU groups	27	53
Less able VRUs	23	46
Terminology	5	8

Themes (other or wider)	0	0
Case Studies	4	4
Inadequate design	6	8
Iteration (or lack of) of good practice	4	18
Layered Guidance (Layered Good Practice)	10	11
Permanent vs Temporary facilities	4	7
The importance of Audience	4	4
The philosophy for managing risks	11	18
The value to the work (for dealing with VRU well)	2	2
Training Requirements (for practitioners)	7	15
VRU Overarching Problem	2	3
Ambiguity and Insufficiency of standards	4	9
Auditing and Compliance	18	24
DSI stats or data	5	7
DSI data methodology or gathering	4	6
International DSI data or stats	13	33
VRU Principles or Frameworks	7	13
Lowest total risk	8	8
Overarching international VRU principles or frameworks	38	98
Overarching TTM Principles or Frameworks	24	43
VRU Terms	96	16088
Cyclist(s) and all derivitives	86	6148
Pedestrian(s)	96	8817
Person(s) with Disabilities (and derivitives)	48	894
Vulnerable Road User(s)	31	229

Appendix N – TTM VRU Hazard Sources

Hazard category	Static/Dynamic	Hazard Source[41]
Physical Environmental Hazards[42]	Static Environment[43]	Surface and geometry (such as the existing surfaces being used, level differences that could cause trips etc.)
		Vegetation
		Permanent infrastructure (includes street furniture, permanent signage, drainage infrastructure, barrier systems, fencing etc.)
	Dynamic Environment	Other vulnerable road users on foot
		Other vulnerable road users on wheels
		Public vehicles in the road environment
		Public vehicles entering/exiting the road environment (e.g., property access/exit)
		Special transport (e.g., garbage trucks, postal vehicles, public transport, emergency vehicles)
		Railway interface[44]
		Animals
Activity Hazards[45]	Activity Static Hazards	Excavations or open fall hazards (i.e. manholes or similar)
		Stored equipment or materials (e.g., construction materials, stockpiles, or static equipment or facilities like ablutions)
		Compromised infrastructure (electrical or other utility hazards, removed facilities such as kerbing or safety devices)
	Activity Dynamic Hazards	Plant and machinery (within the working area)
		Plant and/or machinery entering or exiting the working area
		Workers on foot (including entering/exiting working area)
		Falling objects
		Hazardous substances (including dust)
		Noise

[41] The named hazard sources are explored with a focus on construction-like activities. However, it is important that other activities in the road environment can be captured in this framework, such as special events or filming activities. As written, these hazard sources can be morphed to apply to other activity types.
[42] Hazards that are present regardless of the presence of an activity that changes the normal road conditions (i.e. the work activity that is giving rise to the TTM) (NZQA, 2023).
[43] Factors such as weather and lighting/darkness are introduced later as *risk moderators* that increase or decrease the level of risk presented across other domains.
[44] This combines dynamic hazards (i.e., trains) and static hazards (i.e. permanent rail interface infrastructure).
[45] Hazards introduced as part of the activity being undertaken (but not including hazards that arise from treatment of hazards – these come later) (NZQA, 2023).