

## TRANSPORTATION 2026 CONFERENCE THINK PIECE PAPER

### PAIRED-BACK PEDESTRIAN CROSSINGS – A SYSTEM DESIGN PERSPECTIVE

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#### ABSTRACT

In the face of increasing urban complexity, constrained funding for active modes, and ambitious mode shift goals, Road Controlling Authorities are being challenged to deliver safer, more walkable streets using the tools, funding and infrastructure already in place.

"Paired back" pedestrian crossings - treatments that are context specific and grounded in risk mitigation - have been trialled internationally as a nimble way to support safer streets, particularly at low-speed crossing locations in urban environments. But in the New Zealand context, existing legislative requirements can make this approach difficult for practitioners, thereby resulting in Do-Nothing or Do-Minimum outcomes.

Current legislation, specifically the Land Transport (Road User) Rule 2004, often prioritises uniformity over flexibility, creating unnecessary regulatory and financial obstacles that inhibit Road Controlling Authorities ability to improving walking conditions in their communities.

By applying research on the impact of redundancy on improving systems reliability, we look to understand what design elements of a pedestrian crossing really matter. This paper explores the tension between innovation and compliance, asking whether existing legal frameworks are enabling or constraining progress to improve the safety of people walking.

In a time when transport resilience depends on doing more with less, we ask: is our legislation fit for the future of walking?

## INTRODUCTION

Pedestrian crossings, also commonly referred to as zebra crossings, are a simple, cheap and effective tool to improving the walkability of our urban spaces. They serve a fundamental safety and accessibility function for people walking in our communities.

In New Zealand, the design elements of pedestrian crossings are guided by a highly legislative framework. This framework, while grounded in safety principles, has over time become increasingly prescriptive. The emphasis on compliance and uniformity can, as the author has personally experienced, result in outcomes that are operationally contrived, contextually insensitive or even less safe.

This paper explores the concept of paired-back pedestrian crossings as an opportunity to critique design elements required by legislation, specifically the Traffic control Devices Rule 2004.

The premise is not to abandon standards or legislation, but to acknowledge and gain a better understanding of concepts surrounding systems redundancy. In turn these concepts might be applied to many areas of transport engineering, thereby enabling more resilient and innovative walking outcomes.

## REDUNDANCY IN SYSTEM DESIGN

Redundancy in system design is necessary to ensure system reliability and help mitigate catastrophic failure. It is a generally acknowledged concept in industries such as aerospace engineering where the failure of any sub-system is likely to lead to catastrophic failure of the total system. These concepts are also well understood in recreational activities such as mountaineering and rock climbing when building anchors to protect climbers from a fall.

Harden (2017) has shown that adding a second element improves the reliability of the system by 93%. However, additional elements to increase redundancy provide diminishing returns on the probability of failure. There is less than a 1% return in system reliability when adding more than 4 design elements.

An adapted summary of this study's results is shown in Table 1. This finding allows us a framework in which we can start to explore the pedestrian crossing system from a probabilistic perspective.

Table 1. Estimated reliability and Probability of Failure (adapted from Harden (2017))

<b>% Change in reliability from a single piece of redundancy</b>	<b>% Change in reliability from each additional piece of redundancy</b>	<b>Probability of Failure</b>
Not applicable	Not applicable	(1 in 1,000)
93.0%	93.0%	(1 in 14,300)
95.9%	2.9%	(1 in 24,300)
97.5%	1.6%	(1 in 39,700)
98.3%	0.8%	(1 in 59,500)
98.7%	0.4%	(1 in 76,900)
99.3%	0.6%	(1 in 139,400)
99.6%	0.3%	(1 in 233,200)

A key conceptual point to make here is that the aerospace engineering industry and recreational climbers have an acute understanding of the trade-offs associated with adding redundancy to improve system reliability. In their case, additional redundant elements require trade-offs in terms of weight and size.

The Traffic Control Devices Rule 2004 seems to disregard the negative effects of excessive redundancy. In effect they are considered negligible.

This conceptual and probabilistic framework will be used to critique the various design elements of pedestrian crossings. We can then ask ourselves, what are the negative effects of excessive redundancy in pedestrian crossing design? What is our “weight and size”?

## PEDESTRIAN CROSSING SYSTEM RELIABILITY AND FAILURE MODES

What does *system reliability* mean for a pedestrian crossing? First, we need to define success and failure scenarios.

A successful pedestrian crossing means that a driver will yield, prior to the transverse white lines, so that a person is able to walk across the crossing unimpeded as per Section 10.1 of the Land Transport (Road User) Rule 2004.

There are several failure modes of varying degrees of severity. A minor failure might be considered as a driver not giving way to a pedestrian waiting to cross. A major failure might be defined as a driver colliding with a pedestrian already on the crossing.

For the purposes of this think piece paper, both failure modes are precipitated by the driver deciding to not yield. This is the key moment in which all individual design elements must be considered and evaluated in terms of their contribution towards improving system reliability.

Finally, we must set an acceptable level of risk for the pedestrian crossing. As shown in Table 1, adding more than three redundant elements will achieve less than 1.6% in a systems reliability. As such, the author suggests that a probability of failure of 1 in 24,300 is acceptable for a pedestrian crossing.

## PEDESTRIAN CROSSING DESIGN ELEMENTS AND THE MISSING PIECE

[Appendix A](#) shows the design elements required by legislation to achieve a compliant pedestrian crossing.

The most critical design element of a pedestrian crossing are the white transverse lines. These constitute the primary safety feature of the pedestrian crossing system.

However, there is something missing from this diagram, the *human*. It must be acknowledged that the *human* forms an integral, and equally important part of the safety system of the crossing. Without them the white transverse lines fail, and a driver does not stop. Conversely, without the white transverse lines, the driver is unlikely to yield.

This paper asks the reader to consider in what situations or contexts is this the only design feature needed to improve system reliability in low-speed (less than 30 km/h) crossing locations? Similar “paired-back” layouts operate effectively in everyday environments such as supermarket car parks and petrol stations.

The reader, if they have followed this far, will see that in many low-speed crossing locations, additional treatments above and beyond the white transverse lines may have a limited positive impact on overall system reliability.

Additional design elements start to add “weight” and “size” to the system. The reader is invited to consider what impact these might have on an individual project’s lifecycle, and the surrounding urban form.

We must also acknowledge the inherent risk that will always exist between at any form of at-grade pedestrian crossing. The effectiveness of a raised pedestrian crossing or even a raised signalised pedestrian crossing, is fundamentally based on the compliance of the driver (assuming that they are not a bad actor). The question then becomes what infrastructure can we use to encourage this goodwill, in what contexts is what valid, and how much is too much?

## ANALYSIS OF LEGISLATIVE REQUIREMENTS

This section will focus on each design element required by Section 8.2 of the Land Transport (Road User) Rule 2004 and link it with a specific risk factor that contributes towards the total's system's reliability.

Concepts explained in the previous section's will be used to consider which elements, on a conceptual and first-principles basis, help improve system reliability.

### Vehicle speeds

*8.2(1) A road controlling authority may, except for areas controlled by traffic signals, mark a pedestrian crossing on a road for which a speed limit of 50 km/h or less is set*

*8.2(2) A road controlling authority may mark a pedestrian crossing on a road for which a speed limit of more than 50 km/h is set if it has obtained the approval of the Agency and complies with any conditions specified in the approval.*

Both clauses relating to vehicle speed recognise that vehicle velocity is the primary determinant of harm severity in a pedestrian–vehicle conflict. Installing pedestrian crossings on roads with operating speeds above 50 km/h, regardless of the surrounding environmental context, is likely to lead to an increase in deaths and serious injuries among pedestrians.

However, it is important that that any safety assessment considers the vehicle speed on approach to at the desired crossing location rather than relying solely on the posted speed limit or generalised network classification.

The operating speed of a vehicle travelling mid-block on a 50 km/h corridor can differ substantially from that of a vehicle approaching an intersection or T-junction, where speeds typically range between 10–30 km/h. Recognising this gap is critical to ensuring that pedestrian crossing design is proportionate to risk and context within the speed environment.

### Width of carriageway

*8.2(5) A pedestrian crossing must not, by 30 June 2006, exceed 15 m from one side of the roadway to the other side unless it is:*

- (a) interrupted by one or more traffic islands to form two or more pedestrian crossings; or*
- (b) replaced by traffic signals*

This clause deals with the width of carriageway and how the width of a roadway affects the visibility of a person walking in front of a car.

The average person in New Zealand is approximately 1.8m tall and when walking side on between 0.5m-1.0m wide. As the crossing distance increases, a pedestrian appears proportionally smaller and less conspicuous to approaching drivers, reducing their visual prominence and likelihood of detection. The effect is amplified if the person crossing is a child, in a wheelchair, or elderly as they are often smaller and less conspicuous by nature.

The intent of this clause is to maintain pedestrian visibility in relation to the width of the crossing and set a maximum limit. It does not specify a design element so to speak but sets constraints on the number of viable locations in which a zebra crossing may be considered suitable.

This clause is grounded in our physical ability to perceive movement and is sensible on all accounts.

## Layout of white transverse lines

8.2(3) A pedestrian crossing must be marked in reflectorised white and as specified in Schedule 2.

8.2(6) Markings for a pedestrian crossing must be placed, as far as practicable, either at right angles to the middle line of the roadway or so as to provide the most convenient route for pedestrians.

These clauses prescribe the layout of the white transverse lines that form the primary design element in the pedestrian crossing system.

The M1-1 Pedestrian Crossing layout shown in Schedule 2 may not adequately consider a pedestrian's desire line, their continuous path of travel, or the location of any kerb cutdowns.

In some cases, this layout results in crossings that are offset from a pedestrian's desire line. In some instances, crossing locations may be set further back to provide space for vehicles to queue outside the main flow of traffic.

This has the effect of reducing visibility by positioning pedestrians toward the outside of a driver's field of view and may increase the likelihood of street furniture obstructing the view of someone waiting to cross.

Many New Zealand streets are further constrained by steep topography, resulting in sections without footpaths. In such cases, the current rule is often used to preclude the installation of pedestrian crossings because the minimum 2m width cannot be achieved.

Additionally, some locations like the example shown in Figure 1 would be well served by a simple set of white transverse lines that also function as the give-way limit line for approaching motorists. This would facilitate a prioritised pathway where standard and costly footpath construction is not feasible.



Figure 1. Footpath in Christchurch stops abruptly to due steep topographic constraints. A stepped walkway provides access to houses on the Scarborough hill (Christchurch, 2025)

## Materiality

*8.2(3) A pedestrian crossing must be marked in reflectorised white and as specified in Schedule 2.*

*8.2(3A) If white does not contrast with the colour of the adjacent roadway, the roadway must be resurfaced or marked to provide a contrast to the white lines.*

These clauses prescribe the materiality of the transverse lines. It assumes that the road surface is constructed of asphalt so that white lines provide a sufficient contrast.

Ensuring the visibility of the primary point of redundancy is absolute. If for some reason the transverse lines are not entirely visible, or the view of the person waiting to cross is compromised, then at least one additional element is needed to highlight the presence of a pedestrian crossing to an approaching driver.

In many urban environments, paved surfaces are being used as a way to improve amenity of the area, help slow traffic and enhance the general walking experience. This may mean that white does not contrast to the same extents as to that of asphalt.

Readers are invited to ask whether practitioners might choose to utilise a less safe crossing treatment, with fewer legislative compliance measures, rather than risk delivering a non-compliant pedestrian crossing.

## Visibility

*8.2(7) A pedestrian crossing must be placed so that:*

- a) it is visible to a driver approaching the crossing from any direction; and*
- b) the driver's view of the entire length of the pedestrian crossing is unobstructed by any permanent growth, construction or physical feature."*

These clauses deal with the visibility requirements of pedestrian crossing. Again, this is essential given that the visibility of person on a crossing or waiting to cross form the two coupled elements of the pedestrian crossing system.

This clause does allow flexibility in that it does not specify distances for which the crossing needs to be visible from. Thinking of complex urban spaces, this clause must be considered in relation to the driver's decision to yield point and is strongly linked with stopping sight distance.

There may be instances in which physical features such as power poles do restrict the driver's view of the pedestrian crossing or even a person waiting to cross.

## Lighting

*8.2(8) Lighting pedestrian crossings*

*A pedestrian crossing, other than a pedestrian crossing that in the opinion of the road controlling authority will not generally be used at night, must be kept illuminated when street lights are operating so that the crossing markings and a pedestrian on the crossing are visible."*

The estimated cost to design and construct dedicated lighting for a pedestrian crossing is a common reason for discounting it as a viable alternative during the optioneering phase of a crossing improvement project.

Much of our built environment has enough street lighting for people to navigate without a torch and be seen by drivers passing by. Additionally, in more built up areas, lighting from shop windows provides increased illumination for pedestrians on the footpath.

Vehicles also have headlights which provide a second point of redundancy. Dedicated pedestrian lighting above and beyond these other two points of lighting redundancy may be said to provide limited value.

At this point it might be reasonable to ask whether the discounting of a zebra crossing, based on lighting costs, in favour of a pedestrian refuge island, which has a lower lighting requirement,

actually resulting in a less safe crossing outcome?

## Signs and poles

### 8.2(9) Poles, markings and other indicators of pedestrian crossings

A road controlling authority must install, within 2 m from each end of a pedestrian crossing and on a traffic island that separates two pedestrian crossings, a pole that is:

- (a) 75 mm or more in width and 2 m or more in height; and
- (b) marked with alternate parallel bands of black and white, which may be reflectorised, each of which is approximately 300 mm wide."

8.2(10) A road controlling authority must place on every pole in 8.2(9) either:

- (a) an internally illuminated amber globe (that may flash at between 40 to 60 flashes each minute) that is 300 mm or more in diameter; or
- (b) a fluorescent, reflectorised orange sign in the form of a disk that is 400 mm or more in diameter

Signs and poles constitute the 3<sup>rd</sup> and 4<sup>th</sup> design elements within the suite of visibility controls within the pedestrian crossing system. They are designed to increase the likelihood of a driver recognising the presence of a pedestrian crossing. It is not uncommon for other types of priority control to require a combination of signs and road markings to communicate a traffic control to a driver e.g. give-way control or stop control intersections.

It is plausible that these design elements do little to improve the system reliability of the pedestrian crossing, based on the concept of redundancy in system design. Additionally, mandatory requirements of poles and signage have the potential to visually clutter the crossing point and may divert drivers' attention away from a person crossing or waiting to cross the road.

Clause 8.2 (9) deals with design criteria of the sign pole itself. There are almost no other instances where a specific pole painting pattern is specified. It is reasonable to ask what safety function this provides the overall system other than complementing the overall zebra aesthetic?

Clause 8.2(10) specifies the regulatory signage and is the signage component of the pedestrian crossing system. It complements the white transverse lines and is the equivalent of a stop sign or give-way sign. In all cases providing a third point of redundancy appears to provide some benefit to reducing system failure e.g. (the human, the white transverse lines, and now the orange fluorescent, reflectorised orange sign). It also mitigates the possibility of the white transverse lines being partially hidden due to road gradient and crossfall.

When installing new pedestrian crossings, Road Controlling Authorities in general seem to prefer passive signage (Clause 8.2(10) (b)) over the internally illuminated amber globe (Clause 8.2(10) (a)). In effect, they are both provide a constant warning to drivers and are not triggered at the time of a pedestrian wanting to use the crossing. It is sensible that a cheaper alternative is preferred when there is negligible measurable benefit to improving system reliability.

## Advance warning design elements

8.2(11) "To inform approaching traffic of the presence of a pedestrian crossing, a road controlling authority, on each approach to the pedestrian crossing:

- (a) must place a pedestrian crossing warning sign before the pedestrian crossing; and
- (b) must, if practicable, mark a limit line that consists of a white line that is not less than 300 mm wide and not less 5 m from the pedestrian crossing; and
- (c) may mark a pedestrian crossing warning marking in the form of a diamond on the road surface."

Clause 8.2(11) relates to prescriptive design elements that focus on the suite of visibility treatments within the pedestrian crossing system.

The author proposes that these constitute the 5<sup>th</sup>, 6<sup>th</sup>, and 7<sup>th</sup> redundant elements of the pedestrian crossing system. Based on our principles shown in Table 1, these provide little to no value in terms of system reliability or reducing the probability of failure. Furthermore, they impact the driver's decision making system too early before the yield / no yield decision point when other stimuli are diverting the driver's attention.

Advance warning signs are useful to warn motorists travelling at higher speeds (above 50km/h), or when there are *unexpected hazards* that must be communicated to drivers. It is of the author's opinion, that people and pedestrian crossings only within an urban environment should not be considered *unexpected hazards*. Our transport legislation does not require advance warning for stop signs in urban areas – it is reasonable to ask why then is it mandatory for pedestrian crossing?

It should be noted here that the Traffic Control Devices Rule does not distinguish between a zebra crossing placed mid-block and a zebra crossing placed near an intersection. Future updates to national design guidance would do well to highlight this gap to alleviate compliance tensions for low risk crossing locations.

In isolated, mid-block situations, these compliance requirements may seem benign and don't appear to add "weight" or "space" to the pedestrian crossing system. However, in complex urban environments these requirements can lead to tricky cluttered designs, or insensible signage displays. A similar, example of this would be the placement of a speed limit sign on approach to stop controlled intersection. What is more important for the driver to be aware of at this specific point in time – to stop or to understand the speed at which they can travel?

8.2(11)(b) requires a vehicle to be stopped 5m in advance of the white transverse lines. Providing a set back may provide a sense security for someone crossing the road. Is this approach overly conservative, and does it meaningfully contribute to improved system reliability when, in practical terms, the near edge of the white transverse line functions as the "limit line"?

As a result of these advance warning compliance measures, we can start to see the get a clearer picture of the design elements that really provide value to the reliability of the pedestrian crossing system. At the same time, the "weight" and "space" of these elements starts to manifest in visual clutter, cost, or in more general terms the discounting of zebra crossings in preference to lower compliance options.

## Miscellaneous clauses

8.2(4) *A pedestrian crossing must be marked in accordance with 8.2(3), and if applicable with 8.2(3A), by 30 June 2007.*

8.2(12) *To inform approaching traffic of the presence of a pedestrian waiting to cross at a pedestrian crossing, a road controlling authority may install and maintain an on-roadway flashing yellow light system that is:*

(a) *installed as described in diagram M1-4 of Schedule 2; and*

(b) *illuminated only when a pedestrian waiting to cross is detected and remains illuminated only for a period sufficient to permit the pedestrian to cross the pedestrian crossing*

Clause 8.2(4) was intended to standardise pedestrian crossing layouts across New Zealand by the specified date, due to a previous change in legislation. It deals explicitly with compliance. The author reasonably asks, what value does it add almost two decades on?

Clause 8.2(12) allows for activated on-road lighting treatments to enhance pedestrian visibility at crossings. Such treatments have not received good uptake amongst Road Controlling Authorities, which may be for many reasons. However, experience shows that resilient transport infrastructure often has low maintenance requirements, especially treatments used on the road's surface.

## DOING MORE WITH LESS – THE BENEFITS

A more flexible, risk-based framework for pedestrian crossing design could lead to multiple benefits in terms of installation and costs savings, especially when considered at scale. Equipped with a better understanding of redundancy in system design, we may ask readers to evaluate the effectiveness of each pedestrian crossing design element. Of course the appropriateness of a zebra crossing must be considered in relation to vehicle and pedestrian volumes, site geometry and should sit alongside industry guidance such as the AustRoads Pedestrian Facility Selection Tool.

If a risk-based framework was available Road Controlling Authorities may make significant cost savings by avoiding unnecessary design elements to achieve compliance.

Additionally, if walkability in our communities is improved, this would lead to healthier, more connected communities. The more we can do to support walking, the more we can increase resilience in our communities.

## CONCLUSIONS AND RECOMMENDATIONS

The author concludes that the primary and secondary redundant elements of the pedestrian crossing system are the white transverse lines on the road surface and person crossing or waiting to cross.

Adding passive warning signage (fluorescent, reflectorised orange signs) as the third point of redundancy, is assumed to help the pedestrian crossing system achieve a probability of failure of 1 in 24,300. This is purely from a probabilistic point of view, where all humans are acting as intended. Of course, in the real world there are a myriad of things that may increase the probability of failure at a pedestrian crossing (the presence of drugs or alcohol, distraction caused by mobile phones etc)

Adding signage and markings above and beyond the third point of redundancy in any system is unlikely to result in a lower probability of failure.

In the context of design and planning cities in New Zealand's urban environment, the challenge lies not only in updating transport legislation but also in a better understanding of redundancy in systems and the wider "safety" culture. A risk-averse interpretation of standards and legislation has created an environment where excess is equated with safety. This is based on the incorrect assumption that increased redundancy improves the reliability of that system by a factor equal to

the number of redundant elements. This paper has explored this concept and applied to the legislative design requirements of the Traffic Control Devices Rule 2004.

The result of this culture is a paradox. While transport policy frameworks increasingly emphasise mode shift, sustainability, and accessibility, our legislation remains anchored in outdated assumptions about risk and redundancy. This approach has inflated costs, inhibited the use of simple tools to quickly and effectively retrofit our urban spaces, and propagated our car dependent society.

### Recommendations

- A pilot scheme of risk-adjusted pedestrian crossing facilities that methodically measured and assessed the impact of omitting certain pedestrian crossing elements in specific locations and their impact on safety and accessibility is recommended.
- A suitable monitoring and evaluation methodology would need to be developed and be an integral part of the pilot scheme mentioned above
- Section 8.2 could be updated to allow Road Controlling Authorities to omit certain design elements based on a risk assessment grounded in systems thinking and redundancy, and site specific parameters.

## REFERENCES

HARDEN, A. (2017). *How Much Redundancy is too Much Redundancy?*, Bastion Technologies Incorporated, NASA Technical Reports Server

NTA Cycle Design Office (2022), Zebra Crossing Pilot Scheme Technical Literature Review, AECOM Dublin, Ireland

NZ Transport Agency Waka Kotahi, Traffic control devices manual Part 4: traffic control devices for general use - for intersections, October 2024

NZ Transport Agency Waka Kotahi, Traffic control devices manual Part 5: Traffic control devices for general use – between intersections, Version 1, December 2020

## AUTHOR CONTRIBUTION STATEMENT

Research, writing, and careful comparison of systems undertaken solely by Ben Zmijewski. I'd like to thank my partner and architect, Daniela Vanickova, for her support in helping me understand the value of design.

The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views, policies, or positions of my current employer.

# APPENDIX A - TYPICAL PEDESTRIAN CROSSING DETAIL

