

# Evaluation and Implementation of Shared Spaces in NSW: Framework for road infrastructure design and operations to establish placemaking

## Examination of existing Shared Space knowledge

---

*Final Report*

**February 2022**

Transport Research Centre (TRC), School of Civil and Environmental Engineering,  
University of Technology Sydney (UTS)

### **Contributors**

*Dr Kasun Wijayaratna*

*Dr Cecilia da Rocha*

*Dr Michelle Zeibots*

*Nicholas Bradbury*

*Nafisa Nishandar*

## **Disclaimer**

This report has been prepared on behalf of and for the exclusive use of Transport for NSW, and is subject to and issued in accordance with the agreement between Transport for NSW and the University of Technology Sydney. Care has been taken in the preparation of this report based on available evidence. The University of Technology Sydney does not make any representations or state that the report is free from error, is current, or, where used, will ensure compliance with any legislative, regulatory or general law requirements. The University of Technology does not accept any liability or responsibility, including for any loss or damage, resulting from reliance on this document. Copying this report without the permission of Transport for NSW and the University of Technology Sydney is not permitted.

## Table of Contents

List of Figures .....	4
List of Tables .....	5
Executive Summary .....	6
1 Introduction .....	8
1.1 Stage 1 Objectives.....	12
1.2 Report Structure .....	12
2 Background and Literature Review .....	13
2.1 Definition of Shared Spaces.....	13
2.1.1 Shared Space Terminology.....	17
2.1.2 Shared space Objectives and Design Principles .....	20
2.1.3 Brief summary of Shared Spaces in Australia .....	23
2.2 Relevant Standards, Guidelines and Technical Reports .....	27
2.2.1 Road Safety Guidance: “Towards Zero” Vision .....	27
2.2.2 Global Street Design Guide .....	29
2.2.3 Austroads Guide to Traffic Management (AGTM) .....	29
2.2.4 Australian Standards (AS 1742).....	30
2.2.5 Movement and Place Framework (NSW, Australia) .....	31
2.2.6 Streets for People: Compendium for South Australian Practice (South Australia, Australia).....	31
2.2.7 Federal Highway Administration - Accessible Shared Streets (United States of America) .....	32
2.2.8 Manual for Streets (UK) .....	32
2.2.9 NZ Standards and Guidance.....	33
2.2.10 Other Key Documents.....	34
2.2.11 Complexity of “shared space design” implementation in NSW .....	36
2.3 Shared spaces academic literature .....	37
2.3.1 Qualitative Literature: Understanding the shared space concept and users’ perspectives.....	38
2.3.2 Quantitative Literature: Measuring and evaluating the impacts Traffic Engineering and Modelling publications .....	41
2.3.3 Integration of Qualitative and Quantitative .....	42
2.4 Shared Space Parameters and Metrics.....	42
2.5 Summary of Key Findings .....	50
3 Review of Case Studies .....	52

3.1	Case Study 1: Horseshoe Common, Old Christchurch Road, Bournemouth, UK ..	53
3.2	Case Study 2: Acorn Road, Newcastle upon Tyne, UK.....	56
3.3	Case Study 3: Auckland, NZ.....	59
3.3.1	Elliot Street, Auckland NZ .....	60
3.3.2	Fort Street, Auckland NZ .....	62
3.4	Applications of Shared Spaces in NSW .....	67
4	Challenges and opportunities to implementing Shared Spaces.....	70
4.1	Challenges and opportunities.....	70
4.1.1	Developing trust and collaboration in a transformative concept.....	70
4.1.2	Limited empirical evidence of applications .....	70
4.1.3	Clear guidance, standards and directions for transport professionals .....	71
4.1.4	Opportunities for Transport for NSW.....	71
4.2	Current best practice in the implementation of Shared Spaces .....	72
4.3	Potential applications of Shared Spaces in NSW .....	73
5	Concluding remarks and next steps .....	76
6	References .....	79

## List of Figures

Figure 1: The theory of the shared space design concept .....	9
Figure 2: Shared space research program.....	10
Figure 3: Report Structure and Logic .....	12
Figure 4: Timeline of Shared Space Literature (Developed using Karndacharuk et al. (2014a)) .....	16
Figure 5: Origins of shared space terminology .....	18
Figure 6: The spectrum of shared space design options (CIHT, 2018).....	19
Figure 7: Definition of shared spaces (Adapted from Karndacharuk et al. (2014a) and Local Transport Note 1/11, (2011), Section 1.9, Department for Transport (UK)) .....	20
Figure 8: Shared spaces separated into Frontage Zone/Comfort Zone/Furniture Zone/Shared Zone (Elliot et al., 2017) .....	22
Figure 9: Shared space separated into Accessible Zone/Activity Zone/Circulation Zone (Royce, 2017, Auckland Council, 2017) .....	22
Figure 10: Zoning of shared spaces in academic literature (Karndacharuk et al., 2011).....	23
Figure 11: Relationship between shared zones (as used in NSW) and the traditional Shared Space definition .....	25
Figure 12: Procedure for the implementation of novel designs for local area traffic management purposes .....	36
Figure 13: Categorisation of shared space academic literature .....	38
Figure 14: Preliminary framework with conceptual relationship between performance metrics .....	49
Figure 15: Preliminary framework with conceptual relationship between design parameters and performance metrics .....	50

Figure 16: Location of shared space implementation at Horseshoe Common, Old Christchurch Road, Bournemouth, UK (OpenStreetmap, 2021) .....	55
Figure 17: Old Christchurch Road, Before and After implementation of the shared space design .....	55
Figure 18: Location of shared space implementation at Acorn Road, Newcastle upon Tyne, UK (OpenStreetmap, 2021).....	57
Figure 19: Diagrams of raised platform designs on Acorn Road (combination of Figure 5.7 and 5.8 of (Clarkson, 2017)) .....	58
Figure 20: Acorn Road, Before and After implementation of the shared space design (Clarkson, 2017) .....	58
Figure 21: Location of shared space implementations in Auckland, NZ (OpenStreetmap, 2021) .....	60
Figure 22: Elliott Street, Before and After implementation of the shared space design.....	62
Figure 23: Staged upgrade of Fort Street and adjacent streets (Auckland Council, 2012) ...	64
Figure 24: Before and after - Stage 1 of the Fort Street project .....	65
Figure 25: Before and After - Stage 3 of the Fort Street project.....	66
Figure 26: Horton Street/Clarence Street Intersection Features (Facing East on Clarence Street).....	67
Figure 27: Port Macquarie CBD comparing 2010 and 2021 .....	68
Figure 28: The Entrance Road/Coral Street Intersection, The Entrance .....	73
Figure 29: Bay Street, Ultimo .....	74
Figure 30: Erskineville Road, Erskineville.....	75
Figure 31: Staged Research Program (Highlighting Stage 2) .....	77
Figure 32: The relationship of the Shared Space Research Program with the Movement and Place Framework .....	78

## List of Tables

Table 1: Shared space objectives .....	20
Table 2: Definitions of shared zones/shared spaces across state jurisdictions .....	23
Table 3: Summary of notable qualitative shared space studies since 2014 .....	38
Table 4: Design factors for successful shared spaces (Jayakody et al., 2018) .....	44
Table 5: Design elements assess for four shared space cases: Peel Street, Bank Street, Leigh Street and Hindley Street in Adelaide, South Australia (Archer, 2014) .....	44
Table 6: Objectives and associated performance metrics (Karndacharuk et al., 2013b).....	45
Table 7: Design parameters (explanatory variables) .....	46
Table 8: Performance metrics (response variables) .....	47
Table 9: Summary of the evaluation of case studies (CIHT, 2018) .....	53
Table 10: Summary of Case Study 1.....	54
Table 11: Summary of Case Study 2.....	56
Table 12: Summary of Cast Study 3.1 – Elliott Street.....	61
Table 13: Summary of Cast Study 3.2 – Fort Street .....	63

## Executive Summary

The Transport Research Centre, within the School of Civil and Environmental Engineering at the University of Technology Sydney (UTS) has been commissioned by Transport for NSW (Transport) to complete a comprehensive literature review of the **shared space design concept and applications in practice**. This concept is a network design and traffic management technique implemented to reduce vehicle dominance at a location and achieve improved place outcomes. However, there has been both positive and negative outcomes from reported implementations, thus requiring further research.

The literature review presented in this report supports the delivery of a research program aimed at **re-establishing the definition and understanding of shared space designs in order to provide transport practitioners additional options to define successful places**. The focus of this report was to understand this concept and determine how shared spaces can support and enhance the development of “successful places”, a key strategic priority of Transport.

Broadly, high level critical findings include:

- The **shared space design concept is one tool that can be used to form successful places** across the community.
- A **spectrum of intervention and design options are available to transport professionals to achieve a shared space** within the road network.
- **Defining relationships between design parameters and performance metrics**, are key to determine the factors that lead to successful shared space implementations.
- **Current guidelines, standards and practical processes limit the application of novel shared space solutions as well as other traditional solutions that value place over movement**.

A non-exhaustive list of key findings categorised by section include:

- **Section 2: Background and Literature**
  - Shared space terminology is varied, synthesis of several publications and government documents led to the definition highlighted below which offers greater flexibility to account for vulnerable road users.

### Shared Space Definition:

A public street or intersection that is intended and designed to be used by all modes of transport equally in a consistently low-speed environment. Shared space designs aim to reduce vehicle dominance and prioritise active mobility modes. Designs can utilise treatments that remove separation between users in order to create a sense of place and facilitate multi-functions.

- Though initial implementations of shared spaces focussed primarily on measures to create an entirely shared environment (removal of all separation infrastructure), authorities in New Zealand and the United States of America (USA) have proposed a “zone-based” approach to implementation. The shared space is separated into zones where all users can share the space and other protected zones that provide

vulnerable road users safe accessibility. This is reflected in the multitude of public available standards, guidelines and technical reports.

- In general, Australian authorities have implemented a constrained version of the traditional shared space design concept, referred to as “shared zones”. Shared zones have historically had strict limitations on speed (10km/hr) that limit applications. More innovative designs (for example, flush intersections) require a series of complex approvals that need to be simplified in the future.
- The most recent key author of relevant academic literature concerning shared spaces is Auttapone (Aut) Karndacharuk, who has shaped the evolution of the concept and its application.
- Academic literature concerning shared spaces can be broadly separated into qualitative conceptual studies focussed on user perceptions and quantitative studies that focus on traffic performance measurements. There is a lack of research proposing frameworks for a comprehensive evaluation of shared spaces performance in terms of place and movement.
- Studies on shared space evaluation are fragmented in terms of design parameters and performance metrics with limited correlation between these two domains. The research presents a preliminary conceptual mapping of design parameters and performance metrics currently highlighted in the literature.
- **Section 3: Review of Case Studies**
  - Case studies reveal positive outcomes in terms of safety and objective achievement (creating a successful place) however public perception has been mixed.
  - Small sample size and the limited used of before and after studies are two major drawbacks. This can be rectified in the future using a comprehensive evaluation framework, that can be developed within this research program.
- **Section 4: Challenges and opportunities for the implementation of Shared Spaces**
  - Shared spaces are driven by the requirements of a community and the need to create community, therefore trust, collaboration, and close engagement are integral to their successful design and implementation.
  - Shared spaces need to be developed and implemented in alignment with the Towards Zero vision (a road network free from death and serious injury). This adds important requirements to limit the amount of force that vulnerable road users may be exposed to. It also has implications on regulation (maximum speed limits) and design features that are needed to support safer environments.
  - Transport has the opportunity to be a global leader in shared space adoption by supporting further empirical research of existing and future applications of this innovative concept and defining guidance for effective and sustainable implementation.

This research has shown the potential for shared spaces to develop successful places. By continuing further research and application of this design concept, Transport can better support practitioners in delivering a transformation of the urban landscape and road network that services people rather than vehicles. This can pave the way for a more sustainable transport system while also supporting the development of active communities and places.

# 1 Introduction

A majority of the demand for travel and mobility can be classified as a derived demand, a demand for a commodity or service that is a consequence of the demand for another need. People travel to access employment, education, for commercial purposes or to participate and enjoy leisure activities. Therefore, it is essential for transport practitioners to define a strategic direction and deliver initiatives that provide an effective, efficient and safe transport system to meet the demand for travel. However, this is a complex task, which is reflected by the congested transport systems that exist, in particular road networks in urban centres. Infrastructure Australia prepared a report in 2019, “*Urban Transport Crowding and Congestion – The Australian Infrastructure Audit 2019 – Supplementary Report*” which presented the 2016 annual cost of road congestion as \$19 billion and of public transport crowding as \$175 million, in Australia. The 2031 estimated annual cost of road congestion is \$39 billion and of public transport crowding is \$837 million. These statistics reveal the alarming trend of economic impacts resulting from system inefficiency, but perhaps more importantly the difference in magnitude of impact between road congestion and public transport crowding. In addition to the economic implications, congested systems deteriorate safety, create social inequity due to accessibility limitations and results in a degradation of the environment, especially in the case of road traffic congestion and greenhouse gas emissions. Accordingly, it is essential for transport professionals to address this situation and achieve a more sustainable environment.

Congestion can be managed through infrastructure provision, however in the context of road infrastructure projects, this has often exacerbated problems as a consequence of induced demands. Thus, recently there has been thought and application into travel demand management practices to encourage greater use of active and public transport modes (Loukopoulos et al., 2004). In addition, there has been a change in planning processes to better reflect the concept of travel being a derived demand. **Instead of exclusively focusing on network connectivity, efficiency and meeting demand with adequate supply, there has been a greater emphasis in providing accessibility to transport options and more importantly to land uses that underly the demand for travel** (Global Designing Cities Initiative and National Association of City Transportation Officials, 2016). In other words, designing and operating transport infrastructure to define places within a community. In this context, a clear strategic objective of NSW Transport, discussed in the *Future Transport Strategy 2056*, is to create “Successful Places” throughout the state. The vision is to “*create vibrant, productive, liveable and sustainable places that support community health, safety and wellbeing*” (NSW Government, 2018a).

**A place is an identifiable geographic area that consists of a physical form, has meaning and offers an opportunity for the community to participate in activity** (NSW Government, 2020). This notion of place has been neglected in the design of road networks, as the focus has been on efficient and effective movement of vehicles and not people. Over the last decade, Transport has invested resources to the development of the *NSW Movement and Place Framework*. This initiative has transformed the planning and management of roads in NSW by appropriately accounting for the need to acknowledge and establish “places” within the transport system. *The Practitioner’s Guide to Movement and Place* (2020) along with the *Movement and Place Evaluator’s Guide* (2020), are two foundational publications that provide best practice directions to the planning and implementation of places. In addition to these resources, and to further encourage the adoption of active transport modes, Transport have

developed tools to support implementation such as the “*Walking Space Guide: Towards Pedestrian Comfort and Safety*”, and the “*Cycleway Design Toolbox: Design Toolbox*”. There is an opportunity to **advance these initiatives by taking into consideration novel designs of road and intersection infrastructure based on the concept of *shared spaces***.

Though the definition of shared space designs has evolved over time (further details are provided in Section 2.1.1), it can be briefly surmised as **road infrastructure designs that minimise separation between travel modes and equalises the priority of the multiple modes**. The theory underlying the concept, is described in Figure 1, where equal priority can reduce the dominance of private vehicles, increase the awareness of all users and define a safer environment for people who walk and use other active transport options. Strategies used within shared space designs can vary from simply signifying a change in road environment through de-cluttering, coloured pavements or addition of street furniture to more drastic measures where features such as signalisation, kerbs, line marking and traffic signage are removed to create an unseparated environment.

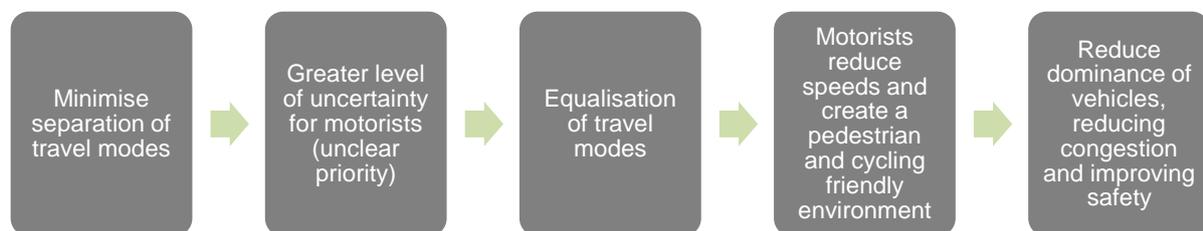


Figure 1: The theory of the shared space design concept

Modifying conventional designs of roads and intersections create greater road user awareness. Removing separation between modes (especially for people who walk and cycle) encourages active transport use and demands people who operate vehicles to reduce speeds and negotiate intersections with greater care. European case studies have revealed benefits of shared space applications in terms of overall safety, efficiency and economic productivity (Hamilton-Baillie, 2008a, Karndacharuk et al., 2016, Frosch et al., 2019). During this period of application in the 1990s and 2000s, there have also been safety incidents and isolated crashes that have occurred at some sites, raising concerns about the application of the approach (Imrie, 2012, Holmes, 2015). This is best reflected by the Department of Transport in London redacting guidance associated with the design and implementation of shared spaces in July 2018, deeming that implementation is not inclusive and the potential risks outweigh the benefits (BBC, 2018). However, only 6 months prior to this decision, a report prepared by the Chartered Institution of Highways and Transportation (CIHT), “***Creating better streets: Inclusive and accessible places – Reviewing Shared Spaces***” presented the following key conclusions (CIHT, 2018):

- “while the schemes **work well for the majority of their users and the place that they are serving**, it is **clear some users consider that the current designs**, especially Informal Streets, **need to be improved.**”
- “**future schemes seeking to improve the public realm through better street design** need to be **promoted, designed, implemented and monitored against a**

series of predefined objectives with clear outcomes that can be measured in a consistent way.”

- “further guidance is required to help local authorities and scheme designers define outcomes... and to develop appropriate ways of measuring them.”

Though there has been a reduction in the application of the shared space design concept, the CIHT report clearly establishes that there are significant benefits to its application. The key issue has been a lack of research, strategic planning guidance and legislation so that practitioners can leverage the concept and also provide a safe and inclusive environment for all users.

Transport has funded a research team at the University of Technology Sydney (UTS) to further investigate the shared design concept for application throughout New South Wales (NSW). The following research report presents the findings of the first stage of a larger shared space research program, presented in Figure 2.

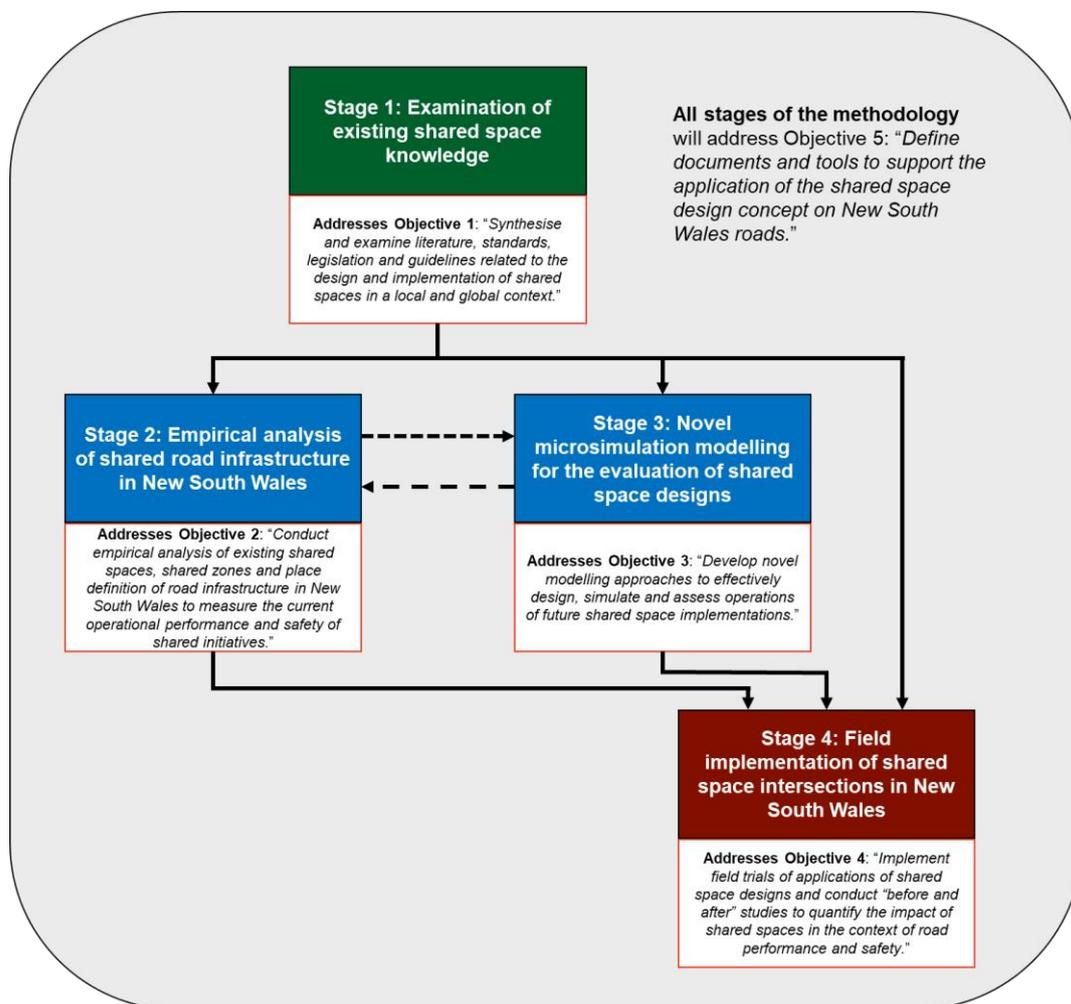


Figure 2: Current shared space research program (June 2021)

The program’s core objective is based on conclusions of the CIHT report and also other recent academic publications (Karndacharuk et al., 2014a, Turner et al., 2020), to **re-establish shared space design concepts in order to provide transport professionals additional options to define successful places in practice**. This requires an investment in research with a particular focus on identifying relationships between design and performance metrics

and then developing methods of quantifying these metrics and relationships. In order to produce the guidance “*required to help local authorities and scheme designers define outcomes*” (CIHT, 2018), there needs to be a transparent evidence base driven by empirical analysis and validated modelling techniques.

The objectives of the research program can be summarised as follows:

1. Synthesise and examine literature, standards, legislation and guidelines related to the design and implementation of shared spaces in a local and global context.
2. Conduct empirical analysis of existing shared spaces, shared zones and place definition of road infrastructure in NSW to measure the current operational performance and safety of shared initiatives.
3. Develop novel modelling approaches to effectively design, simulate and assess operations of future shared space implementations.
4. Implement field trials of applications of shared space designs and conduct “before and after” studies to quantify the impact of shared spaces in the context of road performance and safety.
5. Define documents and tools to support the application of shared space design concept on NSW roads.

As shown in Figure 2, the first stage presents an examination of the foundational knowledge necessary to complete further stages of research which are all critical to thoroughly explore the adoption of shared space design concepts that aid in developing successful places. Additional stages could include quantifying the costs and benefits of the variety of shared space approaches and providing the latest local empirical evidence that will arise from real-world applications of shared space designs.

Prior to the documentation of the findings of the project, it is critical to establish upfront that the shared space design concept is not a singular holistic solution that will result in successful places. **The shared space design concept provides practitioners with additional novel options**, such as by colouring pavements, removing marking and adding street furniture encouraging interaction, to **improve the design, functionality and purpose of place features within the road network**. To achieve this outcome, it is necessary to have a greater appreciation and understanding of the approach as well as measure and compare the effectiveness of shared space designs in developing successful places.

## 1.1 Objectives

The project objectives focus on accomplishing Objective 1 of the research program and specific sub-objectives that are delivered in this report are as follows:

- Synthesise and examine literature, standards, legislation and guidelines related to the design and implementation of shared spaces in a local and global context.
- Collate and summarise global case studies of shared space implementation.
- Define potential challenges and opportunities for the implementation of shared spaces in NSW.

## 1.2 Report Structure

Figure 3 presents the logic and structure of the remaining sections of the report. Initially, the topic of the shared space design concept is contextualised. Literature, guidance documents and standards gathered throughout the project are discussed in **Section 2** to provide a clear understanding of the available knowledge. This section discusses definitions of shared space design, considers these definitions in an Australian context, categorises the body of academic literature, identifies and describes relevant guidelines and standards and finally presents an analysis of metrics definition and development, essential to the design and evaluation of shared spaces. Section 2 is supplemented by **Section 3**, which presents existing empirical evidence of shared space implementations, through a review of publicly available case study data. **Section 4** uses the findings of Section 2 and Section 3 to document the potential for application of the shared space design concept in a NSW context, commenting on current best practice and potential local application sites. Finally, **Section 5**, concludes the report, summarising the key findings of the research, relating the topic back to the strategic directions of Transport and establishing potential next steps of the research program.

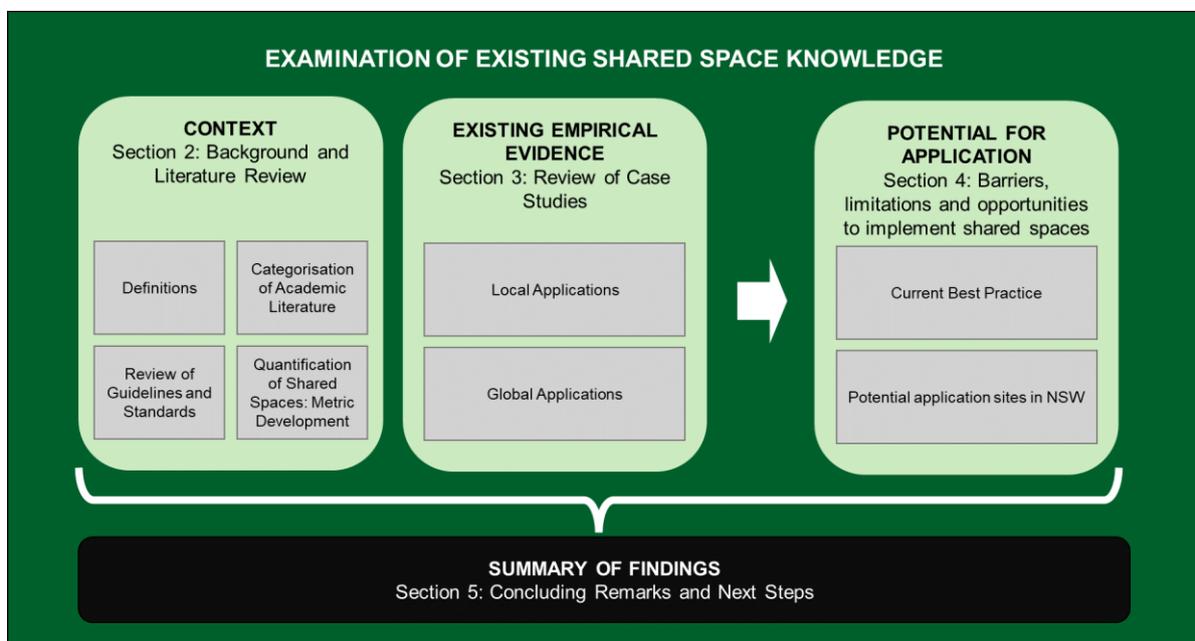


Figure 3: Report Structure and Logic

## 2 Background and Literature Review

Roads are currently being shared by a variety of users, from pedestrians and cyclists to motor vehicle drivers and passengers, this has been a common thread since the creation of road networks. As networks have evolved over time, private vehicles (automobiles) have become the dominant mode of transport, especially in Australia. The 2016 Census revealed that even with the recent considerable investment towards public transport, more than 70% of the journey to work trips are completed using private vehicles (Australian Bureau of Statistics, 2017). Accordingly, road infrastructure has been planned and designed to accommodate this dominant mode while still ensuring the safety of other less dominant modes in the system. This led to the proliferation of highways, grade separated road infrastructure and the implementation of barriers and devices to isolate and control user interactions with infrastructure (Newman et al., 2016). However, as described in Section 1, the dependency on private vehicles, especially cars, has led to traffic congestion, compromising the economic, social and environmental qualities of communities. This forced innovation amongst transport professionals to develop solutions to reduce car use and ownership while also enhancing accessibility to public and active modes of transport. One of the solutions that has been proposed and implemented is the shared space design concept which contradicts the notion that road safety can only be achieved through separation, signage and signalisation. In order to determine the merits of the shared space design concept, it is imperative to understand the background and review all relevant literature.

The following section of the report provides insight into the definition of shared spaces focussing on the core design principles, terminology used and application of the concept within an Australian context. Between 2010 and 2014, Aut Karndacharuk, completed a PhD project in New Zealand focussed on the evaluation of shared spaces. This led to a number of academic publications, government reports and a dissertation. The 2014 dissertation provided the most comprehensive summary of relevant literature related to the topic, and as such the focus of the literature review presented in this report is related to publications since 2014. The report categorises and summarises recent academic publications as well as highlighting the gap in literature that is present. Also included is a review of existing guidelines for shared space application, covering both local and global documents. Finally, a deeper synthesis of academic literature is conducted to provide insight into the evaluation and measurement of shared spaces, by delving deeper into design parameters and performance metrics.

### 2.1 Definition of Shared Spaces

During the 1960's, across Europe, a number of professionals and members of the community advocated to "reclaim streets" by focussing on accessibility of the road network. Sir Colin Buchanan produced the "*Traffic in Towns*" report for the Office of Public Sector Information in the United Kingdom (UK) in 1963, which emphasised that the road network must serve the users and land uses that adjoin the network and not exclusively the vehicles in the system (Buchanan, 1963). This was further developed by Professor of Urban Planning at Delft, Niek de Boer, where he defined the Woonerf Concept (Residential Yard within a Residential Street) in 1965 (Ben-Joseph, 1995). The concept focussed on the removal of signage, road markings, kerbs and barriers to integrate traffic with residential activity. Though undocumented in publicly available literature at the time, Hans Monderman pioneered the implementation of the Woonerf concept across a number of locations in the Netherlands. The articulation of the experiences and impacts of those projects are discussed in Hamilton-Baillie (2008a) as the first applications

of the “shared space” concept. Throughout the 1970s and 1980s, with the focus of improving road safety, many countries, including Australia, investigated and applied techniques such as extensions of the Woonerf concept and also traffic calming measures, to revolutionise traffic management of local areas (Karndacharuk et al., 2014a). The first formal documentation of “shared space design” was presented by Pharaoh and Russell (1991), which discussed the traffic calming policy across a number of European countries.

Since the early 1990s, there has been a number of initiatives and significant progress in the adoption of shared spaces which has been detailed in Karndacharuk et al. (2014a) and summarised using the infographic in Figure 4. Of note are the following key points emerging from around the world:

- **Interreg IIB North Sea Program (2000 to 2006)** – Eight contrasting Shared Space pilots were carried out in 5 countries (Belgium, Denmark, Germany, Netherlands and the UK) with the results being described as the future of planning and design of public spaces (The North Sea Region Programme Secretariat, 2009). Hamilton-Baillie (2008a) provides further details of this and the modern day implementation of shared spaces at the time.
- **UK Experience** – Leveraging the Interreg IIB North Sea Program pilots, and the definition of the Link and Place framework (Jones et al., 2007), which emphasises greater consideration of places in a road network, the UK applied shared space designs across a number of locations. This led to formalisation of guidance for the design concept in 2011, “Local Transport 1/11 ‘Shared Space’ (LTN 1/11)”. However, as mentioned in Section 1, during this time of application, a number of publications (Holmes, 2015, Imrie, 2012, Imrie, 2013) highlighted safety concerns for vulnerable road users (in particular vision impaired users), resulting in the subsequent halt of shared space designs in 2018. Since then, there have been revised applications of “shared-like” designs, coined as shared surfaces, that involve some infrastructure sharing aspects but still maintain a degree of separation to ensure safety is maintained (Essex Planning Officers Association, 2021).
- **New Zealand Experience** – Unlike European experiences during the early 2000s, guidance for shared spaces has emerged since Joyce (2012) and Karndacharuk (2014). Auckland Council have used this research to provide clear guidance specific to shared space design (Auckland Council, 2017), which is currently lacking in Australia. In addition, Auckland Council and the New Zealand Transport Agency have completed a number of trials within the last 5 years, exploring versions of shared space designs which have been successful, and has had a more structured evaluation of impacts. These will be detailed further in Section 3.3. The experiences in New Zealand could shape the path forward for applications in NSW and Australia as a whole.

- Since the abandonment of shared space designs by the UK Department for Transport in 2018, to the research team’s best knowledge, the number of shared space applications that have complete integration of modes and sharing of road space seem to have reduced, or at least not documented widely. However, there have been continual theoretical research contributions, especially articles focussing on modelling and analysis of shared spaces with the objective of defining designs that meet the needs of vulnerable road users (Nasernejad et al., 2021, Friedman, 2021, Jakobowsky et al., 2021, Che et al., 2021, Turner et al., 2020).

Figure 4 also highlights the variation in terminology related to the shared space design concept between jurisdictions and countries. Though coined in 1991, there have been a series of terms used to describe shared spaces or “quasi-shared” spaces (Gillies, 2009) which have been collated by Karndacharuk et al. (2014a) and include the following:

- Woonerf
- Winkelerf
- Stadserf
- Rest and Play areas
- Play street
- Encounter Zone
- Shared Space
- Shared Street
- Shared Zone
- Complete Streets
- Civilised Streets
- Self-Explaining Roads (SER)
- Road Diets
- Context Sensitive Design/Solutions (CSD/CSS)

As the overarching goal of the research is to determine a path to leverage the shared spaces concept, it is critical to clearly establish terminology, objectives and design principles and relate these to an Australian context.

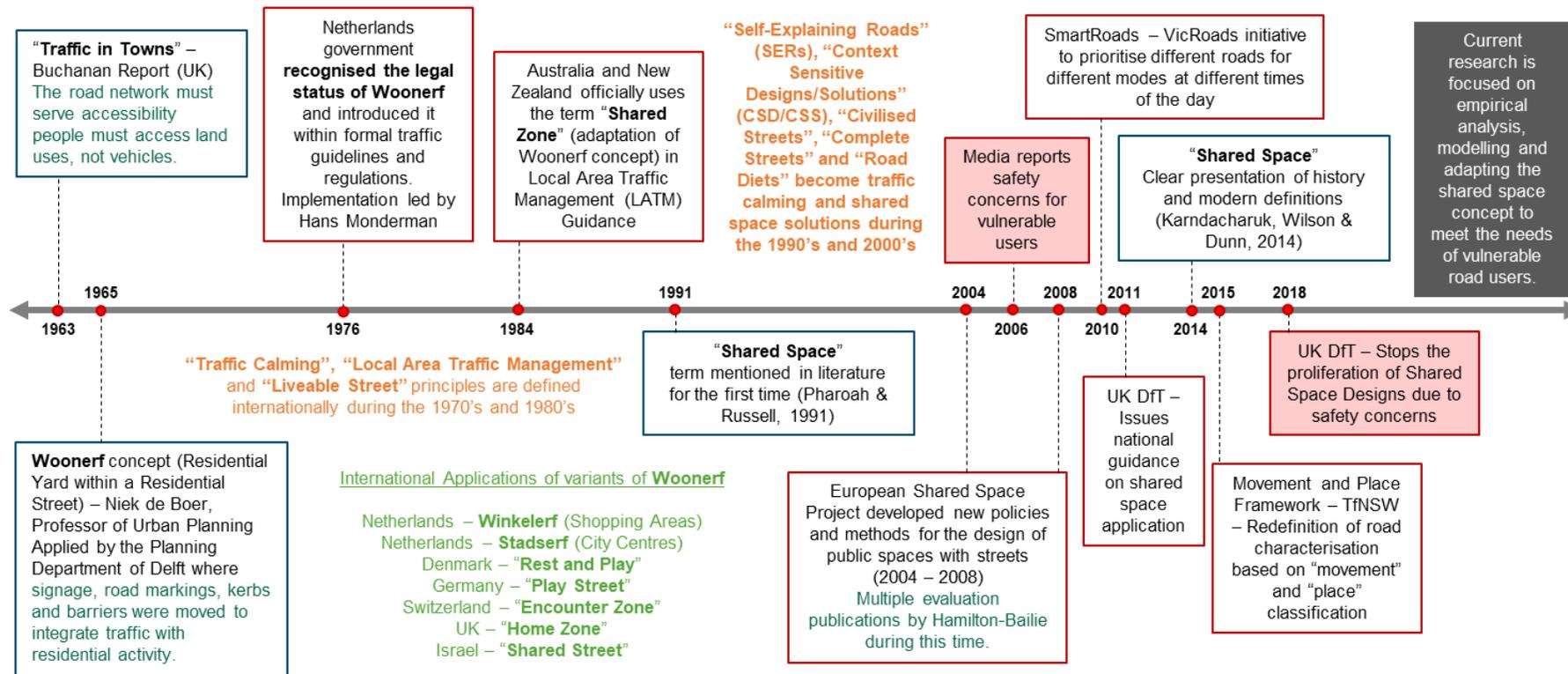


Figure 4: Timeline of Shared Space Literature (Developed using Karndacharuk et al. (2014a))

### 2.1.1 Shared Space Terminology

Academic literature argues that a clear definition of **shared spaces** in a traffic management context is currently lacking (Al-Mashaykhi and Hammam, 2020, Archer, 2014, Biddulph, 2010, Karndacharuk et al., 2014a). The latest available definitions in Australia, UK, New Zealand and the USA are reproduced below:

- **“Shared spaces are typified by removal, or at least reduction, in traffic control devices, and the reduction or removal of the demarcation of separate vehicular and non-vehicular areas.”** (Austroads Guide to Traffic Management Part 8 – Local Street Management, (2020), Section 8.5.6, Austroads Guidance)
- **“In traditional street layouts, footways and carriageways are separated by a kerb. In a street with a shared surface, this demarcation is absent and pedestrians and vehicles share the same surface.”** (Manual for the Streets, (2020), Section 7.2.8, Department for Transport (UK))
- **“A street or place designed to improve pedestrian movement and comfort by reducing the dominance of motor vehicles and enabling all users to share the space rather than follow the clearly defined rules implied by more conventional designs.”** (Local Transport Note 1/11, (2011), Section 1.9, Department for Transport (UK))
- **“An area specified as a shared zone under the Auckland Transport Traffic Bylaw 2012, or a road declared to be a pedestrian mall pursuant to the Local Government Act 1974.”** (Shared Space Guidelines, (2017), Section 1.4, Auckland Council)
- **“A shared street is a street that includes a shared zone where pedestrians, bicyclists and motor vehicles mix through the same space”** (Accessible Shared Streets, (2017), Section 2.1, US Department of Transportation Federal Highway Administration)

These definitions confirm the variation, from the very direct definitions in USA which articulates that a shared space (shared street) has both “shared” (shared zone) and separated components to the more overarching objective-based approach highlighted by the Local Transport Note 1/11 (Department for Transport (UK), 2011). Karndacharuk et al. (2014a) presents a diagram of the classification of terminology, which is expanded upon and recast in this report as Figure 5. The authors reflect on the history and evolution of traffic management to encourage access and safety for all road users. The terminology stems from the original philosophical concept and links to the application in practice. The key divergence is between **“traffic calming”** now referred to as “local area traffic management” or “local street management” and **“shared space designs”**. Traffic calming achieves access and safety through measures that include devices (signage, signalisation), barriers and separation, while shared space design focuses on integration of modes and the removal of barriers and separation.

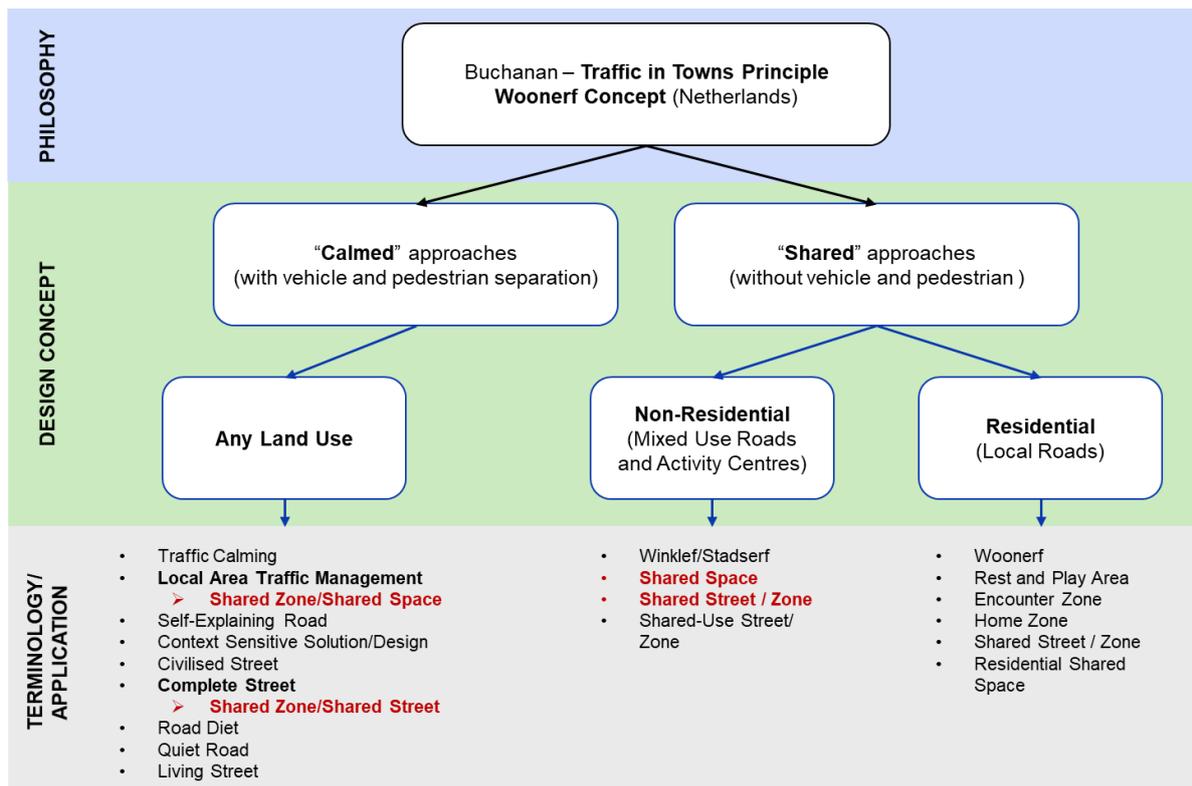


Figure 5: Origins of shared space terminology

Based on recent literature, both traffic calming and shared space design approaches serve complementary purposes (Friedman, 2021, Dijk and Marmeleira, 2021). Shared space designs are beneficial at locations of a network that are void of common nodes allowing members of a community to congregate, interact and leverage the public space (Moody and Melia, 2014, Wargo and Garrick, 2016). On the other hand, traffic calming solutions are beneficial in complicated network scenarios where the preservation of vulnerable road users may be compromised through a shared design. Or if the primary objective is to reduce vehicle flows or speeds within the study region without necessarily requiring any significant aesthetic transformation. However, CIHT (2018) and Elliot et al. (2017) indicate that designs that stem from the fundamental concepts discussed by Buchanan (1963) and the principle of Woonerf follow a spectrum of solutions that exist between “separation oriented traffic calming”, and “removal of separation shared spaces” and it is important to leverage aspects of both categories in the future. This is reflected in the guidance documentation surrounding local area traffic management (Green et al., 2020b) and complete streets which suggest using shared zones, spaces and streets to manage traffic in local areas, as highlighted in Figure 5. In fact, Karndacharuk (2014) and Elliot et al. (2017), insist that accessible shared spaces should be designed with the inclusion of areas of separation for vulnerable road users (termed comfort zones), further emphasising the necessary transformation of the definitions associated with the shared design concept. The review conducted in CIHT (2018) also describes this spectrum by categorising shared spaces as: (i) Pedestrian Priority Streets, (ii) Informal Streets, (iii) Enhanced Streets. This typology of shared spaces is presented in Figure 6.

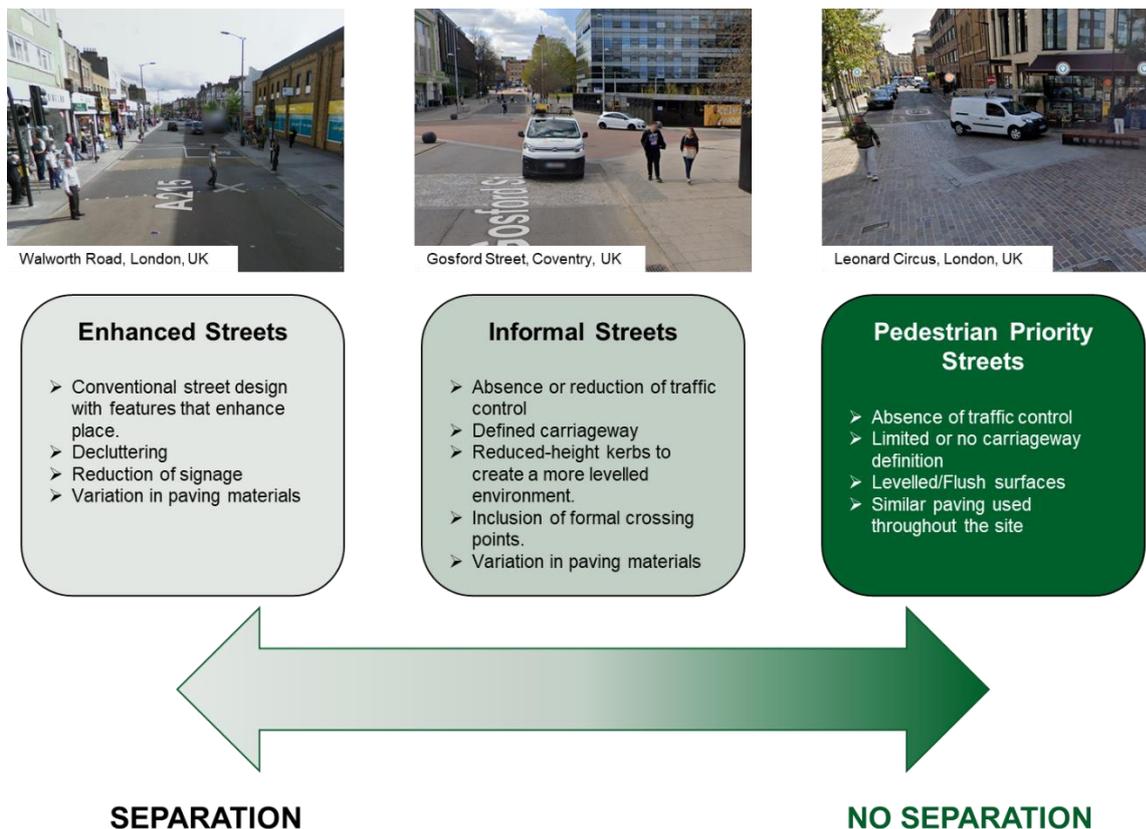


Figure 6: The spectrum of shared space design options (CIHT, 2018)

The fluidity of the definition is also reflected in the use of the term “shared zone” as a substitute for “shared space”, common in Australia and New Zealand. However, as highlighted by Karndacharuk et al. (2014a), the application of a shared zone advocates a degree of separation and belongs to the traffic calming options available to a practitioner, quite different to the traditional shared space but in the same token can deliver on the objectives of a shared space. Further discussion and critical review regarding this dichotomy within Karndacharuk et al. (2014a) resulted in the following definition of a shared space:

***“A public local street or intersection that is intended and designed to be used by pedestrians and vehicles in a consistently low-speed environment with no obvious physical segregation between various road users in order to create a sense of place, and facilitate multi-functions.”***

Definition harmonisation of the shared spaces concept could be achieved by returning to the philosophical root of the concept that advocates “sharing of the road space” but is also inclusive of all users as accessibility is the core objective, not the separation of modes. It is clear from Karndacharuk et al. (2014a), CIHT (2018) and Elliot et al. (2017) that shared space designs involve a spectrum of features that involves both the sharing and separation of modes. **Therefore, the Local Transport Note 1/11 (2011) and Karndacharuk et al. (2014a) provides the most holistic definitions which does not explicitly call for the removal of infrastructure that separates modes, but instead defines shared space designs based on the objective of creating a successful place.** These have been adapted to form the following definition presented in Figure 7 that could be adopted in an Australian context.

### Shared Space Definition:

A public street or intersection that is intended and designed to be used by all modes of transport equally in a consistently low-speed environment. Shared space designs aim to reduce vehicle dominance and prioritise active mobility modes. Designs can utilise treatments that remove separation between users in order to create a sense of place and facilitate multi-functions.

Figure 7: Definition of shared spaces (Adapted from Karndacharuk et al. (2014a) and Local Transport Note 1/11, (2011), Section 1.9, Department for Transport (UK))

### 2.1.2 Shared space Objectives and Design Principles

Contrasting from the varied terminology, objectives of shared space designs are consistent throughout the literature. Furthermore, they satisfy a number of key principles of international “Global Street Design Guide” (2016) which values the importance of designing multidimensional safe public spaces that create value for the community. The five key objectives summarised in Table 1 have been formed using Joyce (2012), (Karndacharuk et al., 2016) Elliot et al. (2017), CIHT (2018) and (Auckland Council, 2017).

Table 1: Shared space objectives

Objective	Description
<b>Create a 'successful' place</b>	“Place based” planning now underpins both local (Greater Sydney Region Plan (2018), NSW Movement and Place Framework (2020)) and global (Link and Place (1990s), UK) strategic planning. This involves understanding the context of a region, the service mechanisms of the infrastructure available within the community and implementing a collaborative process to define environments that connect and enrich the community. In other words, planning to deliver a successful place that provides social and economic benefits. The philosophical root of shared spaces is to create locations throughout the road network that enhance safety without compromising on network efficiency, encourage accessibility, and most importantly provide the opportunity for social interaction that otherwise was lacking. This can lead to the development of a successful place.
<b>Improve accessibility and amenity for active transport users</b>	Removal or reduction of infrastructure which separates modes offers more paths of movement for active modes of transport (cyclists, pedestrians). In addition, this simplification equalises priority and thus encourages the community to use active modes more often. Furthermore, shared spaces are designed with additional street infrastructure, such as seating and shaded areas for the community to congregate and interact.
<b>Reduce vehicle speeds and vehicle volumes</b>	Shared space designs reduce the priority of vehicles within the road network. Designed correctly, vehicle operators are aware of this reduction in priority and take greater care in traversing shared spaces, resulting in reduced vehicle speeds and traffic volumes. These objectives of speed and volume reduction are also generally viewed as key performance metrics in evaluating the effectiveness of a shared space (Joyce, 2012).
<b>Improve Safety</b>	Safety is the primary objective in the design of any component of the road network (Veith and Bennett, 2006). Thus, the use of a shared space design must also take into consideration the potential impacts on safety, especially of vulnerable road users. Historically, with the available case study information, shared spaces have generally seen improvements in crash rates even though the designs have often been perceived as unsafe environments (Pearson et al., 2019). Resolving this imbalance requires further research and modification of the shared space design approach.
<b>Improve Economic Activity</b>	Stemming from the objective of creating a successful place, a shared space also should improve economic activity. Investment into transport infrastructure has shown to increase productivity and lead to economic growth at macroscopic levels but it is less clear at local or regional levels (Banister and Berechman, 2001). However, the topic of measuring wider economic benefits associated with transport infrastructure projects, such as shared space design initiatives, is currently being studied by a number of researchers and practitioners (Legaspi et al., 2015, Alam et al., 2019, Pogonyi, 2020). In addition,

quantifying economic benefits are critical to most new infrastructure proposals, and thus is a key objective.
---

Shared space design principles are governed by the core objectives of improving accessibility for active modes, reducing vehicle volumes and speeds and improving safety. Joyce (2012) provides detailed discussion of design principles for applications of shared spaces in a New Zealand context. The document provides insights for vehicle parameters (volumes, speeds), infrastructure (demarcation, thresholds, parking and loading, signage) and accountability of different users (pedestrians, cyclists, public transport users). In Australia, the “*Streets for People: Compendium for South Australian practice*” clearly summarises what is viewed as the key design principles for creating a shared street (South Australian Active Living Coalition, 2012):

- 1. Reduce vehicle speeds below 25km/hr through physical measures.**
- 2. Provide same level surface across the street (allowing gentle sloping for stormwater drainage).**
- 3. Reduce the distinction between vehicle and pedestrian spaces, though vehicle paths should be legible.**
- 4. Remove traffic signs and minimise line markings.**
- 5. Avoid conventional traffic measures (e.g. signs, chicanes, traffic islands, road markings) in favour of visual cues in the street design.**
- 6. Encourage local expression of the space through urban design.**

These overarching principles are consistent with definitions of the past. The complexity of satisfying principles 3, 4 and 5 is that it poses additional risk for vulnerable road users (Holmes, 2015, Imrie, 2012). There is a discussion in the report prepared by the South Australian Active Living Coalition (2012) demanding the need to create an inclusive environment, consistent with the remarks within CIHT (2018). However, this is not a clear design principle itself.

Recently, a more structured application of shared spaces/streets, as shown in Figure 8 and Figure 9 respectively, has been presented by the Federal Highways Administration, through the *Accessible Shared Streets Guide*, and Auckland Council, through the *2017 Shared Spaces Guideline*. This “zoning” approach to shared space applications, first posited by Karndacharuk et al. (2011) (refer to Figure 10), is a reflection of a hybrid shared space treatment. In addition to the circulation zone/shared zone which constitute the original definition of a shared space, there are also inclusions of a separated zone (Comfort Zone/Accessible Zone) and defined crossing points to create a more inclusive environment for vulnerable users. However, there can be scenarios where a more pedestrianised environment is suitable (CIHT, 2018, Elliot et al., 2017) suggesting the requirement of guidance related to a spectrum of shared space design options explained in 2.1.1 and depicted in Figure 5.

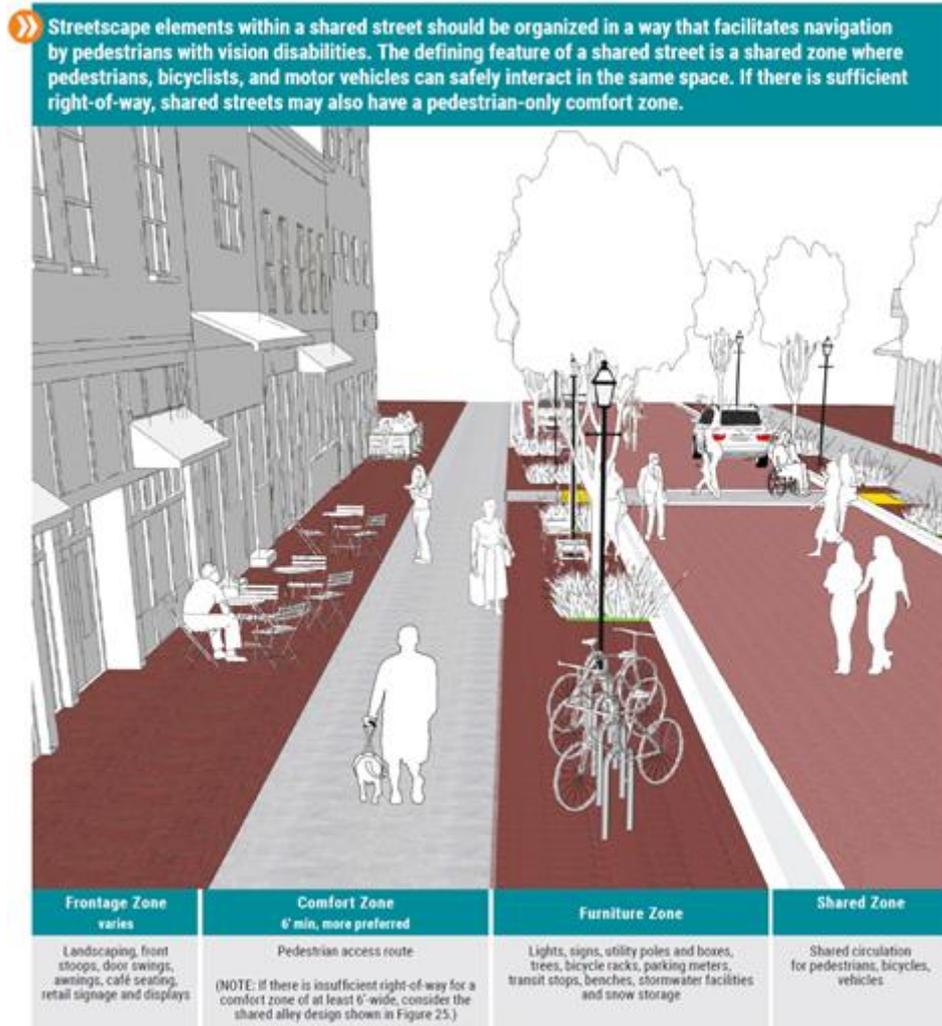


Figure 8: Shared spaces separated into Frontage Zone/Comfort Zone/Furniture Zone/Shared Zone (Elliot et al., 2017)

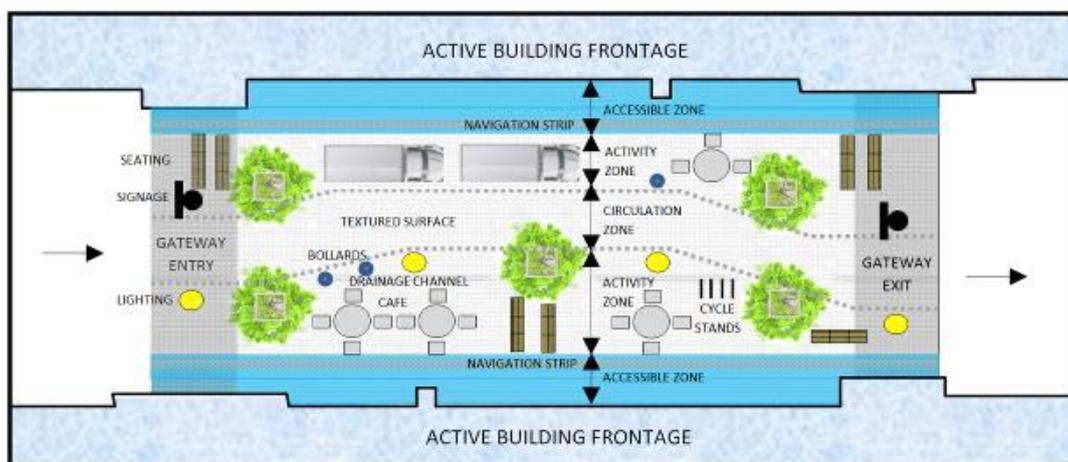


Figure 9: Shared space separated into Accessible Zone/Activity Zone/Circulation Zone (Royce, 2017, Auckland Council, 2017)

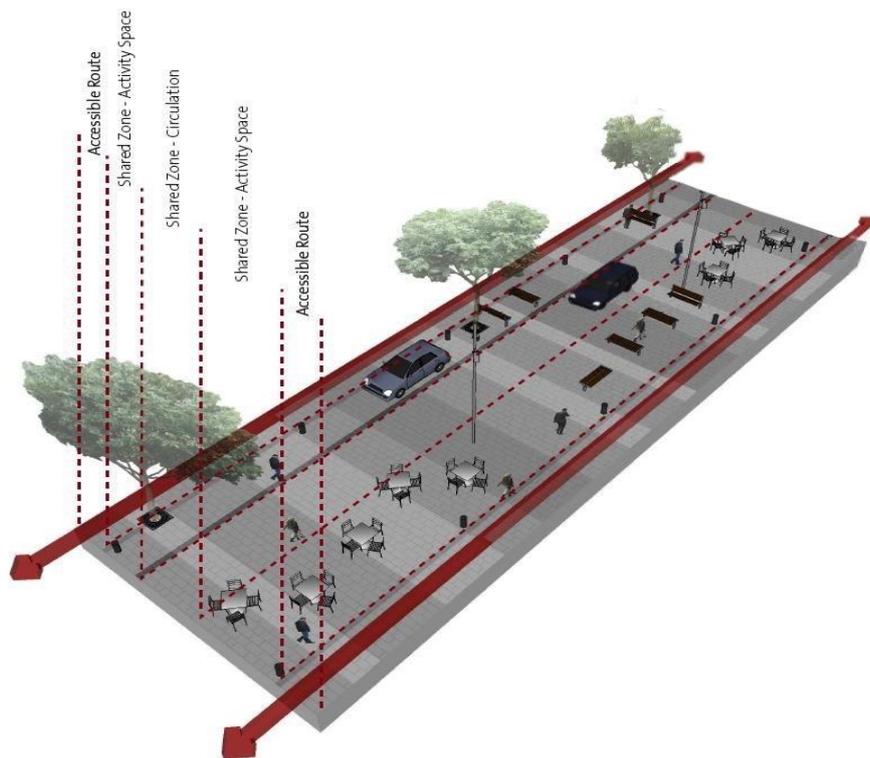


Figure 10: Zoning of shared spaces in academic literature (Karndacharuk et al., 2011)

### 2.1.3 Brief summary of Shared Spaces in Australia

In general, Australian authorities have implemented a constrained version of the traditional shared space design concept, referred to as “shared zones”. It has been a primary tool used in local area traffic management since 1984 (Karndacharuk et al., 2014a), but does not require the removal of infrastructure, signage or the use of level surfaces. It is defined in the former Roads and Maritime Services (RMS) (Transport for New South Wales) Technical Direction (TTD 2016/001) as a “**road or network of roads or a road related area where space is shared safely by vehicles and pedestrians and where pedestrian priority and quality of life take precedence over ease of vehicle movement**”. Table 2 presents the various shared space/shared zone definitions that are used by the different states in Australia.

Table 2: Definitions of shared zones/shared spaces across state jurisdictions

State	Definition	Reference
New South Wales	‘A road or network of roads or a road related area where space is shared safely by vehicles and pedestrians and where pedestrian priority and quality of life take precedence over ease of vehicle movement’. ‘must display a <b>speed limit of 10 km/h</b> . No other speed limit is allowed.’ <i>Traffic flows of 100 or less vehicles per hour or less than 1000 vehicles per day.</i>	<ul style="list-style-type: none"> <li>• TTD 2016/001 – Design and implementation of shared zones including provision for parking (now Transport (originally prepared by RMS))</li> <li>• NSW Road Rules 2014</li> <li>• Shared Zones – Policy, 2012, SS/12/01</li> </ul>

State	Definition	Reference
Victoria	<p>'A Shared Zone is a road or network of roads where pedestrians, cyclists and vehicles share the roadway. A shared zone provides improved amenity for pedestrians and an improved streetscape. Locations for shared zones may include lanes and streets in central business districts, selected residential streets, shopping centres and caravan parks. The speed limit shown on the shared zone sign should be <b>10 km/h or 20 km/h</b>. No other speed limit values should be used unless there are exceptional circumstances. Unsuitable where vehicles <b>more than 200 veh per/hour in peak periods and over 1000 vehicles between 7am-7pm</b> <b>Max 20km/h design speed</b>'</p>	<ul style="list-style-type: none"> <li>• Supplement to Austroads Guide to Traffic Management Part 8 (2008): Local Area Traffic Management (2015), Vicroads</li> <li>• Governed under Road Safety Rules 2017. (Similar to NSW Road Rules 2014)</li> <li>• Traffic Engineering Manual Volume 3 - Additional Network Standards &amp; Guidelines Speed Zoning Guidelines (2017), VicRoads</li> </ul>
South Australia	<p>A shared zone <b>is a 10 km/h speed limit</b> applied to a road or a network of roads in an area where pedestrians and vehicular traffic share the road space. Drivers within a shared zone must give way to pedestrians at all times and must only park in marked bays or where permitted by parking control signs. <i>In residential areas, correctly designed shared zones can also provide safe and attractive play or recreational areas, in addition to catering for vehicle access.</i></p>	<ul style="list-style-type: none"> <li>• Speed Limit Guideline for South Australia (2017), Government of South Australia</li> </ul>
Queensland	<p>This is a zone with the speed limit applied to an area or length of road that is shared by vehicles, cyclists, and pedestrians. Shared zones are generally constructed in areas where the competing demands of pedestrians, cyclists, motorised vehicles, and parking require a form of control which allows complete pedestrian mobility whilst at the same time enhancing pedestrian safety. <b>A speed limit of 10 km/h applies.</b></p>	<ul style="list-style-type: none"> <li>• Queensland Manual of Uniform Traffic Control Devices Part 4: Speed controls. (2019), Queensland Government</li> </ul>
Western Australia	<p>A Shared Zone is a length of carriageway or a network of roads in an area on which vehicular traffic must give way to pedestrians, where the road environment has been adapted for low vehicle speeds and on <b>which the speed limit is 10km/h by law</b> (MRWA, 2019). <b>Traffic volumes shall be less than 300 vehicles per day after the shared zone is installed.</b> <b>The speed limit is 10 km/h and other limits are not permitted.</b> <i>Raised kerbs shall be removed.</i> <i>There shall be <b>minimal turning and intersecting motorised vehicular traffic.</b></i></p>	<ul style="list-style-type: none"> <li>• Speed Zoning Policy and Application Guidelines (2021), MRWA</li> <li>• Planning and designing for pedestrians: guidelines (2011), Department of Transport Western Australia</li> <li>• Road Traffic Code 2000, Western Australian Legislation</li> </ul>
Australian Capital Territory	<p>The ACT Government standard for Active Travel Facilities, considers both shared zones and shared spaces in its design of streets. The Shared zone is defined under the Australian Road Rules (as ACT Rules) as follows; A shared zone is the network of roads in an area with: (a) a shared zone sign on each road into the area, indicating the same number; and (b) an end shared zone sign on each road out of the area. (Australian Road Rules) <i>The maximum speed limit in a <b>shared zone</b> is usually <b>10 km/h</b> or as determined by Road Authority assessment (ACT Government, 2019).</i> <b>The posted speed limit for shared spaces is generally 20km/h in the ACT.</b></p>	<ul style="list-style-type: none"> <li>• Street Planning and Design, Municipal Infrastructure Standards 01. (2019), ACT Government</li> <li>• ACT Government, 2019, Active Travel Facilities Design, Municipal Infrastructure, Standards 05. (2019), ACT Government</li> </ul>

State	Definition	Reference
Northern Territory	A shared traffic zone is usually a street where pedestrians, cyclists and other vehicles can share the road safely. <b>These zones often have a speed limit of 10 km/h.</b> When driving in a shared traffic zone you must give way to all pedestrians.	Road users handbook (2020), Northern Territory Government
Tasmania	As per definition in NSW.	Road Rules (2019) Tasmania

Shared zones are well defined in each State and legislated under the State’s Road Rules, specifically giving priority and right of way to pedestrians. Most jurisdictions limit the operational speed limit of a shared zone to 10km/h, except for Victoria and the ACT, which accommodate shared zones up to 20km/h speed limits. Furthermore, it is interesting to note the maximum vehicle volume limits that different states follow for its shared zones. Western Australia have the most conservative approach to limiting designs to roads that have 300 vehicles per day (Hanning et al., 2011), followed by NSW and Victoria having a criteria of 1000 vehicles per day and 100 or less per hour and 200 or less per hour respectively. These values are significantly lower than the shared space applications presented in Section 3. Therefore, as shown in Figure 11, the application of shared zones in the local context indicate that it is a sub-category of the traditional shared space design concept given the strict technical guidance (10km/hour speed limits and a variety of grading limitations) and the minimal reference to place definition in its application. This has limited the flexibility of the approach that has been synonymous throughout Europe.

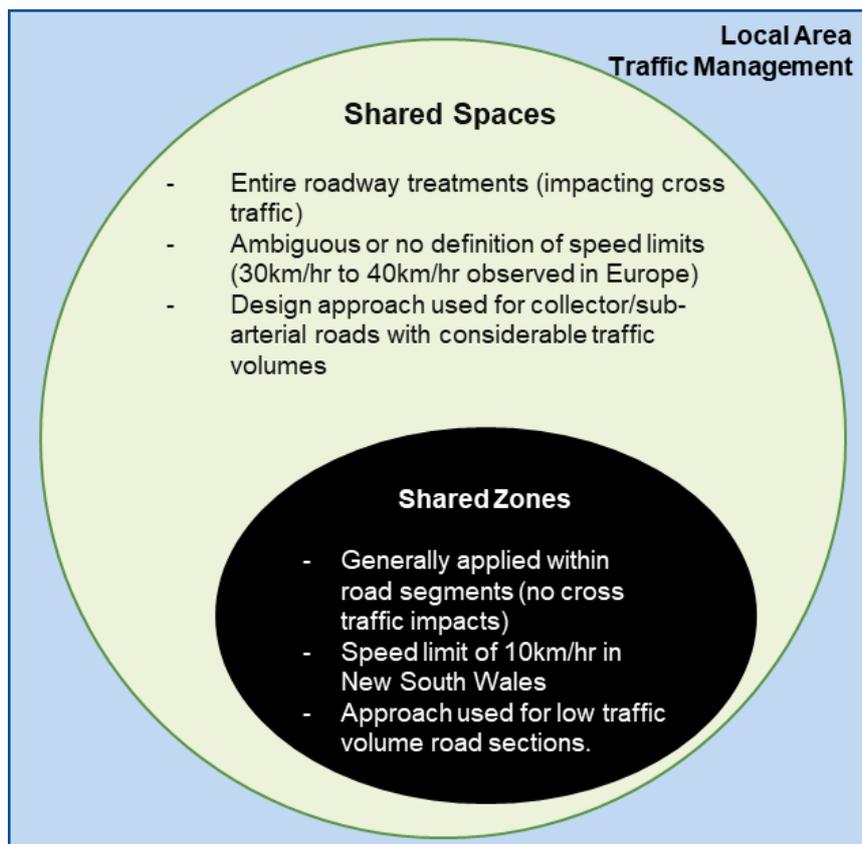


Figure 11: Relationship between shared zones (as used in NSW) and the traditional Shared Space definition

Gillies (2009) presents the first detailed discussion of the shared space design concept from an Australian context, in the undergraduate research project titled “*Is the road there to Share?*”

*Shared Space in an Australian context*". The thesis confirms that Australia implements shared zones (by definition), however some of these shared zones display aspects of the traditional shared space definition and thus were referred to as "quasi-shared spaces". Gillies (2009) suggests locations like Barrack Street in Sydney and Chapel Road in Bankstown reflect a shared space design. Similarly, applications like Pitt Street Mall (between Market Street and King Street) has been pedestrianised with limited vehicle access, driving the development of more successful places.

Since Gillies (2009), the development of the Movement and Place Framework in NSW was initiated, VicRoads conducted the Smart Roads Project and the South Australian Government conducted further research and documentation leading to the production of the *Streets for People: Compendium for South Australian practice* in 2012. This publication formally describes the shared space design concept, termed as "shared streets". In the following years, the Austroads Guide to Traffic Management (AGTM) - Part 7: Activity Centre Transport Management (2020) (Green et al., 2020a) and the AGTM – Part 8: Local Street Management (2020) (Green et al., 2020b) have been updated. The updated documents provide national guidance for practitioners concerning shared spaces. However, the terminology uses shared zones and shared spaces interchangeably, which can result in ambiguity for practitioners. The history of shared zones and spaces in Australia further promotes the need to consider a spectrum of design options that constitute the shared space design concept as suggested in Figure 6.

In 2020, the NSW Department of Planning, Industry and Environment launched the "**Streets for Shared Spaces**" program which is focussed on acknowledging streets as an "important part of our network of public spaces" and had a specific objective to "attract streets as shared spaces" (Department of Planning Industry and Environment, 2021). The program provided grant funding for councils "**to deliver trials that test permanent changes that strengthen the amenity, accessibility and economic vitality of a high street and surrounding area, taking a place-based approach**" (Department of Planning Industry and Environment, 2021). This program is an example of structured tactical urbanism, where temporary changes to the urban built environment are executed rapidly to enhance community connection or as a means of testing potential long-term improvements to neighbourhoods and places (Silva, 2016). The shared space design concept lends well to tactical urbanism, and quantifying the impacts of projects within programs such as this will be valuable to forming standards, guidance and regulation associated with long term permanent changes to road infrastructure.

Two categories of projects can be proposed as part of the "*Streets for Shared Spaces*" scheme: Category 1 – short-term quick response projects that test changes to streets and Category 2 – medium-term pilot projects that activate streets as shared public spaces. During Round 1 of the program, 52 projects were successful in securing funding for a number of innovative solutions to encourage the development of green and interactive public spaces and achieve the above objectives. This initiative has been a resounding success for a number of communities, where pop-up activities generated connection and enriched many neighbourhoods especially in the context of the COVID-19 pandemic (Department of Planning Industry and Environment, 2020). However, not many were Category 2 projects that focussed on significant changes to the road network or road infrastructure (Department of Planning Industry and Environment, 2021). It is important to note that one of the projects that have considered permanent changes, Activate Manly Bilgola (The Serpentine) in the Northern Beaches, received negative community feedback which resulted in the abandonment of the

project. The proposed project involved the conversion of The Serpentine at Bilgola Beach into a shared vehicle, pedestrian and cycle zone (shared zone). This requires a sign posted speed limit of 10km/hr and the construction of a series of traffic management devices along a 1.6 kilometre road section. The community were extremely concerned with the travel delay implications and more critically the lack of consultation when defining the project, resulting in protests against the local council (Northern Beaches Advocate, 2020). On the November 26, Northern Beaches Council decided to not proceed with the proposed changes due to “overwhelming opposition from the community” (Northern Beaches Council, 2020).

The aforementioned Northern Beaches example underlines some of the current issues regarding the implementation of shared spaces in Australia. First, the proposal implord a shared zone that required a 10km/hour speed limit, which was the key detractor for the community. Relaxation of this constraint may have changed some of the opposition. Second, the design of the project may have been problematic as it included an 1.6 kilometre road section of shared space, designs like Exhibition Road in London (800 metres in length) are considered as being too long and somewhat ineffective in slowing vehicles. Finally, though community consultation was present, there seems to have been a mismatch in understanding and objectives which resulted in protests and displeasure. In order to prevent such instances, it is clear that **practitioners and decision makers in Australia require guidance, standards and regulations to design and implement shared spaces. Given the relative infancy of implementing the shared space design concept, especially in the context of quantification and evaluation, it is essential to conduct further research to support this development.**

## **2.2 Relevant Standards, Guidelines and Technical Reports**

Global application of shared spaces and, more critically, the emphasis of creating successful places across the last two decades has resulted in the development of a number of standards, guidelines and technical reports concerning shared spaces. The following section of the report summarises key documents that can be consolidated to provide clearer guidance and procedures for practitioners. Initially, the most critical aspect of road infrastructure implementation, safety, is addressed by discussing the “Towards Zero” vision and related material. Then the focus shifts towards material related to the design and implementation of shared spaces. Global overarching documentation is presented, followed by Australian and international (country based) content, focussed on USA, UK and New Zealand. Finally, other key relevant documents are also summarised.

### **2.2.1 Road Safety Guidance: “Towards Zero” Vision**

The NSW Government, like a majority of global jurisdictions, follow a “safe systems” approach to managing road safety, which in the case of this state is delivered through the “Towards Zero” vision (NSW Government, 2021). This vision aims to achieve zero road deaths and serious injuries through the advancement of a variety of safety measures. The *NSW Road Safety Plan 2021* set out the first phase of strategic objectives that aligns with the Towards Zero vision (NSW Government, 2018b). The primary aim of the plan was to reduce fatalities by 30% by 2021 and focussed on six priority areas: (1) Saving lives on country roads, (2) Liveable and safe urban communities, (3) Using the roads safely, (4) Building a safer community culture, (5) New and proven vehicle technology and (6) Building a safe future. The strategic planning has overall been a success with a number of initiatives improving road safety and is scheduled to be updated for the next 10 year cycle. The 2021 plan and future

plans are based on the core principles of Towards Zero described below (NSW Government, 2021):

- People are human and sometimes make mistakes – a simple mistake shouldn't cost anyone their life.
- Roads, roadsides and vehicles need to be design to minimise crashes or reduce forces if a crash happens.
- Road safety is a shared responsibility – everyone need to make safe decision on and around the road to prioritise safety.

These principles highlight that the design of roads (and other infrastructure) directly impact road safety and also that trust, collaboration and shared responsibility are fundamental to achieving zero road deaths and serious injuries. Shared space designs offer both challenges and opportunities in terms of ensuring and improving road safety. As highlighted in Section 1 and earlier parts of Section 2, a limitation of shared spaces has been negative perceptions associated with safety, in particular for vulnerable road users (Imrie, 2013, Holmes, 2015). Even though these perceptions have not been reflected by empirical assessments of case studies (Karndacharuk et al., 2014b), it results in a mismatch between shared space design and expectations of the community that uses it. However, opportunities exist in the implementation of shared spaces: designs can enforce lower speed environments and develop people centric road infrastructure, which reduce the likelihood and also the severity of crashes.

Literature clearly establishes that crash severity is positively related to speed, with higher speeds resulting in a greater likelihood of fatality and serious injury (Doecke et al., 2020, Doecke et al., 2018, Wang et al., 2018). This is reflected by the Wramborg curves which indicates that the survivable speed limit (assuming the standard 10% chance of fatality) for a pedestrian or cyclist in a crash is 30km/hr or less (Jurewicz et al., 2015). Applications of shared space designs can be constrained to 30km/hr (or less) creating lower speed environments for road users to interact, thus reducing the impacts of potential crashes. Furthermore, shared space safety design features such as the use of strategically placed vegetation or street furniture to create safe zones for vulnerable road users can calm vehicular traffic whilst also defining a place for people. This type of "people centric" road infrastructure also brings to attention the shared responsibility of road safety, as drivers, pedestrians, cyclists and other transport users are made more aware of all the other modes that are present on the road (Archer, 2014).

The Austroads Research Report (AP-R611-20), "***Integrating Safe System with Movement and Place for Vulnerable Road Users***" provides the foundational safety guidance for the application of shared spaces in NSW. The guidance provides optimal safe system elements to be used for road designs to enhance pedestrian and cyclist safety (Corben et al., 2020). In addition, the recent virtual reality research sponsored by Transport and conducted by Swinburne University presents user preferences for road treatments to create safe and successful places. This research is discussed further within Section 2.2.10.4 of the report. There is foundational guidance and a clear direction for further research to define design options for shared spaces that not only maintain, but also improve, road safety.

## 2.2.2 Global Street Design Guide

The international guide for street design is the Global Street Design Guide (2016). Developed jointly by the Global Designing Cities Initiative and the National Association of City Transportation Officials, and funded by Bloomberg Philanthropies. This comprehensive 426 page document is separated into 3 sections: *Section A – About Streets*, *Section B – Street Design Guidance*, *Section C – Street Transformations*, gathering information from experts and case studies across 47 cities in 32 countries. The purpose of the guidance is to provide a vision for future planning based on the principle that street design connects people and place to have an impact on the community. Shared space (street) design is one of many tools that can be used to create a street that is conscious of place. The guide provides overarching design principles, processes and evaluation methods for all types of place development street design tools. *Part 2 and Part 3 of Section A* provides generic practices for street design and management that is consistent with the AGTM series, and *Part 10.4* provides shared space transformation ideas that urban environments can utilise. This guide is incredibly valuable to institutionalise change and educate the wider community, however professionals may require greater specificity and tailored guidance to implement solutions in practice.

## 2.2.3 Austroads Guide to Traffic Management (AGTM)

The AGTM is the leading set of guidance documents for transport professionals in the design, operation and maintenance of traffic management in transport systems. Produced by a collaboration of transport agencies in Australian and New Zealand (Austroads), and supported with Federal funding, the guidelines present best practice approaches. Reference is made to the Movement and Place framework in the recently updated version (2020), and the shift in philosophy from “predict and provide” to “vision and validate” is clearly established. Shared space content is presented in the following sections of the AGTM:

- **AGTM: Part 7 – Activity Centre Transport Management** (Green et al., 2020a), offers guidance to plan and manage regions that have a high level of activity and interaction with people and are generally dominated by pedestrians.
  - Reference is made to shared spaces as a mechanism to influence vehicle speeds in centres (*Section 4.6.2*) but also clearly establishes the need to consider people with disabilities, the young and elderly in the design (*Section 4.8.2*). Guidance then refers to Austroads Guide to Road Design Part 6A (Paths for walking and cycling), which don't explicitly describe shared space design but does provide guidance for shared path designs.
  - *Appendix B.4* presents a case study (Fort Street, Auckland, New Zealand – also discussed in detail in *Section 3.3.2*) as an application of a shared space, indicating that it is best practice.
  - *Appendix E.5* presents design guidance for “Shared Zone/Shared Spaces” which refers to the Streets for People guide (*Section 2.2.6*) and the CIHT Report (*Section 2.2.10.2*) and briefly argues the case for tailored designs and the need to categorise shared spaces as: (1) Pedestrian prioritised streets, (2) Informal streets, (3) Enhanced Streets.
- **AGTM: Part 8 – Local Street Management (Green et al., 2020b)**, previously referred to as “Local Area Traffic Management”, is concerned with the management local roads and the suburban road network with the primary objective of reducing volumes and speeds on local streets and improve safety and accessibility for active modes.

- Reference is made throughout the introductory section of the guide (*Section 2: Local Area Traffic Management*) to **shared spaces as a “new growing trend” highlighting the value but also insisting further research and development is necessary to formalise the concept in Australia.**
- *Section 8.5.6* is titled “Shared Zones / Shared Space” which provides high level discussion of the concept and reference is made back to AGTM Part 7 as well as the Austroads Guide to Road Design Part 4 (Intersections and Crossings).

Overall the AGTM series provides useful guidance regarding the concept but is limited in providing practitioners a tool to plan, design and implement a shared space.

#### **2.2.4 Australian Standards (AS 1742)**

AS 1742 is the Manual for Uniform Traffic Control Devices (MUTCD) (Australian Standards, 2014), a 15 part (Part 8 has been withdrawn) set of standards, that is used for the design of all devices use. These standards replaced the “*Australian Standard Road Signs Code*” that was published in 1935 and revised in 1946 and 1960. The first version of the MUTCD was prepared in 1983 and has been revised consistently as the transport landscape has evolved. Though there is no single part dedicated to shared spaces, the parts that are relevant include:

- **AS 1742.2 – MUTCD Part 2 – Traffic control devices for general use**
  - No explicit guidance to shared space scheme implementation but provides control and movement regulations related to traffic management (un-signalised intersections, signalised intersections and roundabouts)
  - Also provides design specifications for markings, medians and signage which can be used for shared space implementations.
- **AS 1742.4 – MUTCD Part 4 – Speed Controls**
  - Details speed management and the definition of speed limit signage.
  - *Section 2* outlines speed limits that will create uniformity and reduce conflicts but does not explicitly discuss vehicle-pedestrian interactions.
  - *Section 2.2.2* highlights that shared zones have a different speed environment.
  - *Section 3* outlines the speed limit signing and provides a definition for shared zones. Shared zone signage dimensions are given, as well as their position in the zone (at the entrance and exit). *Section 3.1.10* provides very general advice that shared zones must be altered to make obvious that they are different to other streets and have a speed limit of 10km/hr.
- **AS 1742.13 – MUTCD Part 13 – Local area traffic management (LATM)**
  - Contrasting from the updated guidance in the AGTM, **Part 13 has not updated the standards to explicitly discuss shared spaces in the context of LATM schemes**, even though the process of implementation is quite similar (the objective is to encourage active modes, reduce private vehicle traffic and involve the community throughout the process).
  - In general, all devices, signage and standards could in theory be related to a shared space design but at the moment it is not clear for a practitioner. For example, schematics for the layout of various LATM devices (signage and distancing, road modification required for the device, device profile, texturing, visual aids and landscaping) are provided. A shared space would need to adhere to these conditions. However, there may be scenarios where a

modification is necessary to achieve a design objective of the shared space that is currently not clarified or discussed in the standards.

**Overall, the relatively novel design concept has not been explicitly accounted for in Australian Standards, and this is primarily as a result of a lack of clear evidence on what design features and planning is necessary to develop a safe and valuable shared space. Accordingly, it is necessary to conduct further research (Stage 2, 3 and 4 of this research program) to support the development of further standards tailored for shared space designs.**

### ***2.2.5 Movement and Place Framework (NSW, Australia)***

The “Movement and Place” (M&P) framework was developed by Transport in 2016 as a means of providing equity and accountability in the appraisal of road infrastructure. The M&P framework considers the functionality and performance of a road section on the movement of people as means of travelling between origins and destinations as well as defining segments of the network that can be a place for people. The framework was based off the Link and Place guidance that was developed in the UK (Jones et al., 2007). Clear guidance for the application of the framework was released in 2020 through the “*Practitioner’s Guide to Movement and Place*” and the “*Evaluator’s Guide to Movement and Place*”. The value of the framework is that it provides the clearest definition of place for a road infrastructure through the lenses of “physical form”, “activities” and “meaning to the community” – allowing greater quantification of what historically has been a subjective concept. Shared space guidance should align with the NSW M&P framework to provide coherent and consistent information for practitioners. The framework mirrors the AGTM (*Part 7* and *Part 8*), emphasising the importance of community consultation and collaboration in the implementation of the framework within projects at local, regional and state levels. **The appendix of the Practitioner’s Guide to M&P details metrics, measurement methods and data sources for place metrics. As of December 2021, Transport have released further details of metrics which will be critical to measuring and evaluating places. Further research can build upon this progress to not only provide quantification of place metrics but gain improved understanding of the relationship between design and performance of places.**

### ***2.2.6 Streets for People: Compendium for South Australian Practice (South Australia, Australia)***

Streets for People is a support compendium for the practice of designing “people friendly streets that support cycling and walking” in South Australia (South Australian Active Living Coalition, 2012). It aims to be a resource in order to make design and approval of innovative designs such as shared spaces (referred to as shared streets) easier. It is structured on existing national and international best practice with a focus on lower trafficked streets. The document is centred on creating a healthier community that can only be achieved through participation in active modes, which requires a supporting road network. It discusses barriers and issues to implementation to pedestrian friendly streets (generally presented in a South Australian context), the approval process and gives assistance in addressing barriers (i.e. risk and liability concerns) for street design. It also provides key principles to bring about pedestrian and cycle friendly streets in a South Australian Context, introduces the ‘Link and Place’ design approach and provides case-studies for this approach on its application. The key components of the document are summarised as follows:

- *Section A4* addresses the issues and constraints of street design, emphasising the diversity in literature. The document states that there is an absence of guidance for low speed and trafficked streets. It also mentions the complexity and uncertainty surrounding guidance and standards and the approval process.
- *Chapter B* provides an approach for street design, providing conceptual models (i.e. human centred design/evidence based solutions) that could be used for the implementation of shared space. It also introduces the 'Link and Place Matrix', such that planners can define the strategic role of street and its suitability for pedestrian/cycle friendly street design. It provides a matrix with potential for shared space streets and provides two contrasting matrices of the implementation of shared spaces within South Australian Practice compared to International Practice. It also introduces a 'degree of sharedness' scoring system for shared spaces. Using the link and place matrix, the paper identifies desirable street network speeds for shared space design.
- *Chapter C* outlines the principles that should be considered when designing pedestrian/cycle friendly streets that can be used practically to guide design. It defines the strategic role of streets based on the 'Link and Place' method and is aimed to assist practitioners with identifying high level design considerations, that can be interpreted and processed to suit specific environments.
- *Chapter D* provides case studies of shared spaces and pedestrian/cycling friendly streets.

This compendium provides the most detail regarding shared space application in Australia. However, similar to the M&P framework, specific metrics, especially associated with place attributes are disconnected from performance measures of the shared space. This again emphasises the need for further empirical research.

### **2.2.7 Federal Highway Administration - Accessible Shared Streets (USA)**

Shared space (referred to as shared street) guidance in the USA is diverse. There are numerous reports, guidance documents and technical directions related to the concept across a number of municipalities that have a variety of definitions and methodologies for implementation. However, the U.S. Department of Transportation's Federal Highway Administration (FHWA) produced an overarching guide to shared space design, "*Accessible Shared Streets: Notable practices and considerations for accommodating pedestrians with vision disabilities*" which contains very clear and direct information for shared space design. The guide promotes "zone-based" shared space designs to ensure accessibility for vulnerable road users. It establishes navigation limitations of vulnerable users, explains the tools available for design (focus on tactiles), examines case studies to learn from past experiences and critically provides a "Design Toolbox" to support new applications. As discussed in Section 2.1.2, this "zone-based" approach to design seems to be the most balanced for a shared space, even though it does include some separation. Though the document is excellent for design, it does not consider the evaluation of shared spaces.

### **2.2.8 Manual for Streets (UK)**

The Manual for Streets (MfS) is a set of technical guidelines, primarily for lightly-trafficked residential streets, produced in co-operation of Department of Transport (UK), and Communities and Local Government in 2007 (Department for Transport and Communities and Local Government, 2007). This is generally seen as the first set of guidelines that details

shared space applications. It is also noted that the principles from the MfS may be applied in settings such as high streets and low-traffic rural areas. Similar to the Global Street Design Guide, the MfS aims to provide street design guidance that considers the needs of all users, along with a focus on promoting active transport options such as walking and cycling and promoting social interaction in communities by giving importance to the quality and surroundings of the street. It aims to develop streets that balance the place and movement function and offer a safe, efficient and attractive local street network.

The MfS categorises the functions of local streets into five types; place, movement, access, parking and drainage, utilities and street lighting and highlights the place and movement functions as the indicators for the setting the character of a street. *Section 3* discusses the design and implementation process for street design schemes. The concept of shared surface streets and home zones (residential shared spaces) are explored in *Section 7* of MfS. Both design types incorporate an absence of demarcation through kerbs and footpath along with a road surface constructed of pavers instead of asphalt. According to MfS such schemes are suitable for low vehicle volume streets (100 vehicles per hour), that have designated parking spots and extended over short lengths. This may be the case in residential zones, but there have been shared surface streets in the UK itself in urban settings that have been successful with much greater traffic volumes. The key advantage in the UK for implementing Home Zones is that there are legislations, such as Section 268 of Transport Act 2000, and Quiet Lanes and Home Zones (England) Regulations 2006 that give traffic authorities in the UK the power to designate streets for these schemes. This could be a model that NSW follows to improve the structure of creating places on road networks.

### **2.2.9 New Zealand Standards and Guidance**

The concept of shared space is recognised as shared zones in the context of New Zealand's street design. The key guidelines in NZ includes the Traffic Control Design Manual Part 6, which identifies shared zone speeds between 10km/h – 30km/h. Furthermore, the Guidance note (Joyce, 2012), referred by NZ Transport Agency, summarises findings from literature review and UK study tour to help NZ practitioners in implementing shared zones with the philosophy of the European shared spaces. It reflects the key design principles that impact the success of shared spaces (discussed in Section 2.1.2 of this report). This, along with the additional research led by Karndacharuk resulted in the development of ***Auckland Council's Shared Space Guidelines 2017***. In similar fashion to the guidance in USA, this document also promotes the “zone-based” approach to designing shared spaces.

Moreover, ***Auckland's Transport Code of Practice, Chapter 5 (Draft)***, provides design considerations such as creating a distinct street environment that offers visual cues for traffic to slow down in the street, along with recommendation of 600mm wide tactile paving for accessibility. Although design guidelines are offered no technical specifications or warrants related to traffic and pedestrian counts is provided to ascertain where a shared space can be implemented, rather the design is evaluated on a case by case basis having the general shared space design components.

New Zealand's successful applications of shared spaces, especially within the Auckland CBD suggests that the best practical guidance is provided within these documents discussed above. The key difference in New Zealand's guidance is clarity in community engagement and involvement and most importantly monitoring and evaluation of impacts of implementation.

## **2.2.10 Other Key Documents**

### **2.2.10.1 MVA Consultancy Technical Reports**

During 2009 and 2010, MVA Consultancy conducted studies for the Department for Transport in the UK that led to the formation of Local Transport Note 1/11 – Shared space. There are 3 key reports summarising this work:

- DfT Shared Space Project – Stage 1: Appraisal of Shared Space
  - (Reid et al., 2009)
- Designing the Future – Shared Space: Qualitative Research (2010)
  - (Dickens et al., 2010)
- Designing the Future – Shared Space: Quantitative Research (2010)
  - (Shore and Uthayakumar, 2010)

The project delivered a highly detailed synopsis of the value of shared spaces from a conceptual perspective and then conducted a series of data collection exercises to measure qualitatively and quantitatively the costs and benefits of already implemented shared space designs. The reports revealed positive outcomes and the performance measurement of vehicular traffic is reflective of other notable case studies. However, the perception assessment may contain bias as surveys were conducted only post-implementation, sometimes after a considerable time period, affecting the conclusions of the research (Moody and Melia, 2014).

### **2.2.10.2 Local Transport Note 1/11 – Shared Space**

As mentioned in Section 1 of the report, this document is redacted. However, it is important to note that this note provides the most detail considering the design and implementation of shared spaces. In particular, the “Detailed design” part of the note provides comprehensive guidance that still can be leveraged through the lens of a zone-based approach. The section covers the following key areas of: de-cluttering, transitions, speed management, crossings, parking, public transport, seating, signage, lighting, drainage, wheel loading, routing and remedial measures.

### **2.2.10.3 Creating better streets: Inclusive and accessible places – Reviewing shared space, (Chartered Institution of Highways and Transportation – CIHT Report)**

The CIHT Report, published in 2018, was introduced in Section 1 and is mentioned a number of times throughout this study. It is a critical document that reflects on the events of suspension of shared space designs in the UK and aims to re-establish the concept through a review of a number of case studies. The key value-adding component of the report is the categorisation of shared spaces into: Pedestrian priority Streets, Informal Streets and Enhanced Streets highlighting the need for a spectrum of shared space designs. Inadvertently, this document releases the strict guidance emerging from the application of the Woonerf concept and in many ways promotes the 'zone-based' approach that is advocated in New Zealand and USA.

### **2.2.10.4 Exploring balance between movement and place in designing safe and successful places, (iMOVE CRC project for Transport, delivered by Swinburne University of Technology)**

Very recently, Swinburne University of Technology, supported by the iMOVE CRC and Transport completed a research project that use the M&P Framework to develop, test and evaluate prototype streetscape designs using immersive virtual environments (IME). The purpose of the project was to gain insights into citizen perceptions of design elements and safe systems treatments (White et al., 2021). The results of the study indicated the importance of ensuring pedestrian amenities on 'main/high' streets as without proper accessibility participants had to combat sensory overload. Suggestions for design options included reducing traffic noise and speed whilst also separating pedestrian and vehicle traffic, contradicting shared space designs. However, this could be as a result of the study not exposing participants to shared space designs that are discussed in this report. Furthermore, there is clear evidence that removing separation forces lower speed environments which consequently can result in better place experiences for users (Karndacharuk et al., 2013a, Karndacharuk et al., 2016). There are opportunities to further leverage IME technology and the methodologies produced in (White et al., 2021) to specifically test shared space solutions. These results could potentially be compared with empirical data from a shared space or shared zone to define new measurement and evaluation methods.

### 2.2.11 Complexity of “shared space design” implementation in NSW

The process of planning, designing and implementing modifications to the road network that synonymise a shared space design is graphically presented in Figure 12.

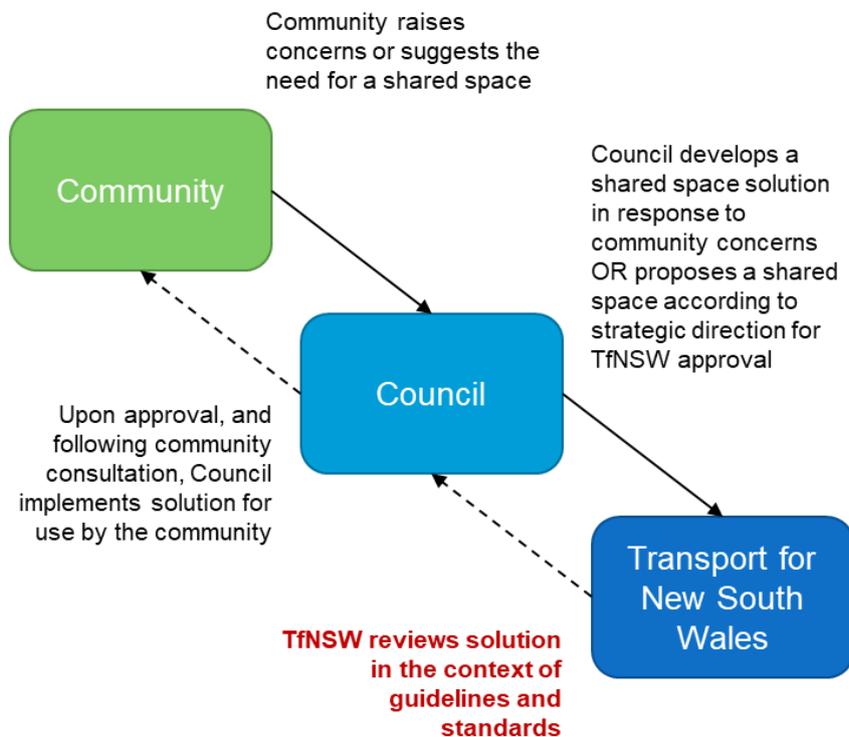


Figure 12: Procedure for the implementation of novel designs for local area traffic management purposes

Considering that modifications of this nature are intended to enhance local community outcomes, a majority of project proposals are classified as “local area traffic management” solutions. Therefore, members of the community raise safety, accessibility or place quality concerns to the Local Council to lead to a shared space solution. Alternatively, the Local Council itself may have a strategic objective to enhance place within their locality and propose a project. For example, the City of Canterbury-Bankstown initiative “*Bankstown Complete Streets Project*” has planned a series of road network transformations to enhance place qualities in Bankstown (City of Canterbury-Bankstown, 2019). Once a preliminary design is developed by a Council, it requires approval from Transport. Though projects are generally local in nature and may not affect the state road network, Transport manages the traffic operations of the entire network and changes to local roads can have feedback impacts on the network as a whole. The complexity of the process arises in the next step. Transport must review the proposal taking into consideration guidance from at least the following documents:

- **NSW Road Rules** (multiple rules depending on the type of solution proposed)
- **Civil Liability Act 2002**
- **Reference Guidelines**
  - AGTM - Part 8 – Local Street Management
  - AGTM – Part 7 – Activity Centre Transport Management
  - Austroads Guide to Road Design (AGRD) – Part 4 – Intersections and Crossings (General)
  - AGRD – Part 4A – Unsignalised and Signalised Intersections

- **Australian Standard 1742: Manual of Uniform Traffic Control Devices**
  - Part 2: Traffic Control Devices for General Use
  - Part 4: Speed Controls
  - Part 13: LATM
- **Transport Technical Standards**
  - “Delineation” Guide (19 part guideline that provides comprehensive information about delineation which is related to the design of shared spaces)
  - NSW Speed Zoning Guidelines (Version 4)
  - TTD 2020/03 – Shared environment intersection treatment
  - TTD 2016/001 – Design and implementation of shared zones including provision for parking
  - TTD 2014/004 – Off-road parking provision for narrow roads
  - TDT 2013/05 – Continuous footpath treatments
  - TDT 2011/01a – Pedestrian Refuges

The novelty of shared space design requires careful consideration, especially in the context of vulnerable road users. However, practitioners are faced with an overwhelming array of documents that only refer to the concept without providing direct guidance, limiting the ability to effectively evaluate a proposal. **The lack of direct guidance is related to the novelty of potential solutions**, such as applications of “flush” or kerb less intersections, **but more critically the impacts of these designs have not systematically empirically evaluated in a NSW or Australian context**. This indicates the pressing need to conduct research necessary to support the formation of a singular holistic standard accounting for shared space design with clear reference within Austroads Guidance.

The final stages of the process, upon approval of the proposal by Transport, involves further consultation with the community, implementation of the design and monitoring to understand the impact of the change. The monitoring and evaluation stage of an implementation requires further standardisation, as currently it is dependent on each Council’s procedures. Critically, post-implementation analysis of metrics and community feedback provides the evidence base for future projects (Green et al., 2020b). Therefore, it is also important for adequate accessibility to data and reporting for all transport professionals to continually improve the development and definition of places across the state.

### **2.3 Shared spaces academic literature**

Academic literature related to the shared space topic can generally be separated into quantitative and qualitative studies as presented in Figure 13. Qualitative literature discusses the philosophical roots of shared spaces as an overall concept, or provides insights of users’ perceptions related to the concept. Contrastingly, quantitative studies commonly focus on specific performance criteria, such as crash rates or conflicts (safety studies), or speed and volume (traffic impacts) and generally do not reveal insights to design implications or place consequences. Outside of case studies, which will be discussed in detail in Section 3, research which combines qualitative and quantitative elements that can advance the theory and evaluation methods of shared space designs are limited. It is important to note that case studies related to shared spaces provide empirical evidence of effectiveness but generally do not use evaluation methods or metrics necessarily tailored to the design concept. This limits consistency between evaluations and most importantly, it may not capture all the necessary relationships between the design and performance of a shared space.

- Qualitative studies **focused on users' perceptions**  
 - Holistic understanding of shared spaces (not focused only transport aspects) connecting philosophy with design principles

- **Quantitative** studies focused on statistical analysis, modelling and metric development  
 - Narrow understanding of shared spaces as a concept but detailed quantification of selected metrics

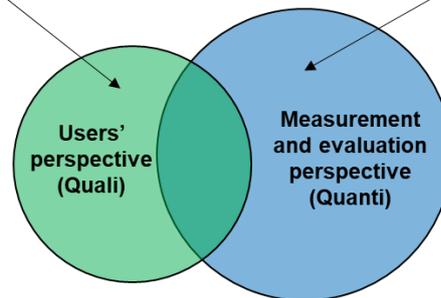


Figure 13: Categorisation of shared space academic literature

The following sub-sections summarises the academic literature to date with a focus on publications since 2014, as Karndacharuk (2014) and (Karndacharuk et al., 2014a) provides a comprehensive review of earlier studies.

### 2.3.1 Qualitative Literature: Understanding the shared space concept and users' perspectives

Though implemented in many European cities since the 1970s, the shared space design concept was introduced in academic literature formally through Pharaoh and Russell (1991) and received greater attention through Hamilton-Baillie (2008a) and Hamilton-Baillie (2008b) which coincided with the Interreg IIB North Sea Program projects that occurred throughout Europe. Hamilton-Baillie recast the concept as "**the integration of traffic into the social and cultural fabric of the built environment**" and detailed the prolific contribution of Hans Monderman to the implementation of shared spaces through the Netherlands.

Qualitative studies have focussed on the definition of shared spaces (Ben-Joseph, 1995), the evolution of the design of shared spaces in different countries (Biddulph, 2010) and also achieving a greater understanding of the people's perceptions towards shared spaces (Moody and Melia, 2014). Since the comprehensive critical analysis of the topic presented in Karndacharuk et al. (2014a), there have been some notable publications which have been summarised in Table 3.

Table 3: Summary of notable qualitative shared space studies since 2014

Title	Key Findings	Reference
<b>Behavioural analysis of interactions between pedestrians and vehicles in street designs with elements of shared space</b>	<ul style="list-style-type: none"> <li>• Development and implementation of qualitative behavioural criteria to analyse the conduct of pedestrians and vehicles when interacting within a shared space</li> <li>• Adaptation of traffic conflict analysis to a qualitative framework the describes the rationale of all road users.</li> <li>• Allows the ability to assess pedestrians' confidence and vehicles' tolerance/patience when interacting in a shared space</li> </ul>	(Kaparias et al., 2015)

Title	Key Findings	Reference
<b>The effectiveness of 'shared space' residential street interventions on self-report activity levels and quality of life for older people</b>	<ul style="list-style-type: none"> <li>• Conducted a longitudinal study of impacts of "home zone" style changes across 7 sites in the UK.</li> <li>• Compares self-reported behavioural indicators of health and quality of life outcomes between 2008 and 2011 for participants aged 65 and older.</li> <li>• Interventions were perceived positively in terms of accessibility and also participants claimed they were more active following the implementation of the home zone.</li> <li>• The study also acknowledges the time span of assessment is too short to draw conclusive results.</li> </ul>	(Curl et al., 2015)
<b>Qualitative evaluation study of urban shared spaces in New Zealand</b>	<ul style="list-style-type: none"> <li>• Conducted on-street perception surveys (400) and expert interviews (15) of city centre streets that have been transformed into shared spaces in Auckland, New Zealand.</li> <li>• Utilised a survey design that was based on the 5 key objectives of shared spaces (refer to Table 1). The results revealed that all the objectives are interconnected, meaning effective designs achieve positive outcomes across all objectives.</li> <li>• Shared spaces were perceived positively by the community and safety is the most important aspect for pedestrians within the shared space.</li> </ul>	(Karndacharuk et al., 2016)
<b>Evaluating the Perceptions of Road Users in Different Scenarios of Shared Spaces.</b>	<ul style="list-style-type: none"> <li>• Conducted a detailed literature review on shared spaces. Table 1 highlighted the various attributes of shared spaces (land use, density, road form, pavement, safe zone, lighting, traffic management tools, vegetation) that have been researched across different publications.</li> <li>• Designed and implemented a photo based survey to gauge perceptions of the shared space attributes.</li> <li>• Applied a multinomial-logit model to quantify and compare perceptions.</li> <li>• Pedestrians felt more comfortable and motorists were more alert in locations that contained greater numbers of adjacent businesses, narrow roads, brick paving and vegetation.</li> <li>• Interestingly, drivers claimed they would be less alert in the context of "zone-based" designs as there was an expectation pedestrians would not demand priority in the shared component.</li> </ul>	(Hsu and Lee, 2017)
<b>Un/shared space: The dilemma of inclusive architecture. (in Disability, Space, Architecture)</b>	<ul style="list-style-type: none"> <li>• Chapter 13 of the book Disability, Space, Architecture</li> <li>• Consistent with other publications, this book highlights the importance of "space" as a place that is constituted by "bodyminds, objects, practices, histories, and traces that inhabit them" indicating that when a section of a road network is identified as a potential place, it must be transformed to satisfy the requirements of a place. (which could trigger the application of the shared space design)</li> </ul>	(Price, 2017)

Title	Key Findings	Reference
<b>Shared space streets: design, user perception and performance.</b>	<ul style="list-style-type: none"> <li>Addresses the key issues of road safety, user comfort and revitalisation aspects of shared spaces by assessing design and user perception of six case study sites in the UK (through the use of a questionnaire survey)</li> <li>Pedestrians find shared spaces as safe and comfortable as conventional streets.</li> <li>Perception and attitudes of pedestrians do not improve with time or the familiarity of the shared space scheme.</li> <li>Weakness of this study is that it is not a before and after study.</li> </ul>	(Ruiz-Apilánez et al., 2017)
<b>How do shared-street design and traffic restriction improve urban soundscape and human experience?—An online survey with virtual reality.</b>	<ul style="list-style-type: none"> <li>Investigates the influence of sound and other sensory impressions in human experience of a place by using an online virtual reality application.</li> <li>Shared-street design made the soundscape calmer and more pleasant.</li> <li>Soundscape is a key contributor to defining the quality of a place, especially shared spaces.</li> </ul>	(Jiang et al., 2018)
<b>The social fabric of cities</b>	<ul style="list-style-type: none"> <li>Book that collates information from sociology, economics, human geography, ethics, political and communications theory to define urban design in the context of an evolving society.</li> <li>Identifies that cities can behave as systems of encounter, communication and material interaction” which present the clearest argument for the necessity of places within road networks and also promotes shared space design as a vehicle to achieving effective cities.</li> </ul>	(Netto, 2018)
<b>Shared Street as A Means of Liveable Urban Space.</b>	<ul style="list-style-type: none"> <li>Uses a Strength, Weakness, Opportunity, Threat (SWOT) analysis to assess a shared space in Malaysia to understand the influence of the design on liveability.</li> <li>Results indicate that implementing the shared space concept will contribute positively to the liveability of the location.</li> </ul>	(Al-Mashaykhi and Hammam, 2020)
<b>Public spaces for sustainability of contemporary metropolises: Project themes and recurring characters for the quality of design.</b>	<ul style="list-style-type: none"> <li>Records recurrent guidelines through a variety of cases studies of architectural and urban design projects.</li> <li>The review highlights that in many cases, enhancing the system of public spaces becomes an opportunity to improve liveability. Therefore, implementation of the shared space design concept can improve liveability.</li> </ul>	(Caldarola, 2020)
<b>Car-free environments and shared streets (in Fundamentals of Sustainable Urban Design)</b>	<ul style="list-style-type: none"> <li>Most recent publication reviewing shared streets impacts.</li> <li>Indicates that shared spaces are useful as one of many tools to define a sustainable road network. There needs to be equal emphasis on parking regulation, public transport advocacy and overall network design.</li> </ul>	(Friedman, 2021)

As noted in Table 3, the qualitative literature has provided incredible insight into the spatial, social and political dimensions of shared spaces. Overall, applications of shared spaces are seen as an important component of creating a liveable community. However, it is also important to combine the theoretical and perception based literature with measurement, evaluation and implementation strategies to provide guidance for future practitioners.

### **2.3.2 Quantitative Literature: Measuring and evaluating the impacts Traffic Engineering and Modelling publications**

The Traffic Engineering domain and more recently, the Computer Science and Data Science domains have led numerous efforts in the quantification of shared spaces. Historically, studies have focussed on measuring traffic impacts (vehicles, pedestrians and cyclists) empirically in terms of efficiency (Karndacharuk et al., 2011, Karndacharuk et al., 2013a, Karndacharuk et al., 2014b, Kaparias and Wang, 2020, Alsaleh et al., 2020) and this is sometimes combined with a qualitative stated preference survey to correlate user perceptions with performance (Moody and Melia, 2014).

Of note are studies that advanced the ability to quantify pedestrian performance, safety and interaction within a shared space. Karndacharuk et al. (2011), Karndacharuk et al. (2013a) and Karndacharuk et al. (2014b) define data collection procedures that captures both pedestrian and vehicle characteristics and also provides a safety assessment of pedestrians within a shared context. Kaparias et al. (2016) investigated gap acceptance values (waiting time, crossing time, crossing speed and critical gap) of pedestrians at Exhibition Road in London. Results indicated that pedestrians felt more comfortable and confident in their interactions with vehicles following the transformation. Pascucci et al. (2017), given the increased interaction complexity, developed a calibrated and validated discrete choice model for solving conflict situations between pedestrians and vehicles, useful for enhanced modelling of shared space designs. Most recently, Kaparias and Wang (2020) completed a detailed level of service (LoS) analysis for both pedestrians and vehicles for the Exhibition Road example by applying the 2010 Highway Capacity Manual (HCM) approach. The results confirmed findings in Kaparias et al. (2016) with post implementation improvements in LoS. However, the application of the HCM approach can be questioned, as it focusses on modes independently rather than by using a singular holistic measure that accounts for interactions between modes. Since publications like Imrie (2012) and Holmes (2015) which commented on the lack of inclusivity of shared space designs (especially in the context of vulnerable road users), a majority of quantitative literature has focussed safety and designing safer shared spaces through enhanced modelling techniques. This type of literature can be separated into the following three categories:

- **Modifications of traditional traffic microsimulation models:** This approach depicts the movement of each individual user within a system. Each users' movement is dictated by a set of rules, for example vehicles utilise car following or other vehicle following models, while pedestrians are captured using a multi-dimensional model like a Legion model. Frosch et al. (2019) presents an application of a traditional microsimulation model for a shared space design in West Virginia. The paper utilises the VISSIM software package and makes modifications to the heuristics for crossing movements to more accurately depict behaviour of all road users. The other streams of modelling research also rely on utilising a microsimulation foundation, however these streams apply significantly different techniques to depict pedestrian behaviour (social force model) and data input methodologies (inverse reinforcement learning).
- **Applications of the Social Force Model:** Helbing and Molnar (1995) proposed the social force model to better capture pedestrian behaviour. This model accounts for "forces" being applied by urban infrastructure that direct the movement of an individual as well as that of other people using a particular space. Shared space modellers have utilised variants of the social force model to define more realistic pedestrian and cyclist

behaviour (Johora and Müller, 2021, Pascucci et al., 2015, Rinke et al., 2017, Johora and Müller, 2018, Johora and Müller, 2020).

- **Inverse reinforcement learning:** The Internet of Things has resulted in more sensors and cameras being installed in public spaces collecting large amounts of data, including mobility data. Leveraging this big data set, researchers are using machine learning techniques and artificial intelligence to extract behavioural information, such as movements, speeds, and densities, of users. This “learnt” behaviour is then replicated in novel environments using microsimulation. Given the unique movement patterns that are observed within a shared space, applications of inverse reinforcement learning have recently emerged (Alsaleh and Sayed, 2020, Alsaleh and Sayed, 2021, Johora et al., 2020)

These techniques, especially applications of the social force model and inverse reinforcement learning are novel, complex and currently only presented at a theoretical level. Opportunities exist for further analysis by comparing with empirical conditions. However, similar to the lack of quantification in the qualitative studies, the quantitative shared space studies generally lack connecting shared space design parameters with performance metrics. The studies that do make this connection are discussed in more detail in the following sub-section and in Section 2.4.

### **2.3.3 Integration of Qualitative and Quantitative**

Comprehensive studies that both quantify metrics associated with movement and place features of a share space that also reflects on design principles are not commonplace. A good example of the gap is exemplified by the study by Hsu and Lee (2017). The research critically analyses the attributes of shared space designs and administers a questionnaire survey on participants to understand the impacts of different designs on perceptions of safety and quality of place. Though a statistical model was developed to make sense of the perception data and provided correlations between behaviour and certain design features, the study could not connect this with the functionality of the space. As shown in Table 3, the study provides valuable behavioural insights for practitioners, the study did link perceptions with performance metrics or shared space evaluation criteria.

Across the literature reviewed within the project, only two theses (Archer (2014) and Karndacharuk (2014)) and three journal or conference papers (Jayakody et al. (2018), Royce (2017) and Karndacharuk et al. (2013b) - this is based on the thesis by Karndacharuk) can be considered as integrated studies. These resources, in particular the body of work completed by Karndacharuk (2014), served as the foundational literature to garner further insights relating shared space design parameters and performance metrics. Given the importance of this topic from planning and monitoring context, a detailed review and analysis of this topic was conducted as presented in Section 2.4.

## **2.4 Shared Space Parameters and Metrics**

Literature reviewed to date in the report indicates the importance of metrics and parameters in the design, implementation and evaluation of shared spaces. Such elements can be separated into two distinct, but related, categories:

- **Design Parameters (explanatory variables)** – number of traffic lanes, width of traffic lanes, surface treatments, shaded areas, presence of public/private spaces, active building frontages and other similar parameters.
- **Performance Metrics (response variables)** – traffic volumes (all modes), traffic speeds (all modes), conflicts and crashes, severity of crashes, social interaction (numbers of people that connect within the space), utilisation of the space, diversity of people using the space and other similar metrics.

As discussed in Section 2.3.3, integrated studies that discuss shared spaces in the context of both **design** and **performance** is lacking, and the project team advances this by: (i) proposing a consolidated set of design parameters and performance metrics based on existing literature, and (ii) devising an initial relationship structure connecting these domains. Prior to detailing this analysis, it is important to provide an overview of the foundational studies used for the analysis.

Royce (2017) conducted a review of shared spaces in Auckland in the context of safety and performance. The study considers a number of design parameters organised into two groups termed in the study as **common design elements** and **desired design features** consistent with the guidance provided by Auckland Council (2017). The common design elements include:

- **Gateway treatment** - clear indication via paved surface and signage at the entry and exit of the shared space to indicate its limits.
- **Level textured surface** - levelled surface across the width of the street to encourage pedestrians and drivers to share the space.
- **Accessible zone** - narrow area adjacent to the building frontage that is clutter free and provides enhanced amenity for pedestrians, particularly vision- and motion-impaired.
- **Activity zone** - area that accommodates street furniture as well as loading/unloading areas, ensuring that sitting areas are separated or clear from the latter.
- **Circulation zone** - central area of the shared spaces catering for the movement of different transportation modes.

The desired design features include the following (Royce, 2017):

- **Reduced traffic speed** - reduce vehicular dominance to encourage street sharing and reduce the severity of eventual crashes.
- **Improved safety** - measured primarily via crash statistics and secondarily by risk perceptions.
- **Reduced traffic volumes** - low traffic volumes such as 100 vehicles per hour or less to reduce vehicular dominance.
- **Increased pedestrian volumes** - ability for pedestrians to congregate in shared spaces by having food activities, art works, seating areas as well as late-night dining and cinema to extent pedestrian activity into the night.
- **Active building frontage** - building usage happening throughout the day to encourage movement within and across the shared space.
- **Circulation zone lateral shift** - desirable to limit straight sections to 50m or less therefore encouraging slower vehicular speeds.
- **Circulation zone narrow width** - having two-way flow in a width less than 5.5m or 4m for a one way to encourage slower vehicular speeds due to 'side friction'.

- **Loading/parking** - necessary service for properties along a shared space.

Jayakody et al. (2018) focused on fine grained design and proposes a three-levelled hierarchical structure (Table 4) containing over twenty factors. In a similar vein, Archer (2014) organises over thirty design elements in five groups (Table 5). A number of these desired design features within Royce (2017) and attributes identified within Archer (2014) can be directly linked to performance measurement as “reduce traffic speed”, “reduced traffic volumes” or “increased pedestrian volumes” can only be identified through measurement and monitoring. Thus, though not explicitly stated as design parameters and performance metrics, these publications provided valuable categorisation that can be used in future analysis.

**Table 4: Design factors for successful shared spaces (Jayakody et al., 2018)**

1 <sup>st</sup> level	2 <sup>nd</sup> level	3 <sup>rd</sup> level
<b>Pedestrian Prominence</b>	Low Traffic Control	Visually narrowed carriage way
		Gateway design
	Convenience in pedestrian movement	De-cluttered environment
		Parking space not interrupting pedestrians' activities
		Pedestrians safe areas
	Sense of a single space	Surface design
Level of surface		
<b>Distinctive and attractive public place</b>	Visual attractiveness	Visual quality of the space
		Visual linkage with other public and semi-public spaces
		Active frontage
	Activities to attract to the place	Design for outdoor public and private activities
	Active engagement of people with the space	Linkage with main public attractions
<b>Inclusive design</b>	Ease of movement	Level of surface
		Surface material
	Sense of safety	Pedestrian safe way
		Seating facilities with regular frequency
Welcoming for all	Design for diverse activities for different age groups	
<b>Location and connectivity</b>	Connectivity with public transportation and network	(No 3 <sup>rd</sup> level for these items)
	Availability of alternative routes	
	Connectivity with public attractions	
	Confirming the need for a shared space	

**Table 5: Design elements assess for four shared space cases: Peel Street, Bank Street, Leigh Street and Hindley Street in Adelaide, South Australia (Archer, 2014)**

Objective	Attribute
<b>To what extent is the space shared?</b>	Absence of kerbs or low kerbs
	Absence of bollards or few bollards
	Absence of any guard railing/pedestrian fencing/planters to delineate road users
	No or only some contrasting surface colours
	Absence of traffic lights
	Absence of road markings
	High pedestrian flow
	Low vehicular flow
	Pedestrians present right across the space
	Vehicles giving way to pedestrians

Objective	Attribute
	Absence of parking/only required parking (e.g. disabled, loading)
<b>Can people easily access the shared space?</b>	Space is visible from the outside
	Entrances are welcoming
	Connections between the space and the adjacent buildings
	Space functions for people with special needs
	Variety of transportation options available to reach the place
	Appropriately placed street furniture (enough seats, choice of places to sit)
<b>Is the space comfortable and attractive?</b>	Space is clean and free of litter
	Presence of greenery
	Presence of street art/sculptures
	The space feels safe
	Good building conditions
	Absence of vandalism and anti-social behaviour
	Self-surveillance from surrounding areas and pedestrian traffic
<b>Is there evidence of activity in the space?</b>	Variety of ages of people using the space
	Variety of activities are occurring
	Absence of unused space
	Presence of cafes or stalls
	Mixed-use of buildings
	Absence of unoccupied buildings
<b>Does the space foster social interaction?</b>	People are meeting others in the space
	Presence of people in groups
	People interacting with strangers

Contrastingly, Karndacharuk et al. (2013b) directly address performance metrics. The paper presents a hierarchical framework for assessing shared spaces, entailing a number of performance metrics that are synthesised to a single performance index for a site. Instead of highlighting specific design factors, Karndacharuk et al. (2013b) relate performance metrics to five objectives of shared spaces. Each objective is measured by two quantitative key performance indicators and by one qualitative construct defined using a perception survey conducted with shared space pedestrians. The objective and performance metrics are summarised in Table 6.

Table 6: Objectives and associated performance metrics (Karndacharuk et al., 2013b)

Objective	Performance Metrics (Quantitative KPI)
<b>Place:</b> Quality of the space in attracting users to spend time and interact with other members of the community	<ul style="list-style-type: none"> <li>• Pedestrian occupancy ratio</li> <li>• User dwell time</li> </ul>
<b>Pedestrian:</b> Mobility of pedestrians in the space (Are pedestrians free to move?)	<ul style="list-style-type: none"> <li>• Pedestrian density</li> <li>• Pedestrian trajectory</li> </ul>
<b>Vehicle:</b> Change in priority of the space from vehicle to other road users (primarily pedestrians)	<ul style="list-style-type: none"> <li>• Motor vehicle speed</li> <li>• Motor vehicle volume</li> </ul>
<b>Economic:</b> Prosperity and economic impetus created in adjacent and surrounding businesses to the shared space (and also the contribution of such businesses in enhancing the range and type of activities in the space)	<ul style="list-style-type: none"> <li>• Active frontage</li> <li>• User accessing adjacent land use</li> </ul>

<b>Safety:</b> Safety and security of the environment for all users (including vulnerable users)	<ul style="list-style-type: none"> <li>• User conflicts</li> <li>• Reported crash history</li> </ul>
--	--

Based on these four comprehensive works (Archer, 2014, Jayakody et al., 2018, Karndacharuk et al., 2013b, Royce, 2017), a preliminary framework entailing **sixteen design parameters organised in six categories** (Table 7) and **seven performance metrics organised in five categories** (Table 8) are proposed. The design parameter ranges from a “macro” (or strategic level) such as the location of the shared spaces within the urban fabric and its connections to other components of infrastructure, the visibility of the shared space from surrounding streets, etc to “micro” (or operational level) such as pavement design and the presence of street art, etc. Such parameters are outlined here as prescriptively as possible, although some parameters such as *visual quality/aesthetics of the space* (design parameter 6) are inherently more abstract and need to be supported by more tangible parameters (e.g. absence of unused space, levelled surface design, etc).

**Table 7: Design parameters (explanatory variables)**

Category	Design parameter	References
<b>Location &amp; Entry</b>	1. Connectivity with the urban fabric: availability of varied public transportation network to reach the shared spaces, availability of alternative route, connection/proximity with public attractions.	Archer (2014), Jayakody et al. (2018)
	2. Space is visible from surrounding streets.	Archer (2014)
	3. Gateway design: a paved surface and signage (Shared Zone) at the entry and exit to clearly indicate the area encompassing the Shared Space. Visually narrowed carriage way so that entrances are welcoming	Archer (2014), Jayakody et al. (2018), Royce (2017)
<b>Surroundings</b>	4. Surrounding buildings: Unoccupied buildings should be avoided, and mixed-used buildings should be preferred. There should be a good connection between the interior of buildings and the shared space.	Archer (2014)
<b>General features</b>	5. Levelled surface design: level block paving materials across the width of the street, with no kerb, encouraging pedestrians and motorists to share the space.	Jayakody et al. (2018), Royce (2017)
	6. Visual quality/aesthetics of space: create an identity, signalling to users they are in a different type of space.	Jayakody et al. (2018)
<b>Features for the Accessible Zone</b>	7. Clutter free space to support the movement of vision and mobility impaired people	Royce (2017)
<b>Features for the Activity Zone</b>	8. Appropriately placed street furniture such as seats, street art, sculptures, lighting, cycle stands, planter-boxes, etc. Street furniture near traffic or loading areas should have sufficient height and bulk to be clearly visible. Avoid seating areas in direct traffic or vehicle manoeuvring areas. Parking space should not interrupt pedestrian activities.	Archer (2014), Jayakody et al. (2018), Royce (2017)
	9. Space functions for people with special needs	Archer (2014)
	10. Presence of greenery	Archer (2014), Royce (2017)
	11. Absence of unused space	Archer (2014)
	12. Design for diversity: varied activities for different age groups, attracting and prompting people to stay in the shared space.	Jayakody et al. (2018)

Category	Design parameter	References
	13. Public-private spaces: presence of cafes or stalls and design the space for outdoor activities (outdoor eating area, billboard displays, etc).	Archer (2014), Jayakody et al. (2018)
<b>Features for the Circulation Zone</b>	14. Narrow Width (<5.5m for two-way flow) for encouraging slower vehicle speeds. Can be achieved using street furniture such as seating, landscaping, art works, monuments, tree canopies, street lighting, cycle stands and the use of paving patterns.	Royce (2017)
	15. Lateral shift limiting straight sections of street and break up long sight lines, thereby encouraging slower vehicle speeds (straight section should be <50m).	Royce (2017)
	16. Integrated “street” and “footpath” areas (perceived as unity): low or no kerbs, no or few bollards, Absence of any guard railing/pedestrian fencing/planters to delineate road users, no contrasting surface colours, absence of formal crossing points, absence of road markings, and absence of traffic lights.	Archer (2014)

The “zonal approach” to designing shared spaces, described in Section 2.1.1 and referred to in Auckland Council (2017), is also used for the framework proposed here where a shared space is separated into (as shown in Figure 9 and Figure 10): (i) accessible zone, (ii) activity zone, and (iii) circulation zone. Floor plans and schematic designs are suitable tools for summarising design parameters as well as their applicability (macro/micro level and the spatial location) in an intuitive fashion. Hence, developing figures similar to Figure 8, Figure 9 or Figure 10 in an infographic format would be ideal for disseminating information to the public, a key component of future research.

**Table 8: Performance metrics (response variables)**

Category	Performance metric	References
<b>Safety</b>	1. Safe environment for all users, including cyclists, the elderly, children, and vision and motion-impaired people, which can be measured by (i) crash history, (ii) injury severity and costs, and (iii) user conflicts.	Archer (2014), Jayakody et al. (2018), Karndacharuk et al. (2013b)
<b>Movement for vehicles (incl. cyclists)</b>	2. Low traffic volume and low traffic speed (10km/h to 25km/h) to reduce vehicular traffic dominance the severity of any crashes and encourage street sharing.	Archer (2014), Jayakody et al. (2018), Karndacharuk et al. (2013b)
<b>Movement for pedestrians</b>	3. Free movement of pedestrians across the spaces, including the ability to walk across and along the circulation zone and to roam such zone.	Karndacharuk et al. (2013b), Karndacharuk et al. (2013b), Royce (2017)
<b>Place Definition</b>	4. An inclusive/welcoming space for all, being reflected by a diversity of people moving and staying in the shared space.	Archer (2014), Jayakody et al. (2018)
	5. Space with an active quality, which can be measured by the (i) number of users dwelling in the area, (ii) time spent in the area or user dwell time, (iii) people are meeting others in the space, (iv) presence of people in groups, (v) pedestrian flow, and (vi) people interacting with strangers.	
	6. Space is clean, free of litter and vandalism/anti-social behaviour	Archer (2014)
<b>Economic impact</b>	7. Enhancements of the activities/income/value of business surrounding the shared spaces, which can be measured by (i) property and leasing values, (ii) retail occupancy rates, and (iii) number of users accessing adjacent land use.	Karndacharuk et al. (2013b)

Performance metrics (Table 8) measure the outcomes of the shared space design implemented, thus explaining the conceptualisation of performance metrics being response variables of the explanatory design parameters. **Relationships between design parameters and performance metrics, first in the form of conceptual connections between the two domains and then via quantification through experiments and empirical research, are key to determine the design factors that lead to successful shared space implementations.** These relationships can also be used to push forward with particular features of a shared space to promote “movement” or “place” functionalities. To the project team’s best knowledge, such co-relations have not been determined in detail within the existing literature. One publication that attempts to address this is recent paper by Lee and Kim (2019) that conducts a regression analysis between pavement types and the performance of pedestrian properties of a shared space. This study provides useful insights, but is limited to a very specific detail of the design and user group. Therefore, it is crucial to conduct a comprehensive study investigating such relationships in order to develop the guidance and standardisation that will be necessary for Transport. Such an understanding will enable the prioritisation of design parameters to achieve desired performance outcomes, potentially saving resources (time, financing, and public approval). For example, results of an empirical analysis may reveal that appropriate urban furniture and presence of greenery (design parameters 8 and 10 in Table 7) are more effective in creating an active space (performance metric 5 in Table 8) than levelled surface design (design parameter 5 in Table 7). Thus, for a particular context, the derivation of this relationship can lead to guidance that advocates the prioritisation urban furniture and greenery over the conversion of road sections to levelled surfaces. Practitioners’ decision-making process is simplified and such a scenario will result in a less intrusive and more economical situation that has a higher likelihood of creating a successful place.

		1	2	3	4	5	6	7
		Safe environment for all	Low traffic volume and low traffic speed	Free movement of pedestrians	Inclusive/welcoming space for all	Active quality	Clean space (no litter/vandalism)	Enhancement of surrounding businesses
1	Safe environment for all							
2	Low traffic volume and low traffic speed							
3	Free movement of pedestrians							
4	Inclusive/welcoming space for all							
5	Active quality							
6	Clean space (no litter/vandalism)							
7	Enhancement of surrounding businesses							

 Indicates correlation between metric categories

**Figure 14: Preliminary framework with conceptual relationship between performance metrics**

As previously highlighted, the first step in identifying the above-mentioned correlations between design parameters and performance metrics is to define from a conceptual viewpoint: (i) the relationships between performance metrics and (ii) the relationships between the design parameters and performance metrics. These should evolve from a series of workshops with industry experts and consultations with other key stakeholders, yet a preliminary outcome for (i) is presented in Figure 14. This figure shows two clusters: *Safe environment for all*, *Low traffic volume and low traffic speed*, and *Free movement of pedestrians* are closely connected, similarly to *Active quality*, *Clean space*, and *Enhancement of surrounding business*, are linked with *Free movement of pedestrians*. It can also be envisioned that *Low traffic volume and low traffic speed* are necessary conditions for *safe environment for all* and *free movement of pedestrians*, however additional research is key to further refine such relationships as well as identifying other relevant metrics for assessing shared spaces. Figure 15 shows a preliminary result for (ii) and depicts the design parameters expected to positively and negatively affect (marked respectively in green and red) the performance metrics. The two clusters of performance metrics are also reflected here with all metrics for the first cluster (*Safe environment for all*, *Low traffic volume and low traffic speed*, and *Free movement of pedestrians*) being linked to a similar group of parameters. These are different to the set of parameters linked to the second cluster (*Active quality of space*, *Clean space*, and *enhancement of surrounding business*).

		Performance Metrics						
		1	2	3	4	5	6	7
		Safe environment for all	Low traffic volume and low traffic speed	Free movement of pedestrians	Inclusive/welcoming space for all	Active quality	Clean space (no litter/vandalism)	Enhancement of surrounding businesses
Design Parameters	1	Connectivity with urban fabric						
	2	Visibility from surrounding streets						
	3	Gateway design						
	4	Surrounding buildings						
	5	Levelled surface design						
	6	Visual quality/aesthetics of space						
	7	Clutter free space (accessible zone)						
	8	Appropriate Street furniture (activity zone)						
	9	Space functions (special needs) (activity zone)						
	10	Presence of greenery (activity zone)						
	11	Absence of unused space (activity zone)						
	12	Design for diversity (activity zone)						
	13	Public-private spaces (activity zone)						
	14	Narrow width (circulation zone)						
	15	Lateral shift (circulation zone)						
	16	Integrated 'street' and 'footpath' (circulation zone)						

■ Indicates positive correlation  
■ Indicates negative correlation

Figure 15: Preliminary framework with conceptual relationship between design parameters and performance metrics

## 2.5 Summary of Key Findings

The shared space design concept has been studied and applied since the 1960s. The review of literature concerning the topic has revealed that shared spaces are a valuable tool to create successful places within a road network. However, further research and evaluation is necessary to establish the method within guidance documentation, standards and technical

directions for practitioners to use. The key findings from the review of literature can be summarised as follows:

- Shared space terminology is varied, synthesis of several publications and government documents led to the following definition established within the report: "***A public street or intersection that is intended and designed to be used by all modes of transport equally in a consistently low-speed environment. Shared space designs aim to reduce vehicle dominance and prioritise active mobility modes. Designs can utilise treatments that remove separation between users in order to create a sense of place and facilitate multi-functions.***" This definition offers greater flexibility in design options to better accommodate vulnerable road users.
- Initial implementations of shared spaces focussed primarily on measures to create an entirely shared environment (removal of all separation infrastructure). More recently, jurisdictions, especially in New Zealand and the USA have **proposed a "zone-based" approach**. The shared space is separated into zones where all users can share the space and other protected zones that provide vulnerable road users safe accessibility.
- In general, **Australian authorities have implemented a constrained version of the traditional shared space design concept, referred to as "shared zones"**. Shared zones have historically had strict limitations on speed (10km/hr) that have restricted applications. **More innovative designs, such as implementations of flush intersections require a series of complex approvals that need to be simplified in the future.**
- Shared spaces need to be developed and implemented in alignment with the "Towards Zero" vision. While this vision assists in creating improved environment for social interaction and defining places, it also adds requirements to ensure we are minimising the amount of force that a vulnerable road users may be exposed to. **This will have implications on regulation (maximum speed limits) and supporting design features of shared space environments.**
- The most recent key author of relevant academic literature concerning shared spaces is Auttapone (Aut) Karndacharuk, who has shaped the evolution of the concept and its application.
- Academic literature concerning shared spaces can be separated into qualitative conceptual studies focussed on user perceptions and quantitative studies that focus on performance measurement. **There is a lack of comprehensive research which integrate both domains that proposes a framework for design and evaluation.**
- Shared space metrics are also separated into design parameters and performance metrics, again with limited correlation between design and performance. The research presents a preliminary conceptual mapping of identified design parameters and performance metrics.

The shared space design concept is one of many tools that a practitioner can use to enhance place attributes of a study area. Furthermore, the details of a design depend on the locational context. However, in order for shared space designs to be applied there must be a degree of standardisation of the approach to ensure inclusivity and consistency in implementation. To gain the benefits of shared space designs in the community, there must be easier implementation mechanisms.

### 3 Review of Case Studies

Currently, there are only very few scientific publications or government reports that document shared space case studies. In terms of “before and after” analysis of transport performance metrics (traffic flow rate, speeds, etc.), studies tend to use a statistically insignificant data sets (small sample sizes) or just focus on post-implementation analysis. More critically, there are almost no revealed preference “before” and “after” data of community perceptions related to place attributes of shared space designs, a point that is raised by Moody and Melia (2014) as well as more recently in the 2018 CIHT report. Qualitative studies investigating user attitudes have been repeatedly conducted following an implementation, where participants are asked to recall their experience prior to the change in infrastructure, potentially resulting in confounding outcomes (Loomis, 2011). The only study that the project team could access that provided a detailed before and after analysis of public perception is a PhD dissertation by Clarkson (2017), which will be discussed in more detail in Section 3.2. This is a significant limitation of appropriately evaluating the impact of shared spaces within a road network, and a primary motivation to undertake further research. Transport could pioneer the evaluation of shared space design implementations, and in general be a global leader in the quantification of place attributes across the road network through further research.

The most comprehensive case study evaluations were initially conducted by the MVA Consultancy Group in 2009, to support the development of the 2011 “Shared Space” guidance provided by the Department of Transport in the UK. These were then followed up by the “Review of Shared Spaces”, completed by the CIHT in 2018. The Appendix of the document provides detailed information regarding 11 case studies in the UK, (CIHT, 2018):

- Elwick Square, Ashford
- Exhibition Road, Royal Borough of Kensington and Chelsea
- Holbein Place, Royal Borough of Kensington and Chelsea
- Leonard Circus, London Borough of Hackney
- Fountain Place, Poynton, Cheshire
- Gosford Street, Coventry
- Kimbrose Triangle, Gloucester
- Fishergate, Preston, Lancashire
- Hamilton Road, Felixstowe, Suffolk
- Walworth Road, London Borough of Southwark
- Borehamwood, Hertfordshire

The above sites were selected based on accessibility to data and documentation. The report presented impacts using a comparison of aggregated quantitative metrics, and also provided a general qualitative evaluation of each site in terms of the 5 main shared space indicators that were defined within the report. The indicators assessed whether shared spaces provided: (1) an inclusive environment, (2) ease of movement, (3) improved safety and public health, (4) a high quality of place and (5) economic benefits. The findings are summarised in Table 9 clearly establishing the positive impact of shared spaces in enhancing the quality of place and ease of movement. Though 3 sites displayed generally negative results associated with creation of an inclusive environment, modifications to designs achieved some positive outcomes. For example, Gosford Street introduce some marked pedestrian crossings for vulnerable road users which rectified the initial community concern. An important point

gathered from the detailed analysis was the lack of information available to determine whether an inclusive environment or economic benefits were achieved in these projects (reflected by the orange shaded cells marked with “II”). Also, the case studies of the CIHT report indicate the challenge in measuring public health impacts. Generally, evaluations occur across a short time horizon which limits the ability to capture long term impacts and more importantly many studies do not collect health data of the communities interacting with shared spaces. There is a need to establish better measurement and monitoring of inclusivity, health and economic impacts in future case studies.

Table 9: Summary of the evaluation of case studies (CIHT, 2018)

Site	Indicators (Performance classified as: Insufficient Information (II), Positive, Neutral, Negative)				
	Inclusive Environment	Ease of Movement	Improved safety and public health	High quality of Place	Economic Benefits
Elwick Square	II/Neutral	Neutral	Neutral	Positive	Positive
Exhibition Road	II/Neutral	Positive	Positive	Positive	II/Neutral
Holbein Place	II/Neutral	Positive	Neutral	Positive	II
Leonard Circus	II/Neutral	Positive	Neutral	Positive	II/Neutral
Fountain Place	Neutral	Positive	Neutral	Positive	Positive
Gosford Street	Negative	Positive	Positive	Positive	Positive
Kimbrose Triangle	Negative	Positive	Neutral	Positive	II
Fishergate	Negative	Positive	II	Positive	II
Hamilton Road	II	Positive	Neutral	Positive	Positive
Walworth Road	II/Positive	Positive	Positive	Positive	II
Borehamwood	II	Positive	Positive	Positive	Positive

In addition to the above case studies, there have been other recent shared space implementations which are described in more detail within academic literature and government reports. Unfortunately, outside of field observations and a highly qualitative comparison completed by Gillies (2009) of sites in Sydney, there are no comprehensive case studies of NSW examples and only 1 example (Port Macquarie, NSW discussed in Section 3.4) that has any publicly available documentation. The following sub-sections describe three case studies that have had notable assessment as well as a discussion of the single application in NSW.

### 3.1 Case Study 1: Horseshoe Common, Old Christchurch Road, Bournemouth, UK

Pearson et al. (2019) presents comprehensive discussion of the complete process of delivering a shared space scheme in Bournemouth, UK. Funded by the Local Sustainable Transport Fund (LSTF), Bournemouth Borough Council delivered two shared space schemes at Horseshoe Common and at Boscombe. Unlike most other case studies that could be identified, Pearson et al. (2019) details the approvals and community consultation processes and implementation challenges in addition to a safety analysis, providing valuable insights. Though 2 sites are identified in the publication, there is a greater focus on the Horseshoe Common location due to significant safety concerns and crash history, and thus is the focus within this section. Table 10 briefly summarises the key aspects of the case study.

Table 10: Summary of Case Study 1

Horseshoe Common, Old Christchurch Road, Bournemouth, UK
<p><b>Location:</b> Old Christchurch Road, adjacent to a key commercial centre, extends over a length of 90m, between the Horseshoe Common Park (east) and the pedestrianised shopping area in the west. <b>(Implementation: 2014)</b></p> <p><b>Traffic conditions (Prior to implementation):</b> 4800 vehicles/day (500 buses), approximately 5 casualty collisions per year (2.43 casualty collisions per year during the day) (2007 to 2014)</p> <p><b>Purpose:</b> Promote sustainable travel (active modes) and improve safety in the Horseshoe Common area.</p> <p><b>Design Features:</b></p> <ul style="list-style-type: none"> <li>➤ Removal of the roundabout (intersection of Dean Park Crescent and Fir Vale Road) and restoration of the crossroad that was previously present.</li> <li>➤ Removal of a formal marked pedestrian crossing and other signage and lane marking.</li> <li>➤ Introduction of tactile pavements and flush kerbs (contrasting road surfacing materials used to signify a different environment).</li> </ul>
<p><b>Reference/s:</b> Pearson et al. (2019) compared before and after implementation (2014), using data between 2007 and 2018.</p>
<p><b>Key Defining Findings:</b></p> <ul style="list-style-type: none"> <li>• <b>38% reduction in casualty collisions</b> (annually) following implementation.</li> <li>• Footfall on Old Christchurch Road <b>increased by 126%</b>.</li> <li>• Initial adverse reaction to changes (especially concerning fears over safety) reduced over time, post implementation.</li> </ul>

Horseshoe Common Park is bounded by Dean Park Crescent, Old Christchurch Road and Madeira Road and is central to the commercial scope of Bournemouth, as shown in Figure 16. Old Christchurch can be classified as “high-street” with a number of adjacent businesses and the purpose of the shared space design was to encourage greater walking and cycling and reduce car traffic. In addition, there were significant safety challenges where there were on average 5 casualty collisions per year within the study area. This was attributed to Old Christchurch Road being a key distributor road within the network being combined with intoxicated members of the public (diminished cognitive function) interacting with the road network after leaving adjacent nightclubs and recreational establishments. Therefore, the redesign also took into consideration enhancing safety in this context.

The shared space that was implemented involved the removal of a roundabout at the intersection of Dean Park Crescent/Fir Vale Road and Old Christchurch Road, and the restoration of a 4-way intersection that was present previously. Furthermore, a formal pedestrian crossing, signage and lane marking was removed while tactile pavements and flush kerbs were introduced. The pavements adopted faced deterioration, displacement and settling issues which required post implementation adjustment. The paper highlights that novel design features used in shared spaces require adequate testing and research to minimise such disruptions in the future. The final measure was to implement timed road closures to minimise interactions between pedestrians and vehicles during critical nighttime hours. Figure 17 presents an image of the change in infrastructure following the adoption of the shared space.



Figure 16: Location of shared space implementation at Horseshoe Common, Old Christchurch Road, Bournemouth, UK (OpenStreetmap, 2021)

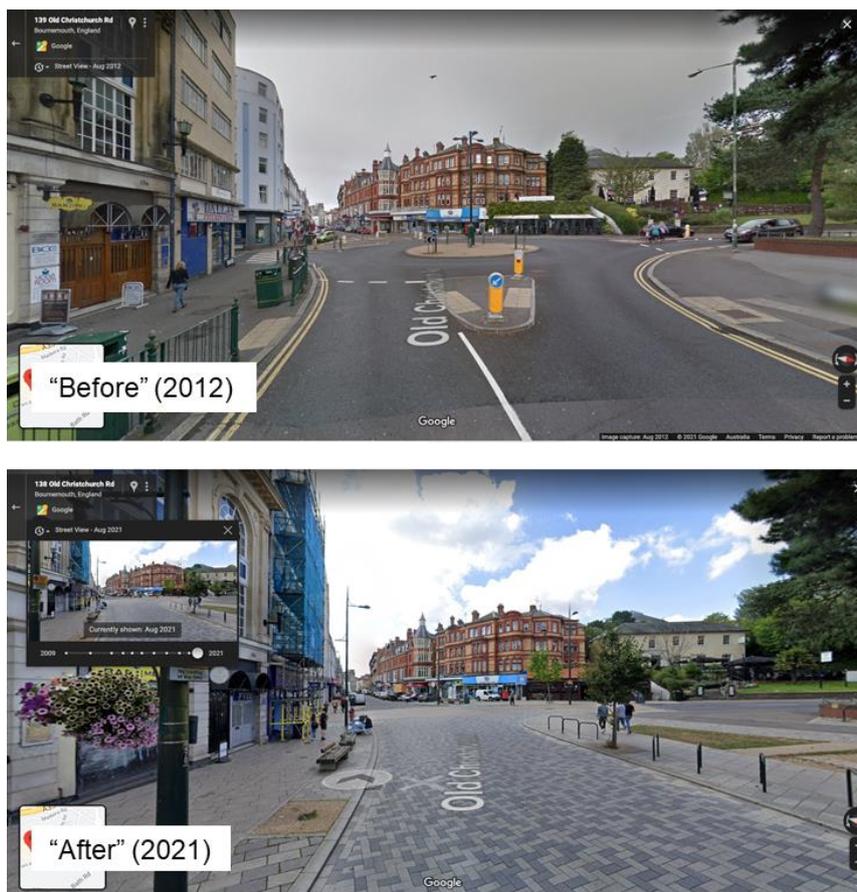


Figure 17: Old Christchurch Road, Before and After implementation of the shared space design

Pearson et al. (2019) collated public reaction feedback and noted that the first year following implementation resulted in significantly higher numbers of complaints when comparing with similar sized infrastructure projects. A majority of complaints revolved around safety concerns,

especially for vulnerable road users, however what is important is that the number of complaints have decreased over time. These results are a reflection of inadequate community consultation and marketing of change prior to adoption, which Pearson et al. (2019) acknowledge as a lesson learned for future applications. The statistical analysis in the paper, albeit limited to annual statistics revealed that since implementation there have been zero casualty collisions during the road closure hours, and outside of those hours, there has been a further 38% reduction in casualty collisions (reduction from 2.5 per year (pre-2014) to 1.5 per year (2015 to 2018)). However as it is based on a small sample size, future data collection and analysis is necessary to establish the safety improvement. In addition, footfall figures along Old Christchurch Road have increased from 97,144 (2014) to 219,936 (2018) which has also been attributed to the change in infrastructure. Overall, this case study presents the shared space implementation as a positive outcome for the community with preliminary improvements in safety and indications of increased social interaction. However, the description of the planning, design and implementation process and also the interactions with the community during this process, emphasises the need for standardisation of implementations to improve future adoption.

### 3.2 Case Study 2: Acorn Road, Newcastle upon Tyne, UK

The Acorn Road redevelopment is an interesting case study as it introduced infrastructure that is normally removed in a shared space to encourage greater pedestrian activity. Clarkson (2017) completed a detailed quantitative and qualitative before and after study as part of a PhD dissertation summarised in Table 11.

Table 11: Summary of Case Study 2

Acorn Road, Newcastle upon Tyne, UK
<p><b>Location:</b> Acorn Road is a “shopping street” in the residential suburb of Jesmond located north of the centre of Newcastle upon Tyne. It is connected to Osbourne Rd in the east, another commercial street, and to St Georges Terrace, a mixed commercial and residential space to the west. <b>(Implementation 2015)</b></p> <p><b>Traffic conditions:</b> Approximately 4,000 to 4,500 vehicles/day, average speed of 25km/hr, pedestrian crossing flow of 300 people/hr (2015)</p> <p><b>Purpose:</b> The objective of the shared space redevelopment was to “create a better environment for walking and cycling by making changes to the road layout to reduce traffic”.</p> <p><b>Design Features:</b></p> <ul style="list-style-type: none"> <li>➤ Three raised platforms were constructed for shared pedestrian and vehicle space.</li> <li>➤ Conversion of a 2-way street to a 1 way street</li> <li>➤ Repositioning of signalised crossings, signage and pavement marking clearly highlighting the shared environment.</li> <li>➤ Reduction of parking</li> </ul>
<p><b>Reference/s:</b> Clarkson (2017) conducts a detailed statistical analysis of attitudinal and behavioural changes resulting from the implementation.</p>
<p><b>Key Defining Findings:</b></p> <ul style="list-style-type: none"> <li>• Vehicle volumes and speeds reduced by 30% and 19% respectively.</li> <li>• Pedestrian flows increased marginally while more crossing opportunities were present.</li> <li>• All user attitudes were positive towards the development and cooperative behaviour was observed between different modes.</li> </ul>

Similar to the properties of Horseshoe Common in Case Study 1, Acorn Road is at the commercial centre of Newcastle upon Tyne. A number of businesses, restaurants and places of community activity are present, as depicted in Figure 18. The purpose of the shared space implementation was to encourage walking and cycling where this would be directly measured by a reduction in vehicle flow and an increase in footfall. This shared space was implemented in 2015.



Figure 18: Location of shared space implementation at Acorn Road, Newcastle upon Tyne, UK (OpenStreetmap, 2021)

Unlike other shared spaces that have removed signalisation and other infrastructure, the development at Acorn Road repositioned signalised intersections (midblock pedestrian crossing moved approximately 20m west to the intersection of Osborne Road/Acorn Road) and introduce signage and pavement marking to clearly indicate the presence of a shared environment. In addition, three platforms (eastern and western boundary intersections and a main mid-block 100 metres in length) for shared vehicle and pedestrian space, effectively creating kerb-less road segments (shown in Figure 19). The general road width was reduced after the development, whilst footpath width generally increased. Clarkson used the ‘shared space rating’ proposed by Dickens et al. (2010) to score the raised platforms based observable criteria and to examine the level of demarcation between the roadway and footpath on Acorn Road. His assessment revealed Acorn Road to be a “quasi-shared space scheme”, with vehicle and pedestrian movement still displaying separation. However, this design aligns with some principles of the zone-based approach to shared space design and may be a more suitable to cater for vulnerable road users. The other main changes of Acorn Road was a conversion from a two-way road to a one-way road and the subsequent reduction and reorganisation of on-street parking. Before and after images facing west at the intersection of Osborne Road/Acorn Road is shown in Figure 20 indicating the change resulting from the redevelopment.

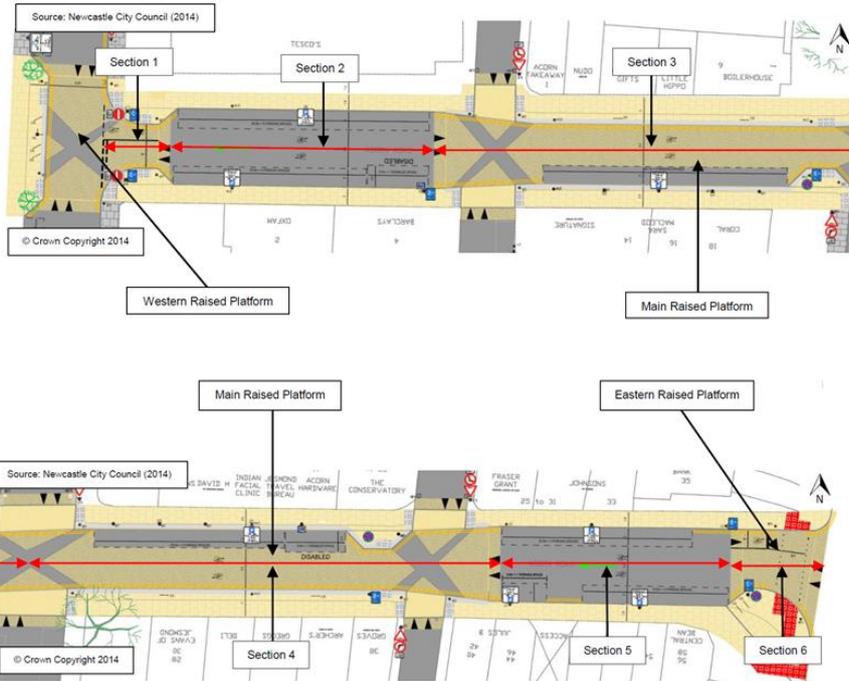


Figure 19: Diagrams of raised platform designs on Acorn Road (combination of Figure 5.7 and 5.8 of (Clarkson, 2017))



Figure 20: Acorn Road, Before and After implementation of the shared space design (Clarkson, 2017)

**The study conducted by Clarkson (2017) is of importance as it examines the performance of the shared space improvements before and after implementation, using a diverse criteria.** The assessment included an evaluation of both traffic performance measures as well as behavioural and attitudinal changes. Importantly attitudinal changes were gathered using two surveys, one conducted before implementation and the other after implementation mitigating the issue of bias discussed in Section 2.3. Clarkson (2017) examined pedestrian attitudes using a Likert scoring system (responses scored 1-7 between Strongly Agree-Strongly Disagree) for 29 different attitudinal statements. Age, gender and occupation were indicated to have affected attitudes prior to development of Acorn Road. Responses after redevelopment indicated positive attitudes, focusing on improvements in safety (especially as a result of the raised pavements), ambience of the environment, the economic vitality, the reduction of vehicle traffic, and the accessibility of footpaths. Aspects of Acorn Road that did not evoke a strong opinion from users were found to be clustered around the statements 'Cyclists and vehicles are considerate to each other' and 'Acorn Road is quiet during the night'.

Pedestrian crossing behaviour changed following the introduction of the shared space. Crossing angles widened, which Clarkson (2017) suggested was an improvement in pedestrian safety. The road narrows at the "Main Raised Platform" creating shorter crossing distances which can improve pedestrian crossing confidence and hence widen pedestrian crossing angles. Statistical analysis of before and after pedestrian flow data (crossing volumes) suggested that the shared space had not significantly increased foot-traffic. This could be related to the data collection method as the widening of crossing angles may mean some crossing movements were missed by the video footage. Furthermore, the design created concentrations of pedestrians at raised platforms which Clarkson (2017) contends compromises accessibility, especially compared to uniform shared space applications. Yielding analysis before and after development indicates that the shared space has encouraged greater accommodation of pedestrians by vehicles, with a 15% increase in yielding rates. Finally, vehicle traffic volumes reduced by 30% and vehicle speeds reduce by 19% achieving the objective desired by the local government area. Overall, this implementation has been received positively by the community and has had positive impacts. However, Clarkson collected data during 2015 and 2016, immediately after the introduction and further monitoring and assessment must be conducted to verify the conclusions of the study.

### **3.3 Case Study 3: Auckland, New Zealand**

Auckland Council has invested in research, trialling and implementation of shared spaces throughout the city. The first application was the Wairepo Swamp Walk (implemented in 2010) that connected the Kingsland township and Eden Park as part of preparations for the Rugby World Cup in 2011 which is classified as the first "purpose-bult shared zone" in Auckland city (Peter Fell, 2019). Since then there have been a number of projects within the vicinity of the major commercial thoroughfare of Queen Street. The following section will detail studies related to two shared space applications: Elliott Street and Fort Street, locations shown in Figure 21. These investigations have been led by Karndacharuk and Auckland Council and provide the most comprehensive publicly available evaluations of shared space designs.



Figure 21: Location of shared space implementations in Auckland, New Zealand (OpenStreetmap, 2021)

### 3.3.1 Elliott Street, Auckland New Zealand

The Elliott Street shared zone was one of the first shared zones implemented in the Auckland CBD as part of the 10-year urban design renewal plan for the city (Auckland’s City Centre Master Plan 2012). It is a one-way northbound link from Wellesley Street West to Victoria Street East, having connectivity to public transport on both the entrance and exit sides of Elliott Street. This would offer a natural flow of pedestrian movement through Elliott Street to access the bus services and also provides improved access to Aotea Square, a significant public plaza. A summary of the implementation is shown in Table 12.

As part of the design process, comprehensive public consultation specifically with the Royal New Zealand Foundation for the Blind was undertaken to ensure the operational needs are met for all users of the shared space. Accessibility for all users is maintained using the “zone-based approach” of shared space implementation. A 1.8m wide safety zone was implemented on both sides on the street in line with the building edges to assist vision impaired and other users requiring further assistance. This zone is separated by a 600mm wide tactile strip used to delineate between other street furniture and vehicular traffic (Karndacharuk, 2014b). Furthermore, “No Stopping” traffic regulations were imposed at all times in the zone, except for bicycle and motorcycle parking in designated areas and loading activities (maximum parking time of 5 minutes) between 6:00AM and 11:00AM (Karndacharuk et al., 2014b).

Table 12: Summary of Cast Study 3.1 – Elliott Street

Elliott Street, Auckland, New Zealand
<p><b>Location:</b> Elliott Street shared zone in Auckland CBD is a one way, 14.2m wide, 200m long shared street, connecting Aoetea Square (a public plaza) and a key main road north. It has significant retail and commercial activity leading to more active frontages and hence providing more opportunities for informal crossing points. <b>(Implementation 2011)</b></p> <p><b>Traffic conditions:</b> 1,800 vehicles per day and peak traffic volume of 150 vehicles per hour. Nine manoeuvring related crashes were recorded in the 5-year crash history prior to the implementation of the shared zone at Elliot Street.(2010)</p> <p><b>Purpose:</b> Reduce vehicular dominance, enhance the street environment for pedestrians and encourage community interactions. Part of the infrastructure development for the 2011 Rugby World Cup.</p> <p><b>Design Features:</b></p> <ul style="list-style-type: none"> <li>➤ Levelled surface by removal of the existing low kerb.</li> <li>➤ New pavers along with the addition of a tactile strip to differentiate the accessible and circulation zones.</li> <li>➤ Removal of bollards that previously separated the carriageway. This provides a more open and less restrictive environment for pedestrians that may want to cross the road to access different buildings along the street.</li> </ul>
<p><b>Reference/s:</b> Karndacharuk et al. (2011) provides before and after data collection methodology and definition of key performance metrics.</p> <p>Karndacharuk et al. (2014b) compared before and after characteristics of various shared zones in Auckland central business district (CBD).</p> <p>Karndacharuk et al. (2016) presents a comprehensive qualitative analysis of perceptions towards the Elliott Road shared space.</p>
<p><b>Key Defining Findings:</b></p> <ul style="list-style-type: none"> <li>• Shared space has been considered a resounding success at improving the quality of place as well as improving traffic conditions to an environment tailored for pedestrians.</li> <li>• Significant reduction in manoeuvring crashes (9 crashes to 1 crash between 2006 – 2016).</li> <li>• 45% reduction in daily average traffic volume (from 1,800 vehicles per/day in 2010 to 985 vehicles per/day in 2016), with a slight 15% reduction in peak traffic.</li> <li>• Although the original 85<sup>th</sup> percentile speed was relatively low (26km/h), post implementation the speed was further reduced to around 20km/h, having a 20% reduction in vehicle speeds.</li> </ul>

Karndacharuk et al. (2016) conducted a comprehensive qualitative analysis of the Elliot Street, Lorne Street and Fort Street shared spaces by using a perception survey. The Elliott Street upgrades were considered to enhance place characteristics and pedestrian accessibility relative to a control site of O’Connell Street. Karndacharuk et al. (2014b) analysed Elliot Street in terms of safety and traffic performance by comparing 2010 (before implementation) and 2011/2012 data (after). The data used for the comparison was based off recommendations from Karndacharuk et al. (2011) and included: video survey, speed study, Road User Interaction and Conflict Study (RUICS) and crash data. The analysis of data revealed a significant reduction in daily traffic volumes of almost 45% and a more moderate reduction in peak traffic volumes of 15%. The RUICS analysis indicated a reduction in speed of all road users, in particular vehicle drivers and lower speeds are the result of more pedestrian-vehicle interactions. The analysis suggests that achieving a low-speed environment requires the presence of more people in the space and for a shared space to be effective, it should contain a high volume of pedestrians. This is further emphasised by the fact that though speeds

reduced significantly during daytime periods, speeds marginally increased during night time periods in the context of low pedestrian volumes. Overall crashes reduced and safety has improved with the implementation. Finally, the most notable feature of Elliott Street and the other case studies is the enhancement of the aesthetic qualities and the perceptions of place which can be seen in Figure 22.



Figure 22: Elliott Street, Before and After implementation of the shared space design

### 3.3.2 Fort Street, Auckland New Zealand

The implementation of Fort Street shared space was initiated in 2008 when Fort Street and the surrounding area was identified to have a significant potential to be renewed into a more attractive and pedestrian friendly road corridor. The Auckland City Masterplan 2012 identifies Fort Street as Auckland CBD's key business destination along with having several symbolic heritage buildings. Unlike the other case studies presented, this was a staged project that involved not only the Fort Street corridor but also all the streets adjacent to Fort Street, including: Jean Batten Place, Fort Lane, Commerce Street, Gore Street, and Gore St Lane. A brief summary of the case study is presented in Table 13.

Table 13: Summary of Cast Study 3.2 – Fort Street

Fort Street, Auckland, New Zealand
<p><b>Location:</b> Fort Street and adjacent streets and laneways of Jean Batten Place, Fort Lane, Commerce Street, Gore Street, and Gore St Lane. The region is a high activity commercial zone with a mix of retail, restaurants and businesses. The project was implemented in three stages, commencing in Nov 2010 and completing in 2013. The total cost is estimated to be around \$23 million. <b>(Implementation 2011-2013)</b></p> <p><b>Traffic conditions:</b> The five day daily average count for Fort Street in 2009, west of Commerce Street was 5,958 vehicles/day (weekdays) with an 85<sup>th</sup> percentile speed of 29km/hr. Seven non-injury crashes were reported five years before implementation.</p> <p><b>Purpose:</b> To transform Fort Street and the surrounding area into a more attractive, distinctive public space that offers priority to pedestrians, increase footfall and becomes an economy stimulating destination.</p> <p><b>Design Features:</b></p> <ul style="list-style-type: none"> <li>➤ Removal of on-street parking to accommodate wider accessible and activity zones and open space environment without compromising pedestrian sight lines while crossing the street.</li> <li>➤ Only parking for police vehicles and time-restricted loading zones were attained within the shared zone.</li> <li>➤ Bicycle racks, trees, planter boxes, benches, outdoor dining, and litter bins placed throughout the space to promote sustainable mode of transport, maintain activity and cleanliness so that visitors can comfortably spend time in the street environment.</li> <li>➤ Well-spaced street lighting throughout Fort Street.</li> <li>➤ Dedicated motorcycle parking within Fort Street along with informal yet designated spots for shared e-scooters.</li> <li>➤ Levelled paving road surface and removal of line marking throughout the shared space.</li> <li>➤ Decommissioning of Give Way signed control at the intersection of Jean Batten Place and Fort Street.</li> <li>➤ Raised threshold treatment at entry and exit points along with Shared Zone entry and exit signs. Signs along the shared zone to inform of No Entry and turning restrictions.</li> <li>➤ Wall art in laneway along with outdoor dining</li> </ul>
<p><b>Reference/s:</b> Auckland Council (2012) presents a report of the evaluation of the Fort Street case study.</p> <p>Karndacharuk et al. (2016) presents a comprehensive qualitative analysis of perceptions towards the Fort Street shared space.</p> <p>Global Designing Cities Initiative (2021) provides a brief summary of impact of implementation</p>
<p><b>Key Defining Findings:</b></p> <ul style="list-style-type: none"> <li>• 54% increase in pedestrian volumes</li> <li>• 47% increase in economic activity through consumer spending</li> <li>• Reduction in vehicle volume by 25%</li> <li>• 49% of people that were interviewed would like to visit the place again</li> </ul>

Figure 23 presents the stages of the development. The stages were completed annually between 2011 and 2013. Stage 1 and 3 involved the development of spaces at the boundaries of Fort Street while the scope of Stage 2 focussed on the upgrade of street layout by expanding footpaths, integrating paving elements into the footpath and updating road line marking. Additional features consisted of the removal of parking, installation of street furniture, planter boxes and bicycle racks and wall art plus the introduction of outdoor dining to generate pedestrian activity.



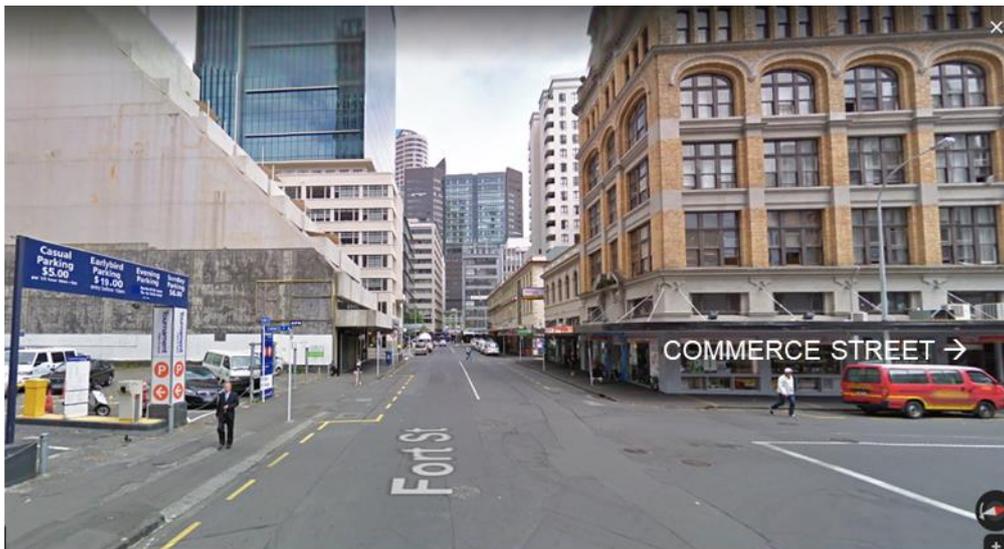
Figure 23: Staged upgrade of Fort Street and adjacent streets (Auckland Council, 2012)

As seen from the 'before' images (Figure 24 and Figure 25) Fort Street was dominated by vehicles using it as a throughfare as well as for short-term parking purposes. High turnover parking can be correlated with the 5-year crash data prior to the shared zone, which illustrates 40% (three of the seven crashes) of crashes recorded as being manoeuvring crashes. The crash data after the Fort Street transformation only reflects one manoeuvring crash between 2011 and 2016, and moreover a reduction in overall crashes by 40% up to 2016. Although the crashes recorded for the shared zone were a shift to rear end and overtaking crash types, this still illustrates an improvement in safety.

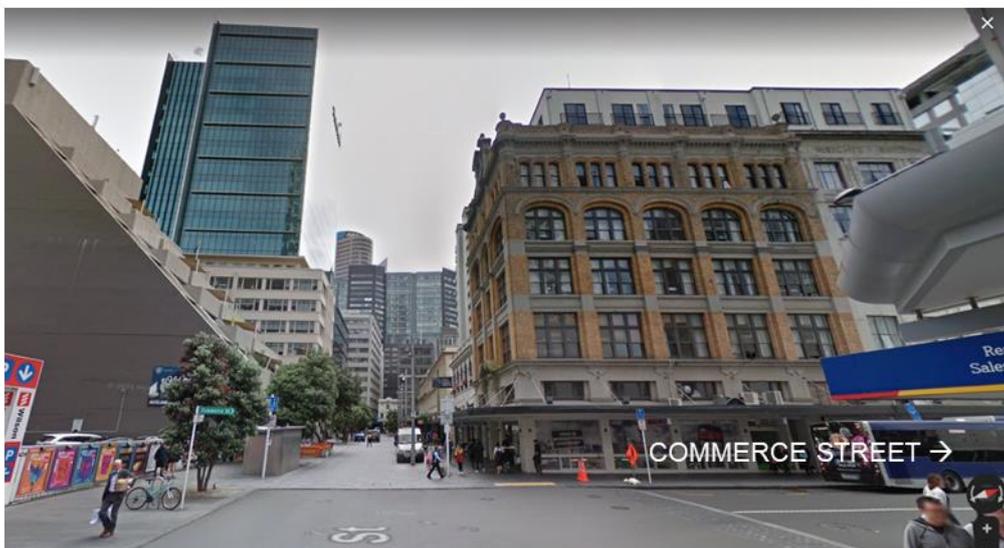
Auckland Council evaluated the Fort Street Shared Zone against seven objectives, related to creating a pedestrian friendly environment, distinct place characteristics, lower vehicle dominance, improved safety, and greater economic performance (Auckland Council, 2012). The indicators to support the objectives were measured through various resources, namely, the collection of vehicle and pedestrian counts, New Zealand Transport Agency (NZTA) crash data, property value and employment statistics, and video and perception surveys. Since the evaluation was undertaken within a year of the opening of the Stage 1 shared zone it offers insights into initial perceptions of users and impact on businesses due to the shared space design. It is noted that the short-term evaluation may not be able to provide enough data to correlate specific trends but does provide a baseline for future assessments.

Surveys conducted by Gravitass and Auckland University of Technology emphasise the drastic change in public perception (Auckland Council, 2012). Prior to implementation, only 15% of respondents felt *pleasant; nice; excellent* and/or *practical; convenient; functional; accessible* in the study area, whereas in 2011, at the completion of stage 1 works, 91% had positive feedback and felt comfortable, and described the space as pedestrian friendly and vibrant. Both surveys also gauged user awareness of pedestrian and vehicle priority. Over 81% of respondents understood pedestrians to have priority, followed by 12% that perceived vehicle priority and 7% that did not know. This reflects that the design elements of the shared zone in

Fort Street have been relatively successful in providing visual cues to invoke and natural perception of pedestrian priority in a shared space. Comparing driver perceptions of shared spaces revealed an equal split between drivers feeling comfortable sharing the street with other road users (49%) verses feeling uncomfortable (41%). The results reconfirm the conceptual philosophy of shared spaces which focuses on intentionally creating a change in the road environment to create greater awareness across all users, and in turn achieving lower speeds. Though sample sizes and survey methodology is not clearly described within the evaluation report, the findings still provide positive indications associated with the development.



“Before” (2009) - View towards Fort Street (west of Commerce St, Stage 1)



“After” (2017) - View towards Fort Street (west of Commerce St, Stage 1)

Figure 24: Before and after - Stage 1 of the Fort Street project



“Before” 2012 - View towards Fort Street (east of Commerce St, Stage 3)



“After” 2020 – View towards Fort Street (east of Commerce St, Stage 3)

**Figure 25: Before and After - Stage 3 of the Fort Street project**

As mentioned in the Elliott Street example, Karndacharuk et al. (2016) presents a detailed before and after study of the Fort Street site as well. Comparatively, Fort Street has improved perception ratings and has achieved similar speed, volume and crash trends. The Global Designing Cities Initiative has highlighted the Fort Street example as a successful case study. This document reveals that there has been a 54% increase in pedestrian volumes, 47% increase in economic activity through consumer spending, 25% reduction in vehicle volumes and most importantly 80% of people felt safer in the area (Global Designing Cities Initiative, 2021). The findings from New Zealand are incredibly valuable as there are very few case studies that collected detailed data to properly compare both perception and performance variations following the implementation of a shared space.

### 3.4 Applications of Shared Spaces in NSW

There are numerous undocumented shared spaces across NSW. For example, the redevelopment of George Street, Sydney to accommodate the light rail can be classified as a form of shared space based on the definition presented in this research. Examples could be: Church Street, Parramatta; Harbour Drive, Coffs Harbour and a number of others. Furthermore, there are numerous “shared zones” across NSW, which again belong to the broader definition of shared spaces. However, as noted earlier in this Section of the report, there are no case studies describing the impacts of these examples. **A primary objective of further research is to create an inventory of these sites so that practitioners and researchers can use such documentation as a reference for future applications.**

The only documented example of a shared space application that could be identified in NSW were a set of intersections in the CBD of Port Macquarie. David Tooby prepared a report explaining the transformation of the main intersection of Horton Street and Clarence Street, titled “*Shared Space Performance Analysis, Port Macquarie NSW*” (Tooby), in an undefined year but post 2007. Though this is not a scientific publication, it provides some insights into the history of the CBD of Port Macquarie and the process of the development of the shared space. The Horton Street/Clarence Street intersection conversion was undertaken as part of the 1992 Port Macquarie Town Centre Master Plan and was delivered in 1995 costing approximately \$10 million dollars. The intersection is critical within the CBD and provides access to the Town Green foreshore and overlooks the Hastings River, signifying a section of the road network with significant place attributes that can connect members of the community. Figure 26 presents a view of the intersection as a shared space. Kerbs have been removed and street infrastructure and vegetation introduced to create a lower speed, place centric environment. The performance analysis undertaken by Tooby was qualitative and it highlighted satisfactory safety and movement performance resulting from the change.



Figure 26: Horton Street/Clarence Street Intersection Features (Facing East on Clarence Street)

Further research was carried out to gather other sources of documentation, but the Tooby report seems to be the only publicly available information regarding the conversion of Horton Street/Clarence Street. However, viewing aerial imagery of Port Macquarie's CBD led to an interesting discovery. Figure 27 shows that the design applied for Horton Street/Clarence Street has been applied for the other adjacent intersections of:

- Short Street/Clarence Street (implemented between 1995 and 2010)
- Hay Street/Clarence Street (implemented between 1995 and 2010)
- Horton Street/William Street (implemented between 1995 and 2010)
- Murray Street/Clarence Street (implemented 2015/2016)

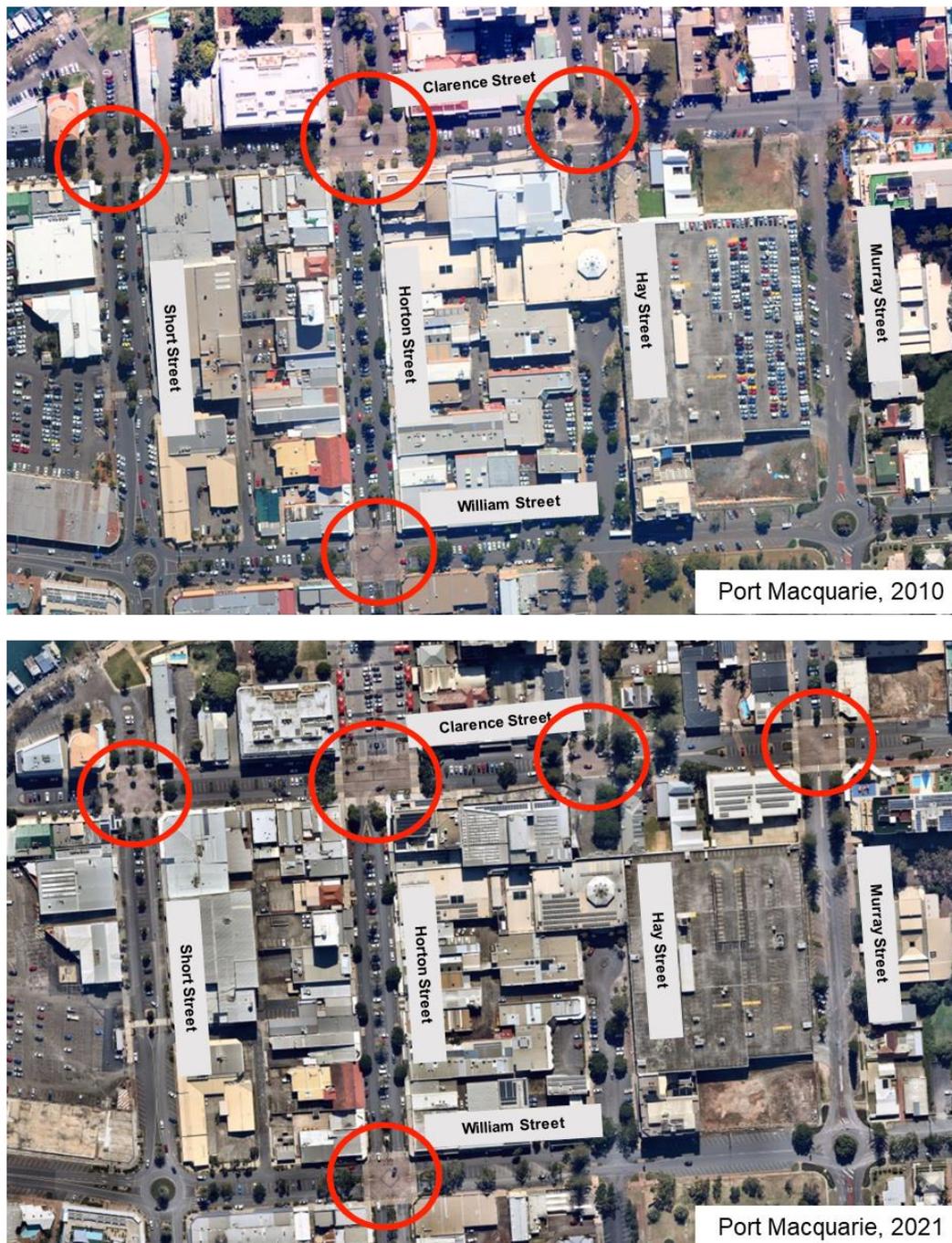


Figure 27: Port Macquarie CBD comparing 2010 and 2021

The progression of the development of additional shared spaces in Port Macquarie indicate that in the local context, the design appears to be effective and appreciated by the community. **However, further research and investigation regarding the examples in Port Macquarie is necessary to draw conclusive relationships, a task that can be completed in further research.**

As briefly explained in Section 2.1.3, NSW has applications of “quasi shared spaces” (Gillies, 2009) that aren’t completely shared by all modes but have components of the concept. In many ways, the definition derived in this report provides a greater scope of consideration for shared spaces as the priority is less about removing infrastructure that separates modes and more about enhancing places on the road network. However, even with the broader definition, there are no comprehensive reports or case studies completed in NSW that could be discussed further. **Further research will conduct a detailed inventory of sites in NSW (focussed on Sydney Metropolitan) and aims to conduct empirical analysis to form evaluations of the identified sites, which can fill this void in literature.** In addition, state-wide initiatives, such as the *Streets for Shared Spaces* program (discussed in Section 2.1.3) offers further opportunities to conduct trials and small scale “before and after” studies to quantify the impacts of shared space applications.

## 4 Challenges and opportunities to implementing Shared Spaces

The literature and case studies reviewed throughout the project has established the history of shared spaces as a concept and in terms of application. The following section summarises the challenges and opportunities in future implementations of shared spaces. In addition, there will be a brief discussion concerning current best practice and the potential applications of shared spaces in NSW.

### 4.1 Challenges and opportunities

#### 4.1.1 *Developing trust and collaboration in a transformative concept*

The novelty of the shared space principle, to encourage infrastructure integration is the primary challenge that faces greater proliferation of shared designs. Since the advent of highway systems in the 1950s and the development of road network hierarchies, the objective of road network management has focussed on efficiency and safety. In order to cater for private vehicles that can travel at rapid speeds, safety can only be achieved by dedicated and separated infrastructure. Footpaths, cycleways, transit lanes all supplemented a road network designed for private vehicles. Shared spaces confounds this by removing such separation intended to safeguard the different modes utilising a road network which is a challenge for both practitioners and more importantly the general community.

This is further exacerbated by some descriptions of shared spaces by Hans Monderman and then Ben Hamilton-Baillie, who have framed shared space designs as creating uncertainty for motorists which subsequently encourages slower and safer driving practices allowing for greater priority of other modes. Though shared spaces do demand slower speeds and greater awareness by drivers, the term uncertainty has been perceived as a risk, especially for vulnerable road users'. Based on the literature review conducted in this project, shared spaces can be interpreted as transforming components of the road network to create awareness of the significance of the place that users are traversing. Urban design and planning literature indicates a successful place requires enhanced social interactions (Friedman, 2021) which is feasible only through active mobility modes. Thus, design components that remove separation are intended to provide greater prominence to active modes and essentially equalises transport modes to best leverage the place aspect of the road network. **Shared spaces are not designs that create uncertainty for motorists, they are one of many possible design options that can be used to heighten and define successful places.**

**The challenge for the community and transport professionals is to develop trust and collaboration to achieve the vision of shared space design and validate initiatives through research and evidence of application.** Auckland Council (2017) and Elliot et al. (2017) have placed efforts into defining a more inclusive framework for shared space adoption by using the “zone-based” structure explained in Section 2.1.2. These frameworks lead to designs that achieve shared outcomes but also address the negative safety perceptions of the community.

#### 4.1.2 *Limited empirical evidence of applications*

There are several case studies and documentations of shared space applications, especially across Europe. As highlighted in Section 3, these case studies provide valuable and insightful information. However, there is a degree of inconsistency in the evaluation of sites and clear

gap in correlating design metrics with performance measurement aspects. Furthermore, though the importance of public perception and community involvement is emphasised, a majority of before and after empirical studies have gathered information following an implementation potentially confounding the assessment. Therefore, there is limited reference to past experiences that can guide practice and implementation, especially in an Australian context that has yet to embrace the widespread adoption of shared space designs.

**The challenge for transport professionals is to improve the data collection, analysis and evaluation processes of shared space designs.** This will consequently enhance the evidence base of the impacts of the scheme but perhaps more importantly, it can improve the design principles of the shared space concept.

#### **4.1.3 Clear guidance, standards and directions for transport professionals**

Section 2.2.11 explains the complexity of implementing novel local area traffic management schemes such as shared space designs. Practitioners must review Australian Standards, Austroads Guidance, Road rules and legislation and Government technical directions to design and approve non-standard solutions like flush intersections or the removal of signage lane-marking which can be components of a shared space. This time consuming and iterative process diminishes the impetus for innovation and results in a barrier for adoption.

**The challenge for transport professionals is to define singular holistic standards accounting for shared space designs** with clear reference to practitioner-oriented documents such as the Austroads and Movement and Place guidance.

#### **4.1.4 Opportunities for Transport for NSW**

Transport can meet the previously defined challenges and create opportunities for more efficient and effective definition of places by completing the following:

- **Identify, catalogue, monitor and evaluate the effectiveness of existing and future shared zones (and other “shared-like” environments) on the road network that are designed to invoke a successful place.**
  - This addresses all three aforementioned challenges. It is important to establish the notion of ‘effectiveness’ by gathering stakeholder perspectives as well as investigating the relationship between design parameters and performance metrics.
  - Comprehensive empirical methodologies provide the evidence base to validate the vision of shared designs, contribute to empirical evidence of shared spaces and can be used to define standards.
  - **This opportunity can be addressed by completing Stage 2 of the proposed research program.**
- **Advance shared space evaluation methodologies by developing and applying state-of-the-art modelling processes to conduct scenario testing of existing and future designs.**
  - This addresses the challenges described in Section 4.1.1 and Section 4.1.3.
  - The confounding nature of shared space designs creates an additional risk for practitioners in defining solutions. Modelling, in particular fine grained microscopic simulation modelling, as highlighted in Section 2.3.2, can offer

practitioners an opportunity to conduct scenario testing useful for the definition of proposals. Modelling results can then be used as a tool to communicate designs across all stakeholders engendering trust. Furthermore, modelling techniques can be included in future guidance for the planning and implementation of shared spaces.

- However, it is important to note that modelling multi-modal shared environments is complex and field of current research, therefore this is a long-term opportunity for Transport to be global leaders in the planning of shared environments.
- **This opportunity can be addressed by completing Stage 2 of the proposed research program.**
- **Trials and implementations of shared space designs to conduct comprehensive before and after research.**
  - This addresses all 3 aforementioned challenges.
  - Trialling and implementing new shared spaces throughout NSW will create awareness, further empirical evidence and support the development of standards. It is critical that future implementations are defined in the context of completing a comprehensive before and after research study that can provide an assessment of changes in perception, revealed travel behaviour and also system performance.
  - Such trialling can be executed through existing schemes, such as the “Streets for Spaces Program” (DPIE) or local government initiatives. Transport could potentially collaborate with research institutions and project delivery leads from these existing schemes to establish this in the near future.
  - **This opportunity can be addressed by completing Stage 3 of the proposed research program.**

Advancement of the *NSW Movement and Place Framework* and supporting documentation, as well as the clear objective of *Future Transport 2056* to create successful places, indicates that Transport can take advantage of the above opportunities to be future global leaders in the implementation of shared spaces.

## 4.2 Current best practice in the implementation of Shared Spaces

New Zealand, in particular applications led by Auckland Council, currently present the best practice for the implementation of shared spaces, based on the review of literature conducted in this study. The quantification techniques and evaluation methodologies defined by Karndacharuk (2014) and the qualitative study tour conducted by Joyce (2012) led to the development of *Shared Space Guidelines 2017 – Requirement for the management and use of shared spaces* which provides clear guidance for practitioners. The success of shared space implementations, as described in Section 3.3, is evidence of best practice. New Zealand authorities have learned from the challenges European agencies have faced (in particular the UK) and have used techniques to generate community driven solutions that are trialled and evaluated with some consistency. Specifically, New Zealand has led the way with leveraging tactical urbanism to test shared space design solutions to gauge public perception. These short temporary trials are useful to pilot and test solutions, especially in the current context where appropriate simulation modelling has not been developed.

The New Zealand philosophy for shared space adoption is to create an inclusive environment through a zone-based layout as described in Section 2.1.2 which offers pedestrians a choice to interact in the shared environment or utilise defined pedestrian only “safe zones”. These designs accommodate vulnerable users’ whilst also creating a shared environment that can lead to enhanced social interactions and improved place outcomes. Guidance within USA also supports the zone-based approach to design shared spaces as evident from Elliot et al. (2017). However, unlike New Zealand, there are several terminologies, documents and strategic directions in relation to shared designs that vary from municipality to municipality which limits consistency at a national scale.

Though New Zealand has achieved successful outcomes, applications are still new and the guidance is evolving. **Australian jurisdictions can build on New Zealand’s efforts to harmonise shared space implementation and address the challenges highlighted in this section of the report.** Globally, there is still a need for greater empirical research and standardisation to have seamless integration of the shared space design concept with other traffic management solutions.

### 4.3 Potential applications of Shared Spaces in NSW

The research team surveyed the road network in NSW, to determine sites that may be suitable for future shared space designs to enhance place attributes. This task provided further justification of the value of taking into consideration shared space solutions, especially through the lens of providing a spectrum of solutions that can create a successful place.



Figure 28: The Entrance Road/Coral Street Intersection, The Entrance

**The survey revealed existing locations where places seem to have been established, that could be trialled as shared spaces with only minor adjustment of the traffic management scheme in place.** For example, pictured in Figure 28, is the intersection of The

Entrance Road and Coral Street (The Entrance) which is adjacent to Memorial Park and without detailed analysis, appears to be a location within the road network that has a number of place attributes. A flush signalised pedestrian crossing is present at the intersection and it may be feasible to trial a completely shared solution at this location by simply deactivating the signalisation. As the intersection already contains different coloured pavements and is level with footpaths, it already has a number of shared space features, and deactivation of signals would create a completely shared environment. However, it is also acknowledged that the location is not free of risk as it is located on a tight bend containing a wide carriageway which needs further investigation prior to any trial. If a trial deactivation is carried out, it should be supplemented in advance with a marketing and education campaign to raise awareness and highlight the purpose of the change. In addition, public perception and performance data can be gathered before and after the trial to evaluate the change. Depending on further investigation and analysis, these types of locations could be immediate trials that Transport can explore to develop the evidence base for shared space solutions.

**There are also locations where a conversion to a shared space would reflect current user behaviour.** Segments of the road network that display illegal pedestrian crossing behaviour could be an indicator of a potential future shared space as the design would match pre-existing user interactions. Figure 29 presents Bay Street in Ultimo, near the entrance to the Broadway Shopping Centre. This location has high volumes of pedestrian activity and though formal pedestrian crossings are provided, crossing behaviour occurs between the intersection of Broadway/Bay Street and the formal raised and marked pedestrian crossing that is highlighted (based on anecdotal and experienced evidence of the project team). Bay Street not only has access to one of the largest shopping centres, Broadway Shopping Centre, but also consists of a number of businesses and is within close proximity to the University of Technology Sydney, The University Notre Dame and The University of Sydney Campuses as well as Victoria Park. These land uses demand and encourage social interaction, which provides further motivation for implementation of a shared space. Proposing and implementing a shared space at this type of location may be more intuitive and be supported by the community.



Figure 29: Bay Street, Ultimo

**The final example of a potential site is a suburban location with high pedestrian and commercial activity that is currently using traditional devices to support connectivity**

**for pedestrians.** This type of example would be a novel form of local area traffic management that is focussed on enhancing suburban communities. Figure 30 presents Erskineville Road, Erskineville between Prospect Street and George Street. Erskineville Town Hall and a number of restaurants and shopping frontages are present on a road segment which has a 40km/hr speed limit. Pedestrians are offered crossing opportunities at two marked pedestrian crossings and given the land use, there is value to providing further opportunities by capitalising on a shared space design. As discussed in Section 2.1.1, a potential conversion will initially require a reduction in speed limit to at least 30km/hr to improve safety. This can be complimented with coloured pavements, footpath widening and allowing for additional informal crossing opportunities. Similar to all the other examples, the design options will need to be defined through a collaboration between practitioners and the local community.



Figure 30: Erskineville Road, Erskineville

Applicability of shared space designs in NSW is evident based on a high-level identification of potential sites. As explained, the examples presented in this Section have been defined on a cursory survey of the road network in NSW and it is likely that there are other equally valid or better opportunities to consider shared space applications. In order to investigate these and other sites, detailed feasibility studies and transport assessments are necessary. The methodology and framework to conduct such studies requires further research relating to the design parameters and performance metrics of shared spaces, which will be achieved during Stage 2 of the research program.

## 5 Concluding remarks and next steps

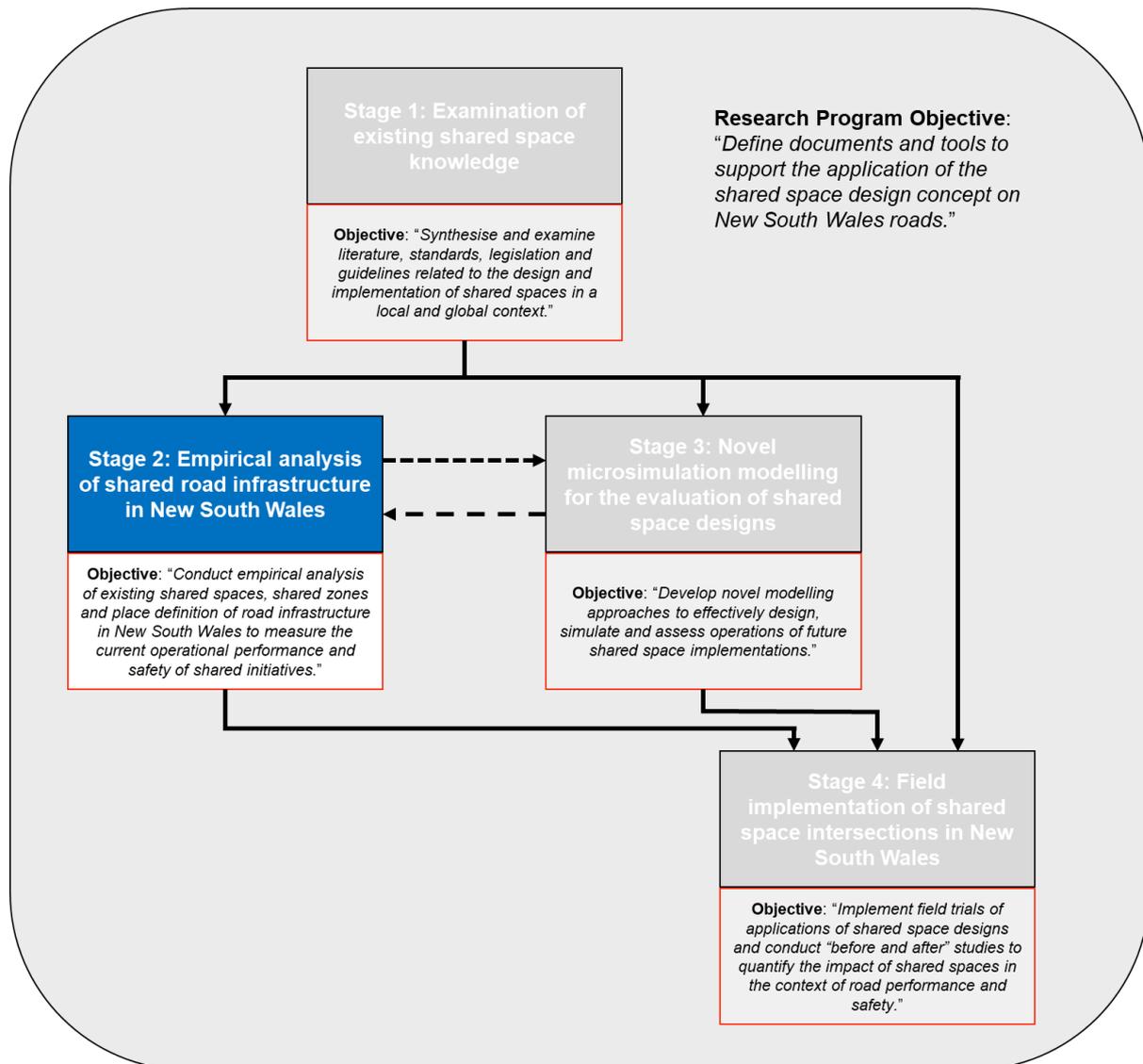
This study examines the definition and potential widespread adoption of the shared space design concept in NSW through a comprehensive review of literature. Most existing work has cast shared space designs as a relatively innovative solution involving the removal of existing road infrastructure that separates transport modes forcing motorists to travel slowly and offering greater priority for pedestrians and cyclists. However, the research has revealed that the objective of shared spaces is to transform components of the road network to low-speed environments that enhance uptake of active transport modes, encourage greater social interaction and create better “places”. Importantly, there is a **spectrum of intervention and design options that are available to transport professionals to achieve a shared space** within the road network, without requiring extreme solutions such as the as kerb-less intersections (flush intersections), removal of signalised junctions and signage. These could be applied in some cases but there can be simpler and more cost-effective solutions, such as footpath widening or inclusion of street furniture, that can achieve the objectives of a shared space and in turn define a successful place.

The shared space design concept can be an incredibly effective tool in generating change and enhancing place characteristics of a locality. The report highlights a number of case studies which have indicated improvements in safety, increases in footfall and economic growth and maintenance of vehicular throughput. However, these studies contain sample size limitations and also note negative outcomes for the community, where there is clear evidence of situations of dissatisfaction through its implementation. The primary reasons for dissatisfaction stem from the inability of designs to cater for vulnerable road users and the limitations of community involvement in the overall implementation process. New Zealand and USA have presented “zone-based” systems that provides a safety net and a more inclusive environment for vulnerable users. Yet, this is emerging guidance and in order to establish shared spaces as a solution to create better places, further urgent research is necessary.

Figure 31 recasts the research program, highlighting additional research which has the objective of conducting empirical analysis of existing shared spaces, shared zones and place definition of road infrastructure in NSW. This report has shown that, currently, there is little understanding of the relationship between the design-oriented metrics that establish a shared space and the consequent performance evaluation metrics that determine the effectiveness of the treatment. This disconnect has limited the effective analysis and evaluation of shared space applications and may be a cause for the variation in guidance observed in the literature. **Therefore, a detailed inventory and survey of all shared space and other related “place” initiatives is required to quantify the relationship between design and performance, a primary task of further proposed research.**

Furthermore, there are only a handful of “before and after” empirical studies that present robust quantitative and qualitative analysis of shared space implementations. This is compounded by very few empirical studies related to any interventions that have focussed on enhancing “place”, such as widening footpaths, changing pavement types or including furniture or greenery near road infrastructure. Without a robust scientifically driven evidence base, innovative solutions are challenging to implement for a practitioner. **It is critical to model possible infrastructure scenarios that correctly account for interactions within a shared space and then test and evaluate impacts in rigorous “before” and “after” studies.** This is a long-term initiative, that can be achieved across a staged program of work.

The outcome of such research will be the foundations to define clear guidance and develop standards that professionals can use to efficiently implement solutions, including shared space solutions, that can define successful places.



**Figure 31: Proposed staged Research Program (Highlighting Stage 2)**

In the context of the strategic direction of Transport for NSW, and in particular the continued development of the **NSW Movement and Place Framework**, additional research on shared spaces will complement this effort, as shown in Figure 32. As explained above, further research concerning shared spaces will add to each pillar of the framework, supporting guidance documentation, tool development and also from an evaluation perspective (mechanisms).

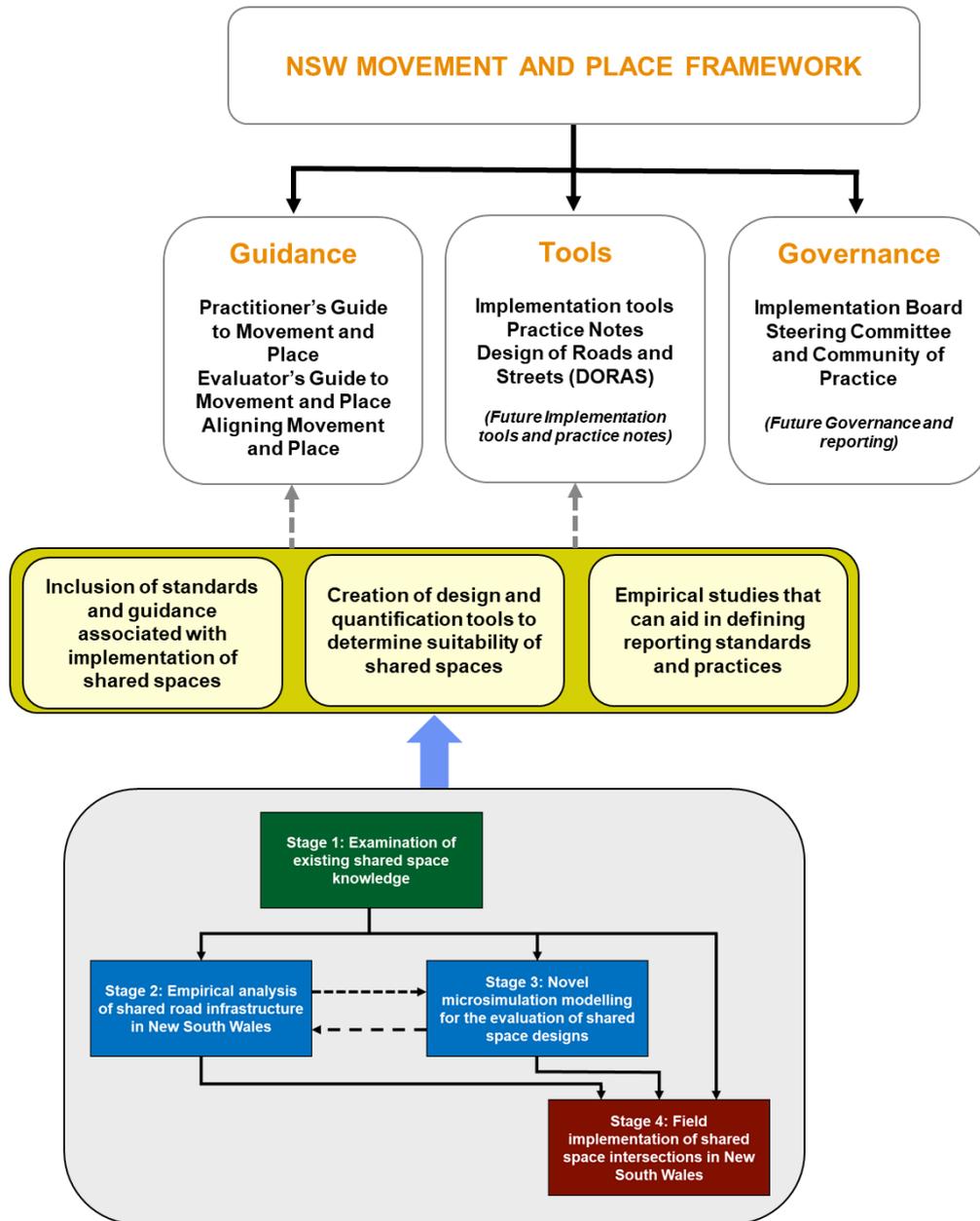


Figure 32: The relationship of the Shared Space Research Program with the Movement and Place Framework

This report has shown that the **shared space design concept is one tool that can be used to form successful places across the community**. However, the current guidelines, standards and practical processes are an impediment to novel shared solutions as well as other traditional solutions that value place over movement. By executing further research, clarity and simplification of processes can be achieved. This can not only be beneficial to practitioners within NSW and Australia but also place Transport as a global leader in proving equitable, efficient and effective delivery of successful places for the local community.

## 6 References

- Al-Mashaykhi, B. & Hammam, R. Shared Street as A Means of Liveable Urban Space. IOP Conference Series: Earth and Environmental Science, 2020. IOP Publishing, 012044.
- Alam, M., Herrera Dappe, M., Melecky, M. & Goldblatt, R. 2019. Wider Economic Benefits of Transport Corridors.
- Alsaleh, R., Hussein, M. & Sayed, T. 2020. Microscopic behavioural analysis of cyclist and pedestrian interactions in shared spaces. *Canadian Journal of Civil Engineering*, 47, 50-62.
- Alsaleh, R. & Sayed, T. 2020. Modeling pedestrian-cyclist interactions in shared space using inverse reinforcement learning. *Transportation research part F: traffic psychology and behaviour*, 70, 37-57.
- Alsaleh, R. & Sayed, T. 2021. Markov-game modeling of cyclist-pedestrian interactions in shared spaces: A multi-agent adversarial inverse reinforcement learning approach. *Transportation Research Part C: Emerging Technologies*, 128, 103191.
- Archer, E. V. 2014. *Improving shared spaces with a placemaking approach: Lessons from Adelaide*. University of Otago.
- Auckland Council 2012. An evaluation of shared space in the Fort Street Area, Auckland New Zealand Auckland Council.
- Auckland Council 2017. Shared Spaces Guidelines 2017 - Requirements for the management and use of shared spaces. Auckland, New Zealand: Auckland Council
- Australian Bureau of Statistics 2017. More than two in three drive to work, Census reveals.
- Australian Standards 2014. 1742.1 - 1742.13 - Manual of Uniform Traffic Control Devices. SAI Global
- Banister, D. & Berechman, Y. 2001. Transport investment and the promotion of economic growth. *Journal of transport geography*, 9, 209-218.
- BBC. 2018. 'Shared' road schemes paused over dangers to blind people [Online]. United Kingdom: BBC News Services. Available: <https://www.bbc.com/news/uk-england-44971392> [Accessed 12/10/2021 2021].
- Ben-Joseph, E. 1995. Changing the residential street scene: Adapting the shared street (woonerf) concept to the suburban environment. *Journal of the American Planning Association*, 61, 504-515.
- Biddulph, M. 2010. Evaluating the English home zone initiatives. *Journal of the American Planning Association*, 76, 199-218.
- Buchanan, C. 1963. Traffic in towns: the Buchanan report. London: HMSO.
- Caldarola, G. 2020. Public spaces for sustainability of contemporary metropolises: Project themes and recurring characters for the quality of design. *WIT Transactions on Ecology and the Environment*, 249, 191-201.
- Che, M., Wong, Y. D., Lum, K. M. & Wang, X. 2021. Interaction behaviour of active mobility users in shared space. *Transportation Research Part A: Policy and Practice*, 153, 52-65.
- CIHT 2018. Creating better streets: Inclusive and accessible places - Reviewing shared space. London, United Kingdom
- City of Canterbury-Bankstown 2019. Bankstown Complete Streets - Detailed Action Plan - CBD Transport and Place Plan. Sydney, Australia.
- Clarkson, J. P. 2017. *The effect of shared space on attitudes and behaviour*. Newcastle University.
- Corben, B., Wilby, L. & Eveleigh, M. 2020. Integrating Safe System with Movement and Place for Vulnerable Road Users. Sydney, Australia.
- Curl, A., Thompson, C. W. & Aspinall, P. 2015. The effectiveness of 'shared space' residential street interventions on self-reported activity levels and quality of life for older people. *Landscape and urban planning*, 139, 117-125.
- Department for Transport & Communities and Local Government 2007. *Manual for streets*, Thomas Telford Limited.

- Department for Transport (UK) 2011. Local Transport Note 1/11. Shared Space. TSO London, UK.
- Department of Planning Industry and Environment 2020. Public Spaces - Streets and Shared Spaces - Engagement Report.
- Department of Planning Industry and Environment. 2021. *Streets as Shared Spaces Program* [Online]. Sydney, Australia: NSW Government. Available: <https://www.dpie.nsw.gov.au/premiers-priorities/great-public-spaces/streets/streets-as-shared-spaces-program> [Accessed 15/09/2021].
- Department of Planning Transport and Infrastructure 2017. Speed Limit Guideline for South Australia. Government of South Australia,.
- Department of Transport and Main Roads 2019. Queensland Manual of Uniform Traffic Control Devices: Part 4 - Speed Controls. Queensland Government
- Dickens, L., Healy, E., Plews, C. & Uthayakumar, K. 2010. Designing the Future - Shared Space: Qualitative Research.
- Dijk, G. & Marmeleira, J. 2021. Streets as Social Places.
- Doecke, S. D., Baldock, M. R., Kloeden, C. N. & Dutschke, J. K. 2020. Impact speed and the risk of serious injury in vehicle crashes. *Accident Analysis & Prevention*, 144, 105629.
- Doecke, S. D., Kloeden, C. N., Dutschke, J. K. & Baldock, M. R. 2018. Safe speed limits for a safe system: The relationship between speed limit and fatal crash rate for different crash types. *Traffic injury prevention*, 19, 404-408.
- Elliot, J., Lohse, K., Toole, J., Lockwood, I., Barlow, J., Bentzen, B. & Porter, C. 2017. Accessible Shared Streets - Notable practices and considerations for accommodating pedestrians with vision disabilities. Washington, DC, USA: US Department of Transportation Federal Highways Administration
- Essex Planning Officers Association. 2021. *Shared Surfaces* [Online]. Available: <https://www.essexdesignguide.co.uk/design-details/streets-and-roads/shared-surfaces/> [Accessed 25/09/2021].
- Friedman, A. 2021. Car-free environments and shared streets. *Fundamentals of Sustainable Urban Design*. Springer.
- Frosch, C., Martinelli, D. & Unnikrishnan, A. 2019. Evaluation of Shared Space to Reduce Traffic Congestion. *Journal of Advanced Transportation*, 2019.
- Gillies, A. 2009. Is the road there to share? Shared space in an Australian context. *University of New South Wales, Bachelor of Planning*.
- Global Designing Cities Initiative. 2021. *Case Study: Fort Street; Auckland New Zealand* [Online]. Available: <https://globaldesigningcities.org/publication/global-street-design-guide/streets/shared-streets/commercial-shared-streets/case-study-fort-street-auckland-new-zealand/> [Accessed 21/10/2021].
- Global Designing Cities Initiative & National Association of City Transportation Officials 2016. *Global street design guide*, Island Press.
- Government of Western Australia. 2000. *Road Traffic Code 2000* [Online]. Available: [https://www.legislation.wa.gov.au/legislation/statutes.nsf/main\\_mrtitle\\_2007\\_homepage.html](https://www.legislation.wa.gov.au/legislation/statutes.nsf/main_mrtitle_2007_homepage.html) [Accessed].
- Green, D., Lewis, K., Ward, J. & Munro, C. 2020a. Austroads Guide to Traffic Management: Part 7 - Activity Centre Transport Management. *In: AUSTROADS* (ed.).
- Green, D., Lewis, K., Ward, J. & Munro, C. 2020b. Austroads Guide to Traffic Management: Part 8: Local Street Management. *In: AUSTROADS* (ed.).
- Hamilton-Baillie, B. 2008a. Shared space: Reconciling people, places and traffic. *Built environment*, 34, 161-181.
- Hamilton-Baillie, B. 2008b. Towards shared space. *Urban Design International*, 13, 130-138.
- Hanning, A., Woomey, J., Golestani, S., McCarnery, G., Carabott, C., Edwards, J., Altham, J., Hewson, N., Carey, M. & Strever, F. 2011. Planning and designing for pedestrians: guidelines. Department of Transport WA.
- Helbing, D. & Molnar, P. 1995. Social force model for pedestrian dynamics. *Physical review E*, 51, 4282.

- Holmes, C. 2015. Accidents by Design: The Holmes Report on "shared space" in the United Kingdom. London, United Kingdom.
- Hsu, T.-C. & Lee, T.-C. 2017. Evaluating the Perceptions of Road Users in Different Scenarios of Shared Spaces. *Journal of the Eastern Asia Society for Transportation Studies*, 12, 1201-1217.
- Imrie, R. 2012. Auto-disabilities: The case of shared space environments. *Environment and Planning A*, 44, 2260-2277.
- Imrie, R. 2013. Shared Space and the Post-politics of Environmental Change. *Urban Studies*, 50, 3446-3462.
- Jakobowsky, C., Siebert, F., Schießl, C., Junghans, M. & Dotzauer, M. 2021. Why so serious?- Comparing two traffic conflict techniques for assessing encounters in shared space. *Transactions on Transport Sciences*.
- Jayakody, R. R., Keraminiyage, K., Alston, M. & Dias, N. 2018. Design Factors for a Successful Shared Street Space (SSS) Design. *International Journal of Strategic Property Management*, 22, 278-289.
- Jiang, L., Masullo, M., Maffei, L., Meng, F. & Vorländer, M. 2018. How do shared-street design and traffic restriction improve urban soundscape and human experience?—An online survey with virtual reality. *Building and Environment*, 143, 318-328.
- Johora, F. T., Cheng, H., Müller, J. P. & Sester, M. An agent-based model for trajectory modelling in shared spaces: a combination of expert-based and deep learning approaches. Proceedings of the 19th International Conference on Autonomous Agents and MultiAgent Systems, 2020. 1878-1880.
- Johora, F. T. & Müller, J. P. Modeling interactions of multimodal road users in shared spaces. 2018 21st International Conference on Intelligent Transportation Systems (ITSC), 2018. IEEE, 3568-3574.
- Johora, F. T. & Müller, J. P. 2020. Zone-specific interaction modeling of pedestrians and cars in shared spaces. *Transportation research procedia*, 47, 251-258.
- Johora, F. T. & Müller, J. P. 2021. On transferability and calibration of pedestrian and car motion models in shared spaces. *Transportation letters*, 13, 172-182.
- Jones, P., Boujenko, N. & Marshall, S. 2007. *Link & Place-A guide to street planning and design*.
- Joyce, M. 2012. Shared Space in Urban Environments - Guidance Note.
- Jurewicz, C., Sobhani, A., Woolley, J., Dutschke, J. & Corben, B. 2015. Proposed vehicle impact speed-severe injury probability relationships for selected crash types.
- Kaparias, I., Bell, M. G., Biagioli, T., Bellezza, L. & Mount, B. 2015. Behavioural analysis of interactions between pedestrians and vehicles in street designs with elements of shared space. *Transportation Research Part F: Traffic Psychology and Behaviour*, 30, 115-127.
- Kaparias, I., Hirani, J., Bell, M. G. H. & Mount, B. 2016. Pedestrian gap acceptance behavior in street designs with elements of shared space. *Transportation Research Record*.
- Kaparias, I. & Wang, R. 2020. Vehicle and pedestrian level of service in street designs with elements of shared space. *Transportation Research Record*.
- Karndacharuk, A. 2014. *The Development of a multi-faceted evaluation framework of shared spaces*. Doctoral Thesis The University of Auckland.
- Karndacharuk, A., Wilson, D. & Tse, M. Shared space performance evaluation: quantitative analysis of pre-implementation data. Institution of Professional Engineers New Zealand (IPENZ) Transportation Conference, 2011, Auckland, New Zealand, 2011.
- Karndacharuk, A., Wilson, D. J. & Dunn, R. 2014a. A Review of the Evolution of Shared (Street) Space Concepts in Urban Environments. *Transport Reviews*, 34, 190-220.
- Karndacharuk, A., Wilson, D. J. & Dunn, R. C. 2013a. Analysis of pedestrian performance in shared-space environments. *Transportation research record*, 2393, 1-11.
- Karndacharuk, A., Wilson, D. J. & Dunn, R. C. 2014b. Safety performance study of shared pedestrian and vehicle space in New Zealand. *Transportation Research Record*, 2464, 1-10.

- Karndacharuk, A., Wilson, D. J. & Dunn, R. C. 2016. Qualitative evaluation study of urban shared spaces in New Zealand. *Transportation Research Part D: Transport and Environment*, 42, 119-134.
- Karndacharuk, A. A., Wilson, D. J. & Dunn, R. C. M. 2013b. Evaluating shared spaces: Methodological framework and performance index. *Road and Transport Research*, 22, 52-61.
- Lee, H. & Kim, S.-N. 2019. Shared space and pedestrian safety: Empirical evidence from pedestrian priority street projects in Seoul, Korea. *Sustainability*, 11, 4645.
- Legaspi, J., Hensher, D. & Wang, B. 2015. Estimating the wider economic benefits of transport investments: The case of the Sydney North West Rail Link project. *Case Studies on Transport Policy*, 3, 182-195.
- Loomis, J. 2011. What's to know about hypothetical bias in stated preference valuation studies? *Journal of Economic Surveys*, 25, 363-370.
- Loukopoulos, P., Jakobsson, C., Gärling, T., Schneider, C. M. & Fujii, S. 2004. Car-user responses to travel demand management measures: goal setting and choice of adaptation alternatives. *Transportation Research Part D: Transport and Environment*, 9, 263-280.
- Main Roads Western Australia 2021. Speed Zoning Policy and Application Guidelines The Government of Western Australia.
- Moody, S. & Melia, S. Shared space—research, policy and problems. Proceedings of the Institution of Civil Engineers-Transport, 2014. Thomas Telford Ltd, 384-392.
- Nasernejad, P., Sayed, T. & Alsaleh, R. 2021. Modeling pedestrian behavior in pedestrian-vehicle near misses: A continuous Gaussian Process Inverse Reinforcement Learning (GP-IRL) approach. *Accident Analysis & Prevention*, 161, 106355.
- Netto, V. M. 2018. *The social fabric of cities*, Routledge.
- Newman, P., Kosonen, L. & Kenworthy, J. 2016. Theory of urban fabrics: Planning the walking, transit/public transport and automobile/motor car cities for reduced car dependency. *Town Planning Review*, 87, 429-458.
- Northern Beaches Advocate. 2020. Showdown over Slow down. *Northern Beaches Advocate* 9/11/2020.
- Northern Beaches Council. 2020. *Community has spoken on proposed changes to The Serpentine* [Online]. Northern Beaches Council. Available: <https://www.northernbeaches.nsw.gov.au/council/news/media-releases/community-has-spoken-on-proposed-changes-to-serpentine> [Accessed 16/10/2021].
- Northern Territory Government 2020. Road Users' Handbook - Your guide to safely sharing the roads in the Northern Territory
- NSW Government. 2014. *NSW Road Rules 2014* [Online]. NSW Government,. Available: <https://legislation.nsw.gov.au/view/html/inforce/current/sl-2014-0758> [Accessed 12/09/2021].
- NSW Government 2018a. Future Transport Strategy 2056.
- NSW Government 2018b. Road Safety Plan 2021.
- NSW Government 2020. Practitioner's Guide to Movement and Place - Implementing Movement and Place in NSW. In: DEPARTMENT OF PLANNING INDUSTRY AND ENVIRONMENT (ed.). Sydney, Australia: NSW Government,.
- NSW Government. 2021. *Towards Zero: Safe System* [Online]. NSW Government. Available: <https://towardszero.nsw.gov.au/safesystem> [Accessed 15/11/2021].
- Pascucci, F., Rinke, N., Schiermeyer, C., Berkahn, V. & Friedrich, B. 2017. A discrete choice model for solving conflict situations between pedestrians and vehicles in shared space. *arXiv preprint arXiv:1709.09412*.
- Pascucci, F., Rinke, N., Schiermeyer, C., Friedrich, B. & Berkahn, V. 2015. Modeling of shared space with multi-modal traffic using a multi-layer social force approach. *Transportation Research Procedia*, 10, 316-326.
- Pearson, R., Philp, S. & Hoyle, S. Delivering shared-space schemes: two case studies from Bournemouth, UK. Proceedings of the Institution of Civil Engineers-Municipal Engineer, 2019. Thomas Telford Ltd, 197-208.

- Peter Fell. 2019. *Wairepo Swamp Walk, Kingsland, Auckland - Case Study* [Online]. Available: <https://www.peterfell.co.nz/wairepo-swamp-walk-kingsland-auckland/> [Accessed 20/10/2021].
- Pharaoh, T. M. & Russell, J. R. 1991. Traffic calming policy and performance: The Netherlands, Denmark and Germany. *The Town Planning Review*, 79-105.
- Pogonyi, C. G. 2020. The wider economic benefits of transportation. *Standard Transport Appraisal Methods. Advances in Transport Policy and Planning*, 6, 129-164.
- Price, M. 2017. Un/shared space: The dilemma of inclusive architecture. *Disability, Space, Architecture*. Routledge.
- Reid, S., Kocak, N. & Hunt, L. 2009. Dft Shared Space Project - Stage 1: Appraisal of Shared Space.
- Rinke, N., Schiermeyer, C., Pascucci, F., Berkhahn, V. & Friedrich, B. 2017. A multi-layer social force approach to model interactions in shared spaces using collision prediction. *Transportation research procedia*, 25, 1249-1267.
- Royce, B. 2017. Pedestrianised 'Shared Spaces' Auckland CBD - An operational and safety review. *IPENZ Transportation Group Conference*. Hamilton, New Zealand
- Ruiz-Apilánez, B., Karimi, K., García-Camacha, I. & Martín, R. 2017. Shared space streets: design, user perception and performance. *Urban Design International*, 22, 267-284.
- Shore, F. & Uthayakumar, K. 2010. Designing the Future - Shared Space: Operational Assessment.
- Silva, P. 2016. Tactical urbanism: Towards an evolutionary cities' approach? *Environment and Planning B: Planning and design*, 43, 1040-1051.
- South Australian Active Living Coalition 2012. Streets for People: Compendium for South Australian Practice.
- State Government of Victoria. 2017. *Road Safety Road Rules 2017* [Online]. Available: <https://www.legislation.vic.gov.au/in-force/statutory-rules/road-safety-road-rules-2017/009> [Accessed 30/09/2021].
- State of Tasmania. 2019. *Road Rules 2019* [Online]. Tasmanian Government. Available: <https://www.legislation.tas.gov.au/view/html/inforce/2019-12-01/sr-2019-061> [Accessed 20/10/2021].
- The North Sea Region Programme Secretariat. 2009. *Shared Space - Reconciling people, places and transport* [Online]. Available: <http://archive.northsearegion.eu/iiib/projectpresentation/details/&tid=14&theme=3> [Accessed 15/09/2021].
- Tooby, D. Shared Space Performance Analysis, Port Macquarie NSW.
- Transport Canberra and City Services 2019a. Active Travel Facilities Design - Municipal Infrastructure Standards 05. ACT Government.
- Transport Canberra and City Services 2019b. Street Planning and Design - Municipal Infrastructure Standards 01. ACT Government.
- Transport for NSW 2012. Shared Zones NSW Government.
- Transport for NSW 2016. Design and implementation of shared zone. NSW Government.
- Turner, R., Kamel Ahmed, E. & Ramadan, A. 2020. Confronting the Conundrum of Shared Space Street Design.
- Veith, G. & Bennett, D. 2006. *Austrroads Guide to Road Design: Part 1 - Introduction to Road Design*, Austrroads.
- Vicroads 2015. Supplement to Austrroads Guide to Traffic Management: Part 8 - Local Area Traffic management (2008). Department of Transport Victoria.
- Vicroads 2017. Traffic Engineering Manual - Speed Zoning Guidelines. State Government of Victoria.
- Wang, X., Zhou, Q., Quddus, M. & Fan, T. 2018. Speed, speed variation and crash relationships for urban arterials. *Accident Analysis & Prevention*, 113, 236-243.
- Wargo, B. W. & Garrick, N. W. 2016. Shared Space: Could Less Formal Streets be Better for Both Pedestrians and Vehicles?
- White, M., Paay, J., Dia, H., Yang, T., Langenheim, N. & Woodcock, I. 2021. Exploring balance between movement and place in designing safe and successful places.