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CHAPTER ONE

INTRODUCTION

Although the terms ‘road’ and ‘street’ are sometimes used interchangeably, a road can be distinguished from a street in the sense that the primary function of roads are essentially for the movement of motor vehicles whereas streets are usually more urban in nature and need to accommodate more diverse functions, including movement, place and community. The UK’s *Manual for Streets* gives a definition of a street as “a highway that has important public realm functions beyond the movement of traffic” (Department for Transport [DfT], 2007). This relatively recent attempt to categorise a public thoroughfare by emphasising ‘other’ functions of a street epitomises a fundamental change in the way public roads and streets are to be designed and operated, particularly in an urban built environment.

The shared space concepts in the literature mainly fall within urban design disciplines that deal with the uses and appearances of urban public space. The distinctiveness of a shared space in comparison to typical urban public spaces is that it embraces the design and management of vehicular activities (with relatively low operating speeds), and socially integrates various aspects of space users within the road transport system. The definition of urban design in accordance with the New Zealand Urban Design Protocol (Ministry for the Environment [MfE], 2005a; 2005b) is as follows;

*Urban design is concerned with the design of the buildings, places, spaces and networks that make up our towns and cities, and the ways people use them. It ranges in scale from a metropolitan region, city or town down to a **street**, public space or even a single building. Urban design is concerned not just with appearances and built form but with the environmental, economic, social and cultural consequences of design. It is an approach that draws together many different sectors and professions, and it includes both the process of decision-making as well as the outcomes of design.*

The use and design of the public (street) space in towns and cities has been increasingly scrutinised by the public, particularly by urban designers and transport planners alike. This is evident in New Zealand by the growing number of signatories to the New Zealand Urban

Design Protocol (MfE, 2010), together with a number of publications on transport strategies and policies that promote enhanced street environments and improved pedestrian amenity, and encourage safe walking and cycling and the use of public transport. These documents include the New Zealand transport strategy (Ministry of Transport [MoT], 2008), government policy statement on land transport funding (MoT, 2012), *Safer Journeys* (MoT, 2010) and *Getting there – on foot, by cycle* (MoT, 2005).

Given that a public street space is statutorily defined as ‘road’ in the legislation (e.g. Land Transport and Local Government Acts) to ensure the public have the basic right of travelling from one place to another, it is not surprising to learn that many conventional approaches of transport planning and traffic engineering had in some areas focused too much on the planning and designing of the road space for motor vehicles, at the expense of other road users such as pedestrians and cyclists and other low speed ‘living, working and eating’ street users.

As a consequence, there are in the past few decades a multitude of street design approaches that aim at reducing vehicular dominance and improving the street environment for pedestrian and community interaction, including the concept of shared spaces. Positioned towards the ‘low vehicle priority’ end of the road user priority continuum, a shared space according to Mackie et al. (2013) is a public space where interactions between pedestrians and very slow vehicles are viewed as an indication of high pedestrian priority and safety (as opposed to a precursor to a crash) within a street environment. In the literature, a prominent figure in the development of a shared space concept in Western Europe is Hans Monderman (Schlabach, 2012). With a traffic engineering and road safety background, he explored the idea as a means to influence traffic speeds and driver behaviour to address transport safety issues. In the UK, another well-known advocate for pedestrian oriented schemes, who claimed to coin the term ‘shared space’, is Ben Hamilton-Baillie. He states that a shared space is a default (*status quo ante*) before the introduction of the separation of vehicles and pedestrians became an acceptable approach for designing public spaces (Hamilton-Baillie, 2006). Further, recent developments of UK shared space applications are documented in a national guideline document (DfT, 2011), which provides the comprehensive design principles and process of shared spaces, albeit with some criticism of the research findings and evaluation methodology (Moody & Melia, 2013).

1.1 Shared Space Concept in New Zealand

Even though the shared space concept where all road users (including motor vehicles, pedestrians, cyclists and the disabled) are able to legally occupy the same public road space without physical separation is relatively new to the territorial authorities of New Zealand, a shared space has had specific legal recognition as a ‘shared zone’. It is defined in the Land Transport (Road User) Rule 2004 simply as “a length of roadway intended to be used by pedestrians and vehicles”. The equal priority and behavioural expectations of different road users are clarified in the Rule as follows:

- A driver of a vehicle entering or proceeding along or through a shared zone **must** give way to a pedestrian who is in the shared zone.
- A pedestrian in a shared zone **must** not unduly impede the passage of any vehicle in the shared zone.

With the use of the word ‘must’ in the legislation, both road users (drivers and pedestrians) are obligated to be equally considerate to each other. Nonetheless, the national guideline of the *Pedestrian Planning and Design Guide* (NZTA, 2009) that gives a brief description of a shared zone and general guidance based generally from overseas experience and observations, advises a shared zone should operate as a pedestrian priority space in order to create an ‘environment of care’ with the significant reduction of vehicular dominance.

In addition, a form of shared spaces in a mixed-use urban centre is identified in the 2010 version of *Land Development and Subdivision Infrastructure* (Standards New Zealand, 2010), which provides a standard for design and construction of land development and subdivision infrastructure. The document recognises both place and movement (link) functions of a public street together with a corridor function for utility and amenity infrastructure. Extracted from this Standard, a typical plan and cross section of shared spaces is illustrated in Figure 1.1.

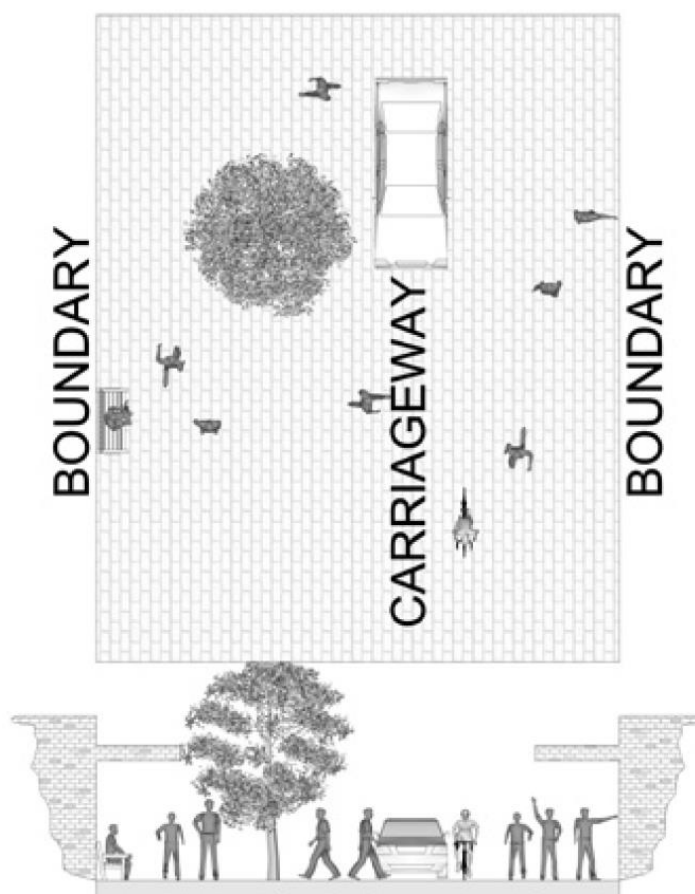


Figure 1.1 Shared space typical plan and cross section
(Source: Standards New Zealand, 2010).

Furthermore, the value of shared space design and implementation in enabling enhanced pedestrian experience, improved urban public space and a sense of place in Auckland's activity centres, is recognised in the Auckland Plan as well as the City Centre Master Plan (CCMP). Both formally launched in 2012, the Auckland Plan is a 30-year spatial plan for Auckland with a vision to become the world's most liveable city (Auckland Council, 2014a) while the CCMP is a 20-year vision for Auckland's city centre to become the cultural, civic, retail and economic heart of the city (Auckland Council, 2014b).

1.1.1 Embracing the Shared Space Concept in Auckland

Auckland Transport, established in November 2010 by combining the transport functions and operations of the previous eight local and regional councils and the Auckland Regional Transport Authority, is responsible for all of the Auckland region's transport infrastructure and services. As a Council Controlled Organisation, it inherited a number of shared space schemes from the legacy councils. They were in different stages of development, varying from planning, preliminary and detailed design, under construction to fully implemented.

This doctoral research had the support of Auckland Transport in order to advance the knowledge and understanding of a shared space performance evaluation, and to provide better consistency in the applications of the concept in the Auckland region.

It was in 2009 when the previous Auckland City Council officially embraced the concept of shared space streets by drawing on international urban design experience and knowledge from Europe, particularly the United Kingdom. The Council rigorously investigated the possibility of introducing shared space schemes in the CBD as part of a 10-year streetscape improvement programme (Auckland Council, 2009). At the commencement of this doctoral research study in 2010, there had been no public local street designed to the shared space concept, and formally declared as a shared zone in accordance with the Road User Rule in New Zealand. Practically completed in June 2011, the clusters of the following streets in the Auckland City CBD, as shown in Figure 1.2, were transformed into shared spaces:

- Elliott and Darby Streets (bounded by Victoria Street West, Queen Street and Wellesley Street West)
- Lorne Street (between Wellesley Street East and Rutland Street)
- Fort Street, Fort Lane and Jean Batten Place (bounded by Custom Street East, Commerce Street, Shortland Street and Queen Street).

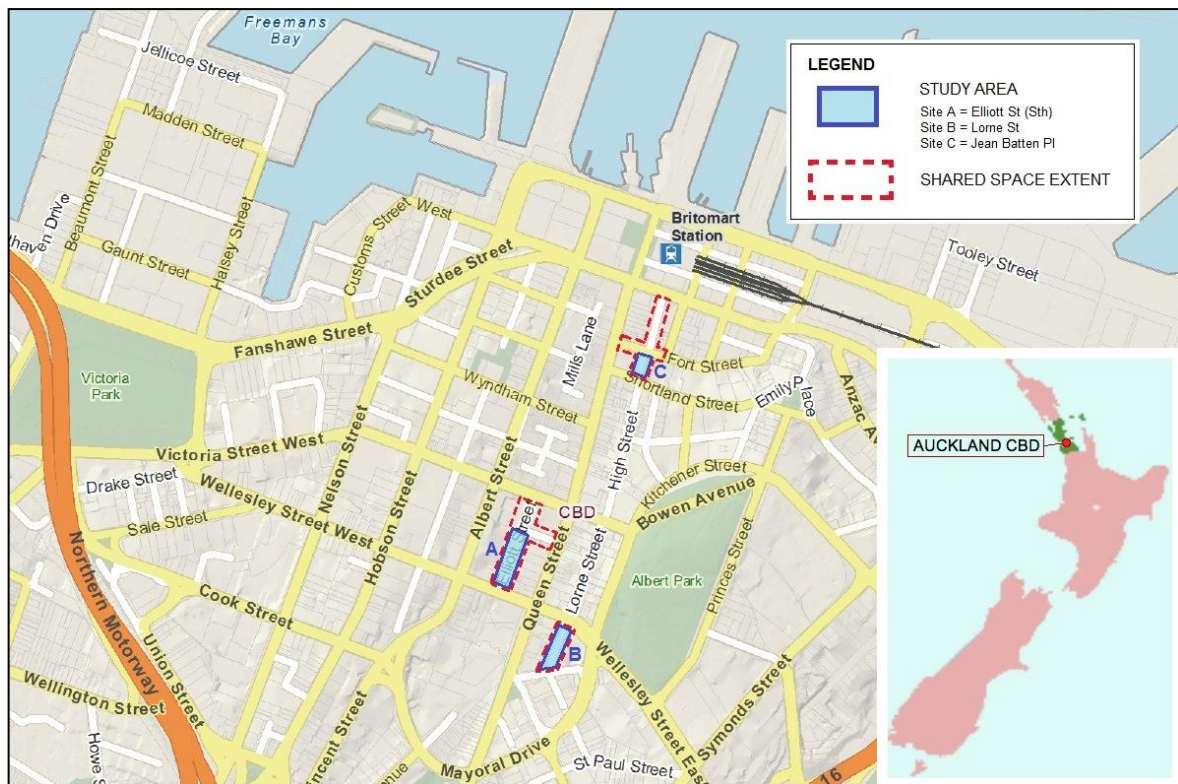


Figure 1.2 Site location (source: Auckland Council GIS Viewer).

The Rugby World Cup international event, that took place between 9 September and 23 October 2011, was considered to be a catalyst for most of these programmed projects for the CBD transformation, including the aforementioned shared space projects (Karndacharuk & Wilson, 2010). There are now several further shared spaces scheme in the city centre that are currently being designed or implemented e.g. Federal and O'Connell Streets.

It is noted that there are also a number of 'pseudo' shared spaces in Auckland (including the Wairepo Swamp Walk in Kingsland, Totara Avenue in New Lynn and Jellicoe Street in Wynyard Quarter) that were designed with some elements of a shared space (e.g. a shared surface across the whole road corridor). Despite having no legal status as shared spaces, these applications of the road user integration concept signify the increasing influence of the shared space concept in the region.

1.1.2 Challenge to Road Controlling Authority

The main challenge for Auckland Transport as a Road Controlling Authority when implementing a shared space or allowing the shared space concept to be applied within the road reserve was how to appropriately manage the safety and operational risks. This was particularly so when the concept was new to road users. This transitional period required special consideration and monitoring until behavioural change occurred and to ensure the street served the intended purpose. The uncertainty was whether the new road environment would trigger such behavioural change required for safe and integrated transport operations. Therefore, the challenges to Auckland Transport can be outlined as follows:

- A proper recognition of safety and operational risks associated with the shared space implementation that allowed for an on-going review and monitoring of the shared spaces, and, if required, mitigation measures or design interventions.
- A street design that was distinctive and context-sensitive as well as different from a conventional street, but maintained design characteristics, standardisation and integrity to achieve a level of consistency throughout the region.
- A robust method of performance measurement and evaluation that guides policy decisions towards a sustainable outcome in achieving performance objectives.

These challenges were acknowledged by the organisation, thereby forming the basis of support for this research project and collaboration. Additionally, with an increasing number

of shared space proposals, submitted to Auckland Transport for consideration, there was a need for the development of evaluation criteria for the appropriate selection and implementation of shared spaces within the New Zealand context.

1.2 Motivation for the Research

Besides the support from the regional transport authority to investigate and evaluate the urban shared spaces, the motivation for the research can be described as follows. Given that the shared space projects were in general driven by urban design objectives and values with the emphasis on place-making (including the creation of a high-quality public space to enhance the CBD environment for pedestrians), there is a need for a systematic evaluation framework that takes into account both quantitative and qualitative performance measures with appropriate consideration of transport planning and traffic engineering.

A review of relevant studies and publications in the literature reveals that little has been undertaken to thoroughly monitor, measure and evaluate the effectiveness of shared spaces, especially the comparison between ‘before and after’ implementation data. The UK Department for Transport’s publication on shared space (DfT, 2011) not only considers the scheme evaluation and monitoring as an integrated part of the holistic shared space development, but highlights the importance of performance monitoring in recording user behaviour and evaluating whether a scheme operates as planned. Furthermore, because conventional road design relied primarily on the mobility and access functions of a roadway, local authorities’ current framework, including associated data collection and monitoring schemes, in assessing the performance of a street network was principally related to the efficiency and safety of motor vehicles. Consequently, this research on the performance evaluation of shared space schemes using both quantitative and qualitative research methodologies is undertaken to address these knowledge gaps.

1.3 Problem Statements

In order to elaborate issues and gaps that this research aimed to address, the following problem statements on different aspects of a shared space evaluation were developed. It is noted that each problem statement corresponds to a thesis chapter from Chapters Two to Seven.

1.3.1 Problem One: Clarity of Shared Space Concept and Terminology

On the one hand, the term ‘shared space’ is considered a public space design philosophy. The European Shared Space project (Shared Space, 2005; 2008a) defines the term as a way of thinking with the vision to improve quality of public space based on the integration of various forms of human activity. It involves not only traffic engineering and urban design techniques on public spaces, but also planning, public consultation, and decision-making processes to seek improvements in interrelated areas of safety, congestion, spatial quality, sense of place, economic prosperity and community involvement. Many review articles and studies (Clarke, 2006; Hamilton-Baillie & Jones, 2005; Hoegh et al., 2007; Joyce, 2010; 2012; Methorst et al., 2007) attributed the original design concept to the Dutch transport practitioner, Hans Monderman who considered the role of social values in modifying road user behaviour e.g. removing standardised traffic control devices to create a sense of uncertainty within a road environment. According to Hans Monderman, a shared space is not a planning or traffic management concept but “an attitude of mind to community” (Schlabach, 2012). On the other hand, a shared space is a street design approach that aims to rebalance the place and transport functions, and between people and vehicles within a public street environment. With the use of shared (and level) surfaces, a shared street gives pedestrians more space and freedom, and removes the presumption that a driver has the right of way (Commission for Architecture and the Built Environment [CABE], 2004; 2008).

The situation is further complicated by a number of working terms that are regarded to constitute aspects of the shared space design approach (Auckland Council, 2009). These included civilised street, living street, simplified street, naked street, complete street, single surface, de-cluttering, traffic calming, encounter zone, home zone, and *Woonerf*. In addition, considering the different urban land uses, Shearer (2010) discusses a set of prescriptive design features of residential, inner city and main streets for New Zealand shared spaces. Even though the UK local transport note (DfT, 2011) offers a definition of shared spaces, without an assertion of an area within the public road corridor, any town square, recreational reserve or even private parking area could as well be recognised a shared space as.

1.3.2 Problem Two: Methodological Evaluation Framework

As discussed in Section 1.2, a comprehensive analysis framework using both quantitative and qualitative measures to evaluate shared spaces was identified as a research gap. While comprehensively reviewing a number of ‘simplified streetscape’ schemes in continental Europe in order to inform shared street designs in the UK context, Quimby and Castle (2006) conclude that there has been little systematic evaluation of the effects of shared space streets based on reported crashes and public attitudes. Additionally, it is noted by Besley (2010) that the difficulty for local authorities in the UK is to undertake thorough evaluation, particularly without capturing ‘before’ data due to a wide range of objectives and the lack of resources.

Without an adequate consideration of the placemaking objective, the majority of the schemes that were subject to a performance evaluation are based on limited performance indicators, including vehicular traffic data and reported crashes. More importantly, the reliability of the outcomes is exacerbated by, as discussed in Section 1.3.1, the lack of a clear definition and the established objectives of the shared spaces.

1.3.3 Problem Three: Quantitative Measurement of Pedestrian Performance in a Shared Space Environment

As discussed earlier, many studies (Department of Transport, Planning and Local Infrastructure [DTPLI], 2012, Edquist & Corben, 2012; Noordelijke Hogeschool Leeuwarden [NHL], 2007, Quimby & Castle, 2006) on the evaluation of shared streets primarily utilise vehicle-related indicators for performance measurement, particularly from a road safety perspective. Although quantitatively measuring pedestrian counts and interactions, a UK study (DfT, 2010a) that informs the national shared space guideline, arbitrarily selects the area and time for data analysis. It is therefore questionable whether the pedestrian data analysed is representative of the actual demand and scheme performance, especially, when comparing such random data across the study areas. Moreover, other evaluation studies were unable to collect and analyse the pre-implementation data (Auckland Council, 2012; Bliet, 2010; DfT, 2010a), or were undertaken absent of the measurement of ‘sojourn’ pedestrian activity that is the main indicator of the placemaking objective (NHL, 2007; Royal Borough of Kensington and Chelsea [RBKC], 2012; Tooley, 2009).

1.3.4 Problem Four: Safety Study and Performance of Shared Spaces

Provided that a road user interaction or potential conflict occurs in a very low operating speed environment, it is hypothesised in this study that more pedestrian-vehicle interactions in a shared space will result in a safer street environment. This is, however, fundamentally in opposition to the accepted theory of a continuum of traffic events (Svensson & Hyden, 2006; Lareshyn et al., 2010) where there is a strong relationship between interactions, conflicts and crashes. Even though Kaparias et al. (2013) developed a Pedestrian-Vehicle Conflict Analysis (PVCA) method based on severity factors (e.g. time to collision and characteristics of evasive action) to classify conflict severity, the analysis method filters out the potential conflicts (interactions) and does not determine who has priority in the interactive events. The PVCA process is therefore unable to assess whether a shared space implementation would improve pedestrian priority in the event of pedestrian-vehicle interactions - nor does a recently developed behavioural analysis of pedestrian-vehicle interactions (Kaparias et al., 2014) addresses this issue.

1.3.5 Problem Five: Qualitative Assessment of Perception Surveys

While reviewing the benefits and problems associated with shared spaces in the context of Australia's built environment, Gillies (2009) identifies a need for in-depth studies of qualitative outcome of existing shared spaces. Subsequently, there are a few performance studies undertaken to qualitatively measure the perception of pedestrians and drivers as well as residents. They are primarily based upon case studies in the UK (for instance, Biddulph, 2010; 2012b; DfT, 2010b; Kaparias et al., 2012a).

Given that this research established the five objectives of shared space implementation within a new methodological framework, there is a need to design a qualitative assessment that is specific to this performance evaluation process for the shared space study areas as well as a control site of a conventional street.

1.3.6 Problem Six: Determining the Overall Success of a Shared Space

There are no studies in the literature on the shared space performance measurement that holistically evaluates shared space schemes via a multi-criteria analysis technique that take into account both quantitative and qualitative performance indicators. This will enable not only a new or existing scheme to be evaluated against a standard baseline, but also an

ability to determine the importance (weight) of each objective or Key Performance Indicator (KPI) in contributing to the overall success of a shared space implementation.

1.4 Research Goal and Objectives

The goal of the research is to develop a multi-faceted evaluation framework of shared spaces that takes account of the place and transport functions of a public street to enable the measurement of social, economic and engineering factors that determine where shared spaces are effective and where they are not.

Subsequently, the specific research objectives can be outlined as follows:

1. To firmly establish the origin and evolution of the shared space concept by reviewing the literature in relation to shared spaces, including design and planning for built environments, road design, safety and transportation engineering;
2. To better determine the definition of a shared street space in a mixed-use environment by taking into account the multi-functions of a public urban street, especially the sense of place;
3. To elaborate and establish the place function in an urban street design and performance evaluation process in recognition of the area within and outside of the road reserve;
4. To design an appropriate data collection process based upon a multi-faceted evaluation framework, including the identification of shared space objectives and Key Performance Indicators;
5. To implement a quantitative methodology in collecting and analysing 'before and after' data with an emphasis on pedestrian performance;
6. To quantitatively devise and put to the test a safety performance analysis of a shared space scheme by examining pedestrian and vehicle conflicts and interactions;
7. To develop and implement user perception surveys in order to qualitatively measure and compare shared space performance based on the shared space objectives;
8. To analyse both quantitative and qualitative data using the Analytical Hierarchy Process to determine the overall effectiveness of shared spaces;

9. To develop a practice-ready design guideline that can be used to inform shared space design and implementation.

For each objective, the outcomes achieved in this research study are discussed and summarised in the Contributions to Knowledge section of Chapter Eight.

1.4.1 Scope of the Research

This research focused on the data collection and analysis of the following three shared space projects in Auckland City's Central Business District (CBD) in New Zealand. Figure 1.3 shows the location of the three case studies in relation to the surrounding land use zones in accordance with the Proposed Auckland Unitary Plan (Auckland Council, 2014c).

- a. Elliott Street (between Darby Street and Wellesley Street West)
- b. Lorne Street (between Wellesley Street East and Rutland Street)
- c. Fort Street (between Queen Street and Commerce Street), including Jean Batten Place and Fort Lane.

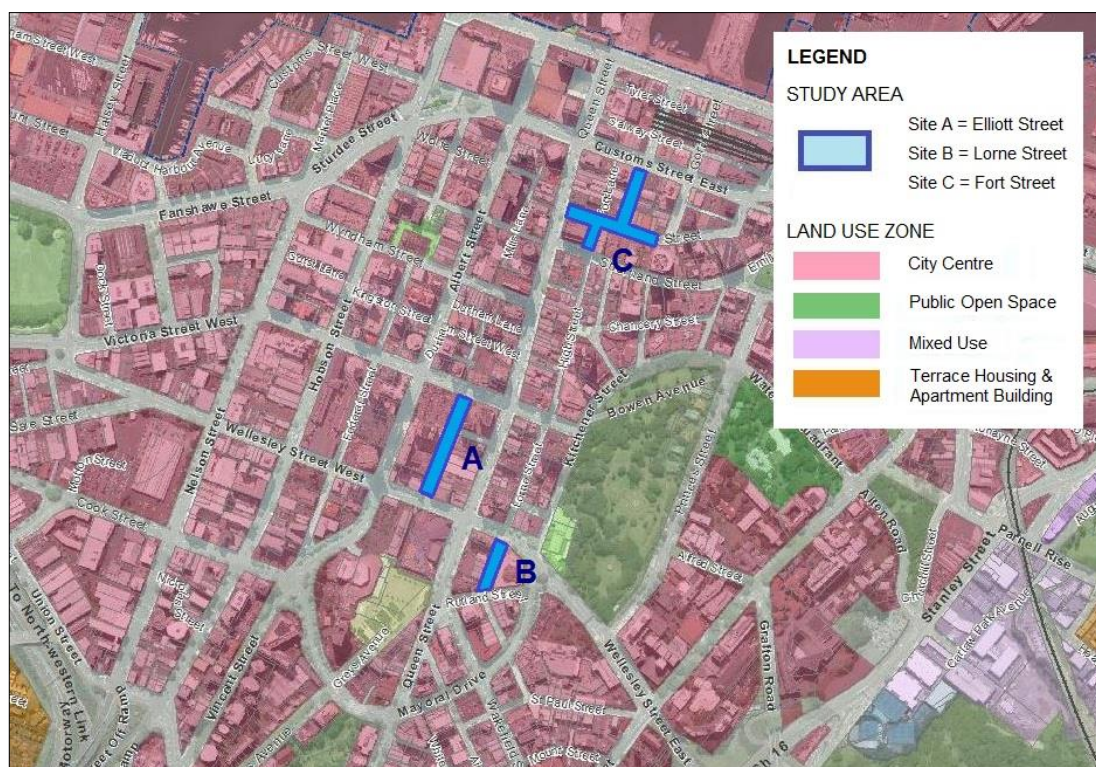


Figure 1.3 Three shared space case studies (Source: Auckland Unitary Plan GIS Viewer).

The three shared space schemes were initiated and designed by the then Auckland City Council, which has been amalgamated with other local and regional councils to form a

single Auckland Council for the region. The urban public streets are now managed and maintained by Auckland Transport. The international event of the Rugby World Cup that was hosted in Auckland in 2011 was considered a catalyst for the above projects as part of a wider Auckland CBD transformation exercise.

Being an employee of Auckland Transport, which is an Auckland Council Controlled Organisation, allowed the author to access council database and an accurate programming of the shared space projects, together with obtaining the organisation's strategic transport plans and policies and internal traffic safety and operational information

1.4.2 Resource Requirements

This section records the resources utilised in completing the research project. Appendix B presents pictorially the equipment employed in the qualitative data collection, including the video cameras and traffic counters.

Access to Software and Database

Auckland Transport (AT) and the University have access to New Zealand Transport Agency (NZTA)'s Crash Analysis System (CAS), which contains vehicular traffic crashes reported by the New Zealand Police and related crash factor data. Vehicular traffic data at the signalised intersections surrounding the sites was extracted from the SCATS (Sydney Coordinated Adaptive Traffic System) via AT and NZTA's Joint Transport Operations Centre. Additionally, the licence for the statistical software package IBM SPSS for Windows and the software package NVivo 10 was provided by the University.

Cameras, Computer and Central Box

For the video surveys of the three sites, four Axis cameras were used. A computer was required for storing data collected from the video surveys, compiling research related documents and analysing the data. The central box, used in a video survey, contained a network switch and a 12-volt power hub. The network switch was used to combine the data from all cameras and feed it into the computer. The power hub was for power supply, which was linked to a power source inside an adjacent building.

Human Resources

Technical staff (Electrical, IT, materials and equipment) from the Transportation Research Group was allocated to assist in the development of the data collection methods, including the video survey and camera installation.

Traffic Tube Counter

With support from Auckland Transport, the vehicular traffic surveys were undertaken using MetroCount Roadside Unit at approximately the same period as the video surveys to measure traffic volume, speed and composition.

1.5 Organisation of the Thesis

This thesis documents the research work undertaken to achieve the established goal and objectives described in the previous section of this chapter. At its core, the thesis contains a series of published journal articles (Chapters Two to Five) and working papers (Chapters Six and Seven) that for all intents and purposes are in a suitable state for a journal submission. As outlined in Table 1.1, main thesis elements are presented with regard to their contents, relevant research problems and associated contributions.

Chapter Two documents a comprehensive review of the literature of the shared space concepts and a comparative performance analysis of New Zealand and international shared space schemes. Chapter Three outlines the multi-faceted evaluation framework, including the place function of an urban street, shared space objectives and key performance indicators. Quantitatively, Chapter Four presents a detailed analysis of pedestrian related performance, and Chapter Five outlines the details of a road user interaction and conflict study in the context of before-and-after evaluation. Chapter Six discusses the qualitative evaluation process, using the user perception surveys. Chapter Seven contains the details of a new multi-faceted evaluation framework using the Analytical Hierarchy Process to determine an overall performance index. Finally, a research summary, contributions and proposed future research are presented in Chapter Eight. The thesis is concluded by a list of references and appendices.

Table 1.1 Thesis structure.

Thesis Element	Content	Related Problem	Related Contribution
Chapter One	Research background, broad challenges, motivation for the project, research problems, goal & objectives, thesis structure	-	-
Chapter Two	Review of the literature on the topics of urban street functions, road user integration, shared & calmed streets, shared spaces in theory & practice, and terminology & definition	1.3.1	8.2.1 & 8.2.2
Chapter Three	Presentation of an evaluation framework, place function of urban streets, shared space objectives, key performance indicators, data collection & analysis process, and a quantitative analysis of pre-implementation data	1.3.2	8.2.3 & 8.2.4
Chapter Four	Presentation of a quantitative analysis of pedestrian performance in the three case studies, vehicular data analysis and a relationship between pedestrian density and vehicle speed.	1.3.3	8.2.5
Chapter Five	Presentation of a quantitative analysis of safety performance of the Elliott Street shared space, Road User Interaction and Conflict Study (RUICS), and correlation between pedestrian-vehicle interaction and vehicle operating speed	1.3.4	8.2.6
Chapter Six	Presentation of a qualitative analysis of user perception survey, including on-street questionnaire and expert interview, and a performance comparison with a control site	1.3.5	8.2.7
Chapter Seven	Presentation of an analysis of a multi-faceted evaluation framework based on the 2013 post-implementation data, the implementation of Analytical Hierarchy Process (AHP), and performance index	1.3.6	8.2.8
Chapter Eight	Description of research findings, conclusions, contributions and recommendations for future works	-	-
Bibliography	List of references	-	-
Appendices	Documentation of research publications and presentations and data collected from both quantitative & qualitative performance evaluation process	-	8.2.1 - 8.2.9

CHAPTER TWO

LITERATURE REVIEW

This chapter presents a critical review of the literature on shared space concepts in the context of the road user integration philosophy. By reviewing the literature in the disciplines of both transportation engineering and urban design, the origin and evolution of the concepts can be firmly established. A comparative analysis of shared spaces between New Zealand and international case studies highlights not only the importance of street design with no obvious segregation between pedestrians and vehicles, but also the need to promote pedestrian and cycling activity, and to utilise the road space as a place in order for a public street to function as a genuine shared space for all road users.

Contents of this chapter are published in *Transport Reviews: A Transnational Transdisciplinary Journal* (Karndacharuk, Wilson, & Dunn, 2014a), and adapted for coherent expressions in this thesis.

2.1 Introduction

The notion of different street users sharing the same public road space is not new. However the idea of encouraging the mixing of slower-speed, smaller-mass pedestrians or cyclists with higher-speed, larger-mass vehicles is novel, particularly after the pinnacle of widespread automobile domination in the automobile era of the twentieth century and previous objectives of separating vulnerable road users from vehicles. The road user integration idea can be traced to Buchanan's environmental area philosophy and further developed in the Netherlands in the form of the residential shared space (*Woonerf*) concept (Karndacharuk, Wilson, & Dunn, 2013b). The renewed interest in the shared space concept, one of many integrated street design approaches, reaffirms the multi-faceted functions of a public street, including the 'place' function as well as the shifting of public demand and expectations away from auto vehicles towards sustainable and safe transport for all users.

The shared space concept in recent literature (Biddulph, 2010; 2012a; Hamilton-Baillie, 2008a; 2008b) mainly falls within the disciplines of urban design and planning that deal with the uses and appearances of urban public space. The distinctiveness of a shared space in comparison to typical urban public spaces is that it embraces the design and management of vehicular activities (with relatively low operating speeds), and socially integrates various aspects of space users within the road transport system. Nevertheless, such space is typically defined as 'road' to ensure the public have the basic right of travelling from one place to another. A public space in the context of a shared space is an area situated exclusively within the road reserve. It differs from the term 'public realm', commonly used in urban design and landscape architecture disciplines because the 'public realm' definition also includes open spaces, town centres and parks outside of the road reserve.

Figure 2.1 illustrates different fields of knowledge that contribute towards the development of built-up environments within and outside the road reserve. The emerging field of urban design has interests in all urban areas whereas the focus of transportation engineering and planning is mainly on the public area within the road reserve. Transport engineering traditionally has been accommodated largely within the civil engineering discipline because of the origin in road and pavement construction, and later in vehicular traffic management. The need for multi-disciplinary professions to work together in the development of transport corridors and surrounding land uses to achieve an integrated solution is also signified in Figure 2.1. The inclusive and collaborative approach in the design and use of public (road) space, particularly for the vitality of neighbourhoods, towns and cities, has long been argued by many authors (Appleyard, Gerson, & Lintell, 1981; Gehl, 1971; Jacobs, 1961; Robinson, 1971). In recent times, the importance of establishing a multidisciplinary team as part of transport planning and the delivery process cannot be overemphasised as reflected in many transnational publications (Austroads, 2009a; DfT, 2011; Institute of Transportation Engineers [ITE], 2010).

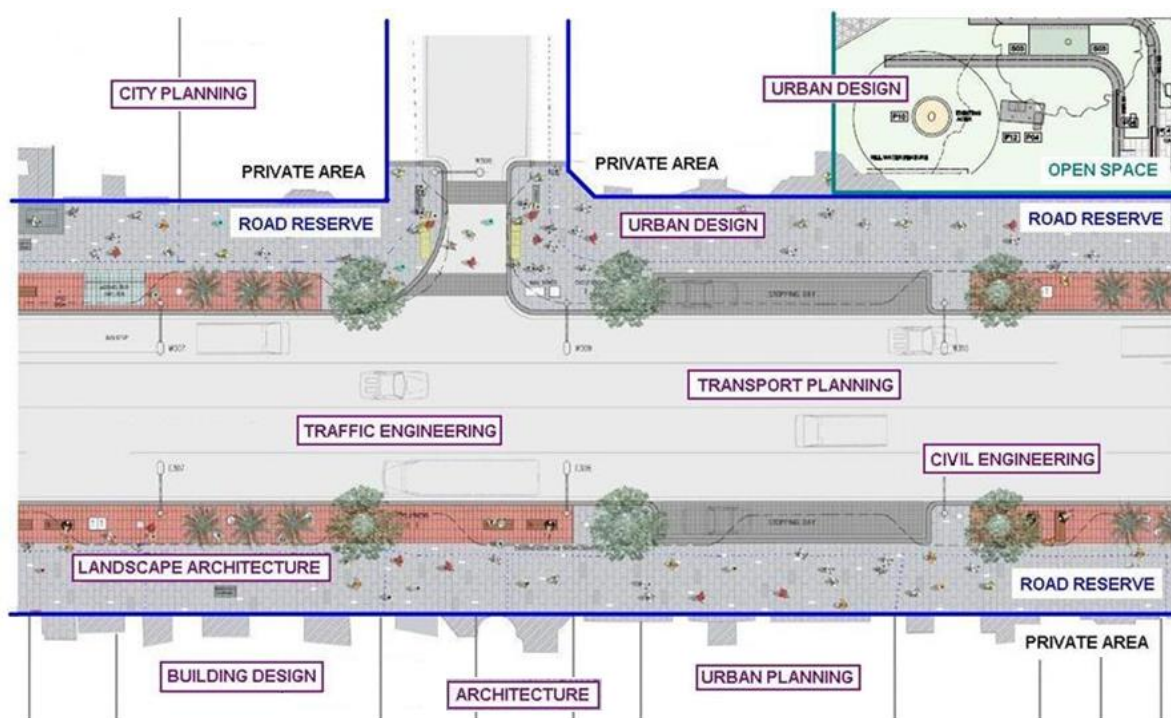


Figure 2.1 Multidisciplinary knowledge within and outside the road reserve in urban areas.

With the multiple disciplines required for successful urban street design, it is concerning to learn that the traffic engineering profession is often singled out by shared space advocates (for example, Hamilton-Baillie, 2008a, p.132) for criticism, especially with respect to the design and planning for motor vehicles based on the segregation principles – that in essence contradicts the integration idea of the shared (street) space concept. This literature review chapter discusses some of these issues, and is subsequently structured as follows:

- Section 2.2 briefly outlines the value of urban street to recapitulate the use and function of a public road space that reflects the changing public expectations over time, particularly during the twentieth and the twenty first century. This section also provides a background on the prevailing public discourse of the automobile in the period during which the concepts for the integration of motor vehicles and pedestrians began to transpire.
- Section 2.3 discusses how shared space concepts fit in a wider spectrum of the road user integration philosophy. The nature of a public street designed for integrating all road users, and ‘moderating’ the impact of motor vehicles has evolved over time since the 1960s with various approaches being created, including traffic calming measures, self-explaining roads and context-sensitive solutions.

- Section 2.4 offers from a New Zealand perspective a review of shared streets both in practice and in theory, including terminology and definition. The comparative analysis between New Zealand and international designs and implementation is conducted using an Auckland scheme as a reference case.
- Section 2.5 provides the summary and conclusion of this chapter along with presenting key design elements that constitute a shared street space with an overall goal of adding value to the literature.

The terms ‘shared space’, ‘shared street’ and later in the chapter ‘shared zone’ are used interchangeably within the context of public street design.

2.2 Urban Street Value and Changing Public Expectation

The purposes, design and use of the public urban space between private property boundaries has evolved over time in response to the demand of predominant users. The process of designing and redesigning most urban streets is subject to a series of negotiations and compromises. Studies on urban design and planning (Barnett, 1982; Krier, 2003; Spreiregen, 1965) identify the significance of streets as the framework of public open space and the basic structure of urban forms. Streets surround a city block, which is the fundamental component of every urban structure. Investigating a spatial and physical composition of towns and cities, Krier (2003) describes the nature of a street network from being finely meshed and permeable in the urban centre, loosening up and widening out in the suburb. Additionally, while analysing the form and public image of three American cities, Lynch (1960, p. 96) proposes that the visual hierarchy of streets and paths is the skeleton of the city image. The unique characteristics of any street are derived from the integration of social, political, technical and artistic forces that generates a city form (Celik, Favro, & Inersoll, 1994). Therefore, urban streets reveal a city’s history, urban form and societies that have created them.

The dominating functions of urban streets reflect what society expects in a certain period of time. In addition to the function of providing access to a building in a city block, a street, since the classical era, has served functions of both movement and place for various groups of pre-automobile users; both travellers and street occupiers. In the pre-automobile modern period, when considering streets as public open space, Haussmann’s renovation of Paris

implemented during the 1850s to 1870s stands out. Although believed to serve the military ends in supporting troop mobility and keeping the citizens from erecting barricades, a street network of wide boulevards were put together in such an influential way with the major purpose of traffic movement (Barnett, 1982). Consequently, it can be seen the primary purpose of a street has mainly been the movement of people and goods. Summed up by Krier (2003), the width of streets was determined by the speed and manoeuvrability of the carts and carriages together with traffic volumes. With increasing crowding of population and economic activity in city centres, Owen (1966) argues that as early as at the turn of the twentieth century urban traffic congestion (with the use of horse-drawn buses, trucks and electric cars) was bad before the automobile made it worse.

Given that Carl Benz invented one of the very first modern cars in 1885 (Glancey, 2006), it is interesting to see how society changed its demands and expectation on the functions of streets over the twentieth century, and how the automobile influenced the design, and dominated the use of urban space. When the prices of cars were lowered due to mass production on the assembly line, the inherited road infrastructure was found to be inadequate (especially the pavement surface) to cater for the higher speed of automobile traffic (Volti, 2004). The dominance of the automobile along with the decline of railroads and mass transit began after World War I, and exponentially increased after the Second World War (Homburger, 2002). Cities were soon rebuilt to provide more room for vehicular traffic. Norton (2008) examines the influence of the automotive industry (e.g. manufacturers, dealers, operators and auto clubs) from the mid-1920s in America as a cohesive social group that advocated major road construction projects to resolve urban transportation problems. The cohesiveness of the *Highway Establishment* in the United States is echoed in Robinson's work (1971). Similar situations happened in Great Britain where the British Road Federation aimed for the fullest possible provision for motor traffic (BRF, 1964) as well as in Australia where the *Motor Lobby* exerted its influence to ensure road space was allocated to the needs for the automobile (Davison & Yelland, 2004). It was when motor vehicles became affordable to the middle-class population from the 1940s that people via public policies on urban transport planning in the United States and the United Kingdom began planning additional road infrastructure capacity. The policies aimed to address growing traffic congestion and predicted traffic growth. Furthermore, Homburger (2002) alludes to this growing public demand when describing the change of emphases for the transportation engineering profession over the fifty-year period after the 1950s. In the

early days, the major concerns and design criteria were traffic mobility and increasing road safety, and mobility was commonly understood as the movement of the motor vehicle. It is therefore obvious that any political decisions on transport policy, planning and infrastructure investment for the most part of the twentieth century mirrored contemporary public demands and interests (cf. exclusively driven by street design standards and road hierarchies in traffic engineering), which resulted in urban streets being reconstructed and used as a place fundamentally for motor vehicles.

Notwithstanding a standardised, predictable environment for the movement of vehicles and the removal of institutional barriers to urban street improvement naturally shifted in favour of motorists' interests, Hebbert (2005) points to the emergence of alternative engineering design approaches due to a paradigm shift for city centre regeneration, traffic calming and the neo-traditional design at the turn of the 21st century.

2.3 Spectrum of Road User Integration Concepts

2.3.1 Traffic in Towns and Woonerf Concept

From a broad philosophical perspective, the concept of shared space in the context of road user integration can be traced back to the introduction of environmental areas in the *Traffic in Towns* in the 1960s (Ministry of Transport [MoT], 1963), published in the backdrop of forecasted massive growth of car-ownership at a relatively early stage of the Motor Age in Britain. Commonly known as the Buchanan Report in the United Kingdom, the study approach used in the report was prominent and influential to transportation engineers and planners worldwide. Besides the recognition of the problems of the through vehicular traffic in built-up environments, the studies proposed a cellular concept to describe the relationship between the road network and environmental areas. The environmental areas must be a good environment where people can live, work, shop and move around on foot in a reasonably safe and comfortable manner. The road network should be designed to suit the capacity of the areas, and to serve the environmental areas, not vice versa (MoT, 1963). Based on the cellular concept local distributors or access roads would incorporate shared spaces where the road space not only serves the functions of mobility and accessibility (i.e. an ability to access adjacent land-use activities), but also functions as a destination or a place to stay and move around within an environmental area.



Contrary to interpretation by many authors (Hamilton-Baillie, 2004; 2008a; Kaparias et al., 2010; 2012b; Moran, 2006) that segregation is supported in the Buchanan Report for the multi-functional urban streets, Buchanan et al. (MoT, 1963) propose an idea that mixed use between pedestrian and vehicle is viable in a safe manner within certain capacities of the environmental area. The Buchanan Report is instrumental in the development of the *Woonerf* concept and subsequently the traffic calming concept (Banister, 1991; Clayden, Mckoy, & Wild, 2006). Further, as pointed out by Ben-Joseph (1995), Buchanan is in fact considered the ‘father of traffic calming’ in the Netherlands and Germany.

Nonetheless, the Buchanan Report did not offer any practical discussion on how an urban street could be utilised for mixed use of vehicles and other users, nor what form a shared street should take. Instead, the design approach identified in the Report to tackle the urban traffic problem was primarily based upon large-scale planning and redesign of cities or towns by integrating land use (buildings) with transport corridors (traffic). An ideal scenario proposed in the report was an expensive, arguably impractical redevelopment of a superblock in urban areas with a complete segregation between motor vehicles and pedestrians. For example, in a case study of a central metropolitan block in Newbury, the movement of vehicular traffic would be provided at ground level via a newly created one-way hexagonal system of distributors whilst a pedestrian circulation system is set above the traffic (MoT, 1963, pp. 133-143). It is therefore not surprising that subsequent road design guidelines (British Road Federation [BRF], 1964; MoT, 1966) along with practitioners and researchers (Hamilton-Baillie, 2004; Hamilton-Baillie & Jones, 2005; Moran, 2006; Pharoah, 1993) interpret the Report’s aim at essentially supporting the separation concept, and advocating a complete segregation between the pedestrian and motor traffic. With national policies of increasing road building at the time, the idea of road user integration failed to gain acceptance by British policy makers and transport planners alike (Ben-Joseph, 1995).

There were a number of similar concepts in the early and mid-twentieth century that promoted better street and neighbourhood planning with high environmental quality of transport corridors. Whilst these concepts included restrictions on vehicular traffic, they did not put forward the concept of mixing motor vehicles with other road users of lower travelling speeds (e.g. pedestrians and cyclists) within the same road space. These reported concepts are, for example, Clarence Perry’s neighbourhood unit (Goss, 1961; Johnson,

2002; Patricios, 2002) and Henry Wright and Clarence Stein's Radburn concept (McClelland, Reed, & Wallace, 2006; Schaffer, 1982). Similar to the idea of Alker Tripp's precincts (Tripp, 1942), an environmental area envisaged by the Buchanan Report is a terminus of traffic where a motor vehicle would not enter the area unless to access its destination. Further, while explaining the theoretical basis that the complete separation of pedestrians and vehicles is not practical in an environmental area, Buchanan et al. (MoT, 1963, p. 51) state that "up to a point, a mixture of pedestrians and vehicles is not seriously harmful." It is therefore fair to conclude that the environmental area principles in the Buchanan Report paved the way for the creation of the shared space concepts.

With the prevailing social presumption of the 1960s aimed at providing and prioritising for the automobile within the road space, the theoretical construct of a local transport link with multi-faceted functions in the *Traffic in Towns* was soon realised via the implementation of *Woonerf* (also *Woonerven* as a plural) in residential areas in the Netherlands. The term 'Woonerf' was first coined in 1965 by Niek de Boer, Professor of Urban Planning at the University of Emmen (Nio, 2010). Generally translated as 'residential yard', the first experiment of the *Woonerf* idea was undertaken in the late 1960s by the Planning Department of Delft, consisting of Joost Vahl and colleagues, to integrate vehicular traffic into social residential space (Hass-Klau, 1990). Standardised road signage, marking, kerbs and barriers were removed in order for the integration of traffic and residential activities, and to promote pedestrian movement. With the success in Delft, the *Woonerf* concept became widely accepted in the country. The concept was recognised by the Netherlands government in 1976 with legal status and formal traffic guidelines and regulations (Southworth & Ben-Joseph, 2003). Therefore, the shared space concept was first officially embodied in the form of a residential shared street in the Netherlands with the following typical design and operational characteristics:

- Pedestrians have priority to use the full width of the road whilst drivers are urged not to drive faster than walking speeds.
- There is little demarcation between carriageway and footpath. The entire width is often constructed in a continuous surface with special pavers.
- Through vehicular traffic is discouraged. Vehicle speeds and flows are restricted by street design (e.g. horizontal curves and the location of bollards and parking spaces).
- There are streetscape elements to encourage users to stay within the space.
- The access points to the residential shared street area are clearly marked.

The importance and implication of the *Woonerf* idea along with the philosophical influence of *Traffic in Towns* on subsequent street design concepts in response to the dominance of motor vehicles within urban areas can be demonstrated in Figure 2.2. The diagram also aims to demonstrate how the different, but comparable terms and concepts can generally be classified based on the design and use of the physical separation between vehicles, pedestrians and the adjacent land use to distinguish the shared (street) space concepts from other similar design approaches such as traffic calming and self-explaining roads. An analysis of these interrelated road space design concepts that embrace the user integration principles is presented in the following section.

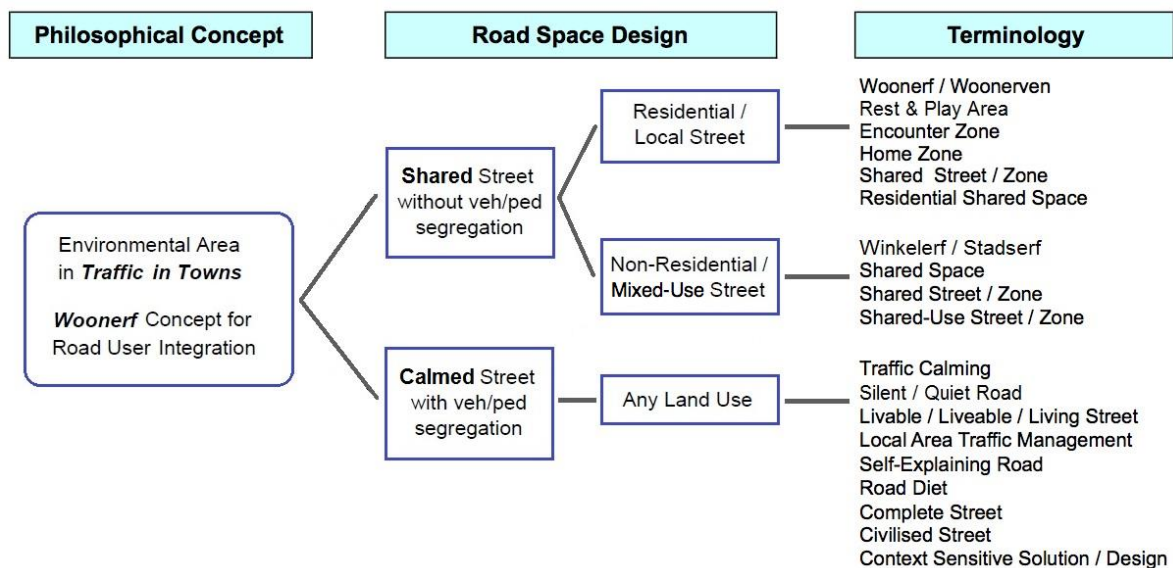


Figure 2.2 Woonerf concept and subsequent design approaches for road user integration.

2.3.2 Shared and Calmed Streets for Road User Integration

As shown in Figure 2.2, the street design approaches to integrate pedestrian social activity into the underlying transport functions of a public road space can generally be divided into two categories based on whether they were designed for the segregation between vehicles and pedestrians. Both shared and calmed streets were principally evolved from the (original) *Woonerf* concept. Even though the different concepts can be classified in theory, the design outcomes and arrangements of the same concept could differ from one jurisdiction to another. It is evident in *Woonerf* streets where the departure from a continuously paved and kerbless surface design was primarily adopted when the

implementation cost of street reconstruction was perceived to be significantly higher than the implementation of traffic calming measures and lower speed limit zones (Hass-Klau et al., 1992; Pharoah, 1993). Therefore, it is reasonable to see from the *Woonerf* case study how the terminology used to describe shared streets is shifted to partly cover, and often interchange with, calmed streets that are equipped with speed control measures and vice versa.

The similarities and differences between these concepts and how they relate to each other are further explained in Table 2.1. The table presents a summary review of the implementation of the shared and calmed streets based on the theoretical aspects of the concepts as well as their common, practical applications. The table also indicates the decades that the implementation of the concepts was documented in the literature.

In the **Shared Street** category, the *Woonerf* design features incorporate a shared surface and the use of streetscapes and on-street parking to restrict vehicle dominance. The applications of the *Woonerf* concept were also extended to town centres and shopping areas (termed *Winkelerf* and *Stadserf* in Dutch, respectively) in the late 1970s (Kraay & Dijkstra, 1989; Pharaoh & Russell, 1991). As pointed out by Pharaoh and Russell (1991, p. 82), the aim of shared surface streets was to integrate vehicular traffic and parking activity with what the Dutch call living functions and to give greater priority to vulnerable road users. Subsequently, the *Woonerf* principles from the Netherlands as early as the mid-1970s, influenced residential street design for the neighbouring European countries such as Denmark, Germany and Switzerland. Guidelines and regulations for shared streets were later adopted in many countries to enhance liveability in residential neighbourhood environments (Southworth & Ben-Joseph, 2003). In Denmark, local government authorities were able to deviate from normal traffic regulations to create ‘Rest and play areas’ where drivers must give way to pedestrians. The area has no distinction between carriageway and footpath with a 15 km/h speed limit (Russell, 1988). A *Woonerf* designed street in Germany can be referred to as a ‘Play Street’ whereas in Switzerland it is called an ‘Encounter Zone’ with a 20 km/h speed limit (Sauter & Huettenmoser, 2008).

Table 2.1 Overview of selected shared and calmed street concepts for road user integration

Terminology	Jurisdiction	Decade	Land use	Objectives	Design features	Authors' comments	References
<i>Shared Street</i>							
<i>Woonerf</i> (<i>Woonerven</i> as a plural)	The Netherlands	1960s	Residential	(1) To integrate vehicle traffic into social residential space. (2) To enhance liveability	(1) Shared, level surface with special paving across the full road width. (2) Trees, bollards and parking spaces used to restrict vehicle speeds. (3) Gateway treatment with legal signage	(1) A woonerf often referred to as a calmed street due to its main objective of calming vehicular traffic. (2) Subsequent design from the 1980s includes safety areas, exclusively for pedestrians. (3) Design speed of walking speeds with frequent traffic restraining measures. (4) Vehicular traffic subordinated to pedestrians	Ben-Joseph (1995), Hass-Klau (1990), Nio (2010), Pharoah and Russell (1991), Quimby and Castle (2006), Russell (1988) and Southworth and Ben-Joseph (2003)
<i>Winkelerf & Stadserf</i>	The Netherlands	1970s	Activity centres	(1) To improve economic viability, community interaction and quality of life	(1) In principle, same as a <i>Woonerf</i>	(1) The original Woonerf regulation was replaced by Erf regulations to reflect wider land-use applications. (2) The term 'Woonerf' applied to residential streets, 'Winkelerf' and 'Stadserf' for shared streets in shopping areas and city centres, respectively	Kraay (1986), Kraay and Dijkstra (1989), Pharoah and Russell (1991) and Quimby and Castle (2006)
Rest and Play / Shared Area	Denmark and Germany	1970s	Various, predominantly residential	(1) To improve street environments for pedestrians and playing	(1) In principle, same as a <i>Woonerf</i> where the entire road area designed for rest and play	(1) The concept emphasises no distinction between carriageway and footpath. (2) Speed limit of 15 km/h	Kjentrup and Herrstedt (1992) and Russell (1988)
<i>Begegnungszone/</i> Encounter Zone	Switzerland	1970s	Various, predominantly residential	(1) To improve street environments for pedestrians and playing	(1) In principle, same as a <i>Woonerf</i>	(1) Posted speed limit of 20 km/h	Sauter and Huettenmoser (2008)

Home Zone	UK	1970s	Residential	(1) To integrate vehicle traffic into social residential space. (2) To enhance liveability and environmental quality	(1) In principle, same as a <i>Woonerf</i> ; however many home zones do not incorporate level surface across road corridor	(1) Before the implementation of pilot home zones, traffic-calming measures were used to control vehicle speeds	Ben-Joseph (1995), Biddulph (2001, 2003), Clayden et al. (2006), DCC (1991), Hass-Klau et al. (1992) and IHIE (2002)
Shared Street	International	1980s	Residential	(1) To improve road safety. (2) To minimise environmental effects, e.g. noise and emission	(1) Similar to a <i>Woonerf</i> , with some specifying alternating vehicle path or chicane treatments	(1) Shared street design in Israel specifically incorporates a safe zone free of vehicles on either side of the shared street, which provides for the disability and other vulnerable users. (2) Design speed of 15–25 km/h	Ben-Joseph (1995), Blik (2010), Craus et al. (1993), Ichikawa, Tanaka, and Kamiya (1984), NACTO (2013) and Polus and Craus (1988, 1996)
Shared Zone	Australia and New Zealand	1980s	Various	(1) To increase safety for pedestrians and cyclists. (2) To improve public amenity	(1) In principle, same as a <i>Woonerf</i>	(1) Shared zone in Australia has a compulsory speed limit of 10 km/h while the 10 km/h speed limit in a New Zealand shared zone is optional	Austroroads (2008b, 2009b), Kamdacharuk et al. (2013b), NZTA (2009) and RMS (1987, 2012)
Shared Space	International	1980s	Various, predominantly activity centres	(1) To improve street environments and road safety. (2) To provide a better social interaction and sense of community and place	(1) In principle, same as a <i>Woonerf</i> , but design outcomes vary between jurisdictions. (2) Linear alignment of street and vehicle path often encouraged for improved legibility and urban form. (3) Emphasis on de-clutter and removal of traffic control devices (giving rise to the term 'Naked Street')	(1) Hans Monderman applied the <i>Woonerf</i> concept of integration in towns and villages. (2) Shared space concept became internationalised largely due to a European Shared Space project in the 2000s. (3) The term sometimes describes a calmed street with a focus on CSD and social interaction	DFT (2009, 2010a, 2010b, 2011), Hamilton-Baillie (2008a, 2008b), Kaparias et al. (2010), Kaparias, Bell, Miri, Chan, and Mount (2012), Kamdacharuk et al. (2013a) and Shared Space (2005, 2008a, 2008b)

(Continued)

Table 2.1 Continued

Terminology	Jurisdiction	Decade	Land use	Objectives	Design features	Authors' comments	References
<i>Calmed Street</i>							
<i>Woonerf</i> (as Traffic Calming)	The Netherlands	1970s	Residential	(1) To improve road safety, especially by vehicle speed reduction. (2) To reclaim vehicle space for other road users. (3) To improve street environments	(1) Various physical calming measures, e.g. speed humps, raised platforms, carriageway narrowings, chicanes, gateway treatments, rumble strips and change in surface material	(1) The Woonerf design evolved from a shared to calmed street with design separation between vehicles and pedestrians. (2) High cost of shared, paved street contributed to the invention of certain physical calming measures and lower speed limit areas	Ben-Joseph (1995), Hass-Klau et al. (1992), Kjemtrup and Herrstedt (1992) and Pharoah and Russell (1991)
<i>Stillevej</i> /Silent or Quiet Road	Denmark	1970s	Residential	(1) To improve residential street environments	(1) Various physical calming measures	(1) Urban roads where 'living' has priority are designed with maximum speed of 30 km/h. (2) 'Quiet Road' forms part of wider traffic calming and speed management concepts	Kjemtrup and Herrstedt (1992) and Pharoah and Russell (1991)
<i>Verkehrsberuhigung</i> / Traffic Calming	Germany	1970s	Various	(1) To improve street environments. (2) To reduce motor vehicle dominance	(1) Various physical calming measures, e.g. vertical and horizontal deflections	(1) According to Hass-Klau (1990), the traffic-calming concept initially included pedestrianisation and shared streets, and later expanded to an area-wide concept, including 20 mph (32 km/h) speed zones	Brindle (1991, 1992), Hass-Klau (1990) and Pharoah (1993)
Traffic Calming	UK	1970s	Various	(1) To reduce vehicle speeds. (2) To reallocate carriageway space for other activities. (3) To improve street environments and quality of life	(1) Various physical calming measures	(1) Policy framework for traffic calming involves classification of urban roads into living, mixed-priority and traffic areas. (2) Shared streets are included in a wider traffic-calming application	CIHT (2005), DCC (1991), Harvey (1992), Hass-Klau and Bocker (1992) and Pharoah and Russell (1991)

LATM (Local Area Traffic Management)	Australia and New Zealand	1970s	Various	(1) To improve road safety and liveability. (2) To reduce vehicle speeds. (3) To remove non-local, through traffic	(1) Various physical calming devices (e.g. chicanes and humps) and streetscape elements	(1) LATM considers neighbourhood traffic- related problems on an area- wide basis. (2) It also involves strategically social, cultural and attitudinal changes in travel behaviour. (3) Shared streets also included in LATM	Austroroads (2008b) and Brindle (1991, 1992, 1997)
Liveable/Living Street	International	1970s	Residential	(1) To improve street liveability and amenity. (2) To reduce vehicular dominance	(1) Various physical calming measures. (2) Space reallocation for community activity and pedestrian amenity	(1) Appleyard's liveable street is considered in a neighbourhood context, and designed as a pleasant place for social interaction. (2) Broader definition of the term 'Liveable Street' incorporates streets and roads with lower speed limits	Appleyard (1980), Appleyard et al. (1981), Bain et al. (2012), LAC (2011) and ODT (2002)
Traffic Calming	North America	1980s	Various	(1) To reduce vehicle speeds and volumes. (2) To improve road safety and liveability	(1) Various physical calming measures	(1) Definition of US traffic calming excludes non- engineering measures that are designed to slow or divert vehicular traffic, e.g. roadside planting and neighbourhood safety campaigns	Ewing (1999), Ewing and Brown (2009), Ewing et al. (2005), Lockwood (1997) and TAC (1998)
SER (Self-Explaining Road)	International	1990s	Various	(1) To ensure road design and user behaviour match their intended functions. (2) To reduce driver's errors and enhance driving comfort	(1) Design varies based on road classification, including pedestrian crossings and refuges, special vehicle lanes and traffic-calming measures. (2) Minimum road marking and signage on local streets	(1) SER focus on consistent road design within each category, ranging from urban arterials to local rural roads. (2) Traffic-calming measures primarily used in local and collector roads, e.g. roundabouts and lateral shifts	Charlton et al. (2010), Mackie et al. (2013), Theeuwes (1998) and Theeuwes and Godthelp (1995)

(Continued)

Table 2.1 Continued

Terminology	Jurisdiction	Decade	Land use	Objectives	Design features	Authors' comments	References
CSD/CSS (Context Sensitive Design / Context Sensitive Solution)	North America	2000s	Various	(1) To ensure transportation projects and systems fit into the context of enhancing community values while maintaining safety and mobility (1) To improve road safety and liveability and community interaction. (2) To ensure streets designed for all users	(1) Traffic-calming measures often employed (1) Traffic-calming measures used on residential and activity centre streets	(1) The term 'CSD' was the early terminology, which evolved into CSS to recognise the wider spectrum of issues from planning through construction and beyond (1) Besides street design, the concept incorporates transport policy and strategy to enhance active modes and quality of life. (2) The term often manifested as calmed streets with traffic-calming measures to reduce vehicular dominance	ITE (2010) and TRB (2009)
Civilised Street	Europe	2000s	Various				CABE (2008), Hass-Klau et al. (1992) and LCC (2010)
Complete Street	North America	2000s	Various	(1) To provide safe movement and access for all users, especially pedestrians and cyclists	(1) Wide range of design measures, including traffic-calming measures for local streets	(1) Rebalancing priority for various road users prevents a vehicle-dominated street environment	Kingsbury et al. (2011), Laplante and McCann (2008) and NCDT (2012)
Road Diet	North America	2000s	Various	(1) To reallocate vehicle space for other transport modes, especially pedestrians. (2) To reduce vehicle speed and improve road safety	(1) Reduction of vehicular travelling space to provide for footpath, cycle lane and on-street parking	(1) Although calming vehicular traffic is not a primary objective, decreased space for vehicular movement contributes to reducing vehicle dominance	Huang et al. (2002) and Rosales (2006)

In the United Kingdom, the term ‘Home Zone’, coined in the early 1990s by Barbara Preston, is the English expression of a *Woonerf* in the Netherlands (Biddulph, 2001; 2003). Essentially, home zones are residential streets in which the road space is shared between all users by making them places for people with the wider needs of residents in mind (Institute of Highway Incorporated Engineers [IHIE], 2002). A vehicular travelling lane of a ‘Shared Street’ in Israel not only incorporates colour-paving blocks at the same finished level as the rest of the environment, but also alternates from one side of the street to the other to enable slow speeds (Craus et al., 1993).

In New Zealand and Australia, ‘Shared Zones’ can be applied to both residential and retail shared streets (Austroads, 2008; 2009b, 2013; New Zealand Transport Agency [NZTA], 2009). The concept of shared (traffic) zones, which forms part of local area traffic management schemes, dates back to 1984 when the New South Wales’s Traffic Authority consulted with the local government municipalities and shires, triggering legislative changes to allow formalising a shared zone with a speed limit of 10 km/h (Roads and Maritime Services [RMS], 1987; 2012). Figure 2.3 shows a shared space scheme of Elliott Street in the Auckland Central Business District (CBD) that has been transformed to a shared zone with a level, paved surface.

Further to the early development, there has been in the past two decades a rise in the applications of the shared street concept in non-residential areas and the introduction of term ‘Shared Space’. A prominent figure in the development of shared streets in activity centres was Hans Monderman (Hamilton-Baillie, 2004). With a traffic engineering and road safety background, he further developed the idea as a means to influence traffic speeds and driver behaviour to address transport safety issues in the Netherlands (Methorst et al., 2007; Quimby & Castle, 2006). Monderman did not publish his theories nor guidelines, but rather invited practitioners to observe the effectiveness of shared spaces at actual locations (Besley, 2010; Vanderbilt, 2008). Another well-known advocate for shared space schemes is British architect and urban designer Ben Hamilton-Baillie. Unlike Monderman, Hamilton-Baillie produced a number of publications (Hamilton-Baillie, 2004; 2008a; 2008b), admiring the user integration principles of the *Woonerf* whilst criticising the conventional urban traffic engineering practices that put too much emphases on catering to motor vehicles, especially the separation of vehicles and pedestrian and the excessive use of traffic signs and road marking.

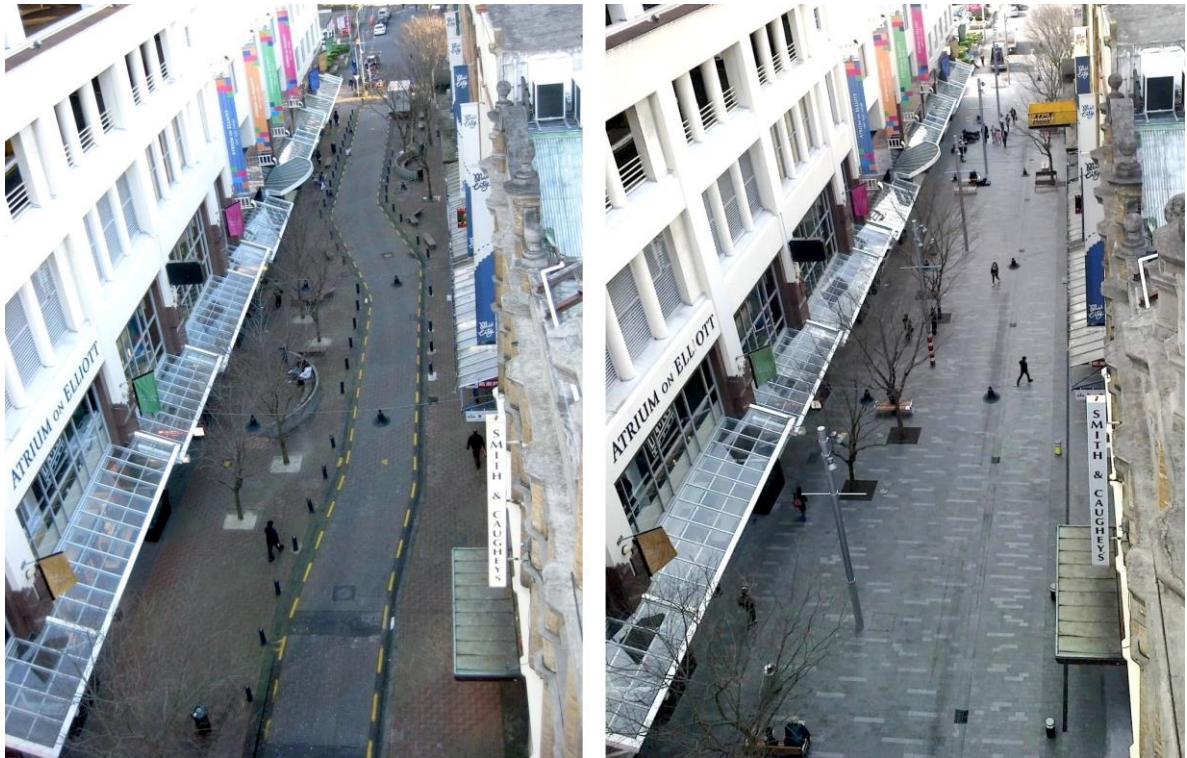


Figure 2.3 Before (left) and after (right) shared space transformation for Elliott Street with a mix of land uses in Auckland, New Zealand.

In the **Calmed Street** category, the *Woonerf* concept to redesign the urban roads to improve the local environment as well as for pedestrians and cyclists has also evolved various traffic calming measures (Harvey, 1992; Pharaoh & Russell, 1991). The term ‘traffic calming’ is a direct derivation of the German word ‘verkehrsberuhigung’, which describes speed control measures such as 30 km/h speed limits and zones of care to improve street environments (Brindle, 1991; 1992). Traffic calming techniques have been well developed and incorporated in an established branch of transport and land-use planning as well as traffic engineering management (for example, Chartered Institution of Highways and Transportation [CIHT], 2005; Devon County Council [DCC], 1991; Ewing, 1999; Hass-Klau & Bocker, 1992; Transportation Association of Canada [TAC], 1998). Like that of the shared space concept, the definition of traffic calming differs, ranging from physical measures for lowering vehicular speeds and volumes to a speed limit zone and an overall transportation policy concept (Brindle, 1997; Ewing, Brown, & Hoyt, 2005; Hass-Klau et al., 1992; Lockwood, 1997). Some definitions of traffic calming are outlined as follows:

Traffic calming is the attempt to achieve calm, safe and environmentally improved conditions of streets” (Pharaoh & Russell, 1991, p.80).

Traffic calming involves changes in street alignment, installation of barriers, and other physical measures to reduce traffic speeds and/or cut-through volumes, in the interest of street safety, livability, and other public purposes (Ewing & Brown, 2009, p.2).

In Australia and New Zealand, traffic calming on local street networks is called Local Area Traffic Management (LATM). With the primary goal of changing driver behaviour, LATM often involves the use of physical traffic calming devices and streetscape treatments to reduce the negative effects of motor vehicles, thereby improving liveability and road safety. It considers neighbourhood traffic-related problems on an area-wide basis as opposed to at isolated locations. Brindle (1992) describes how LATM measures contribute to an overall traffic calming strategy that induces social, cultural and attitudinal changes in travel behaviour. Figure 2.4 displays a calmed street section with a half road closure on Beresford Street and a shared street on Fort Street in Auckland, New Zealand. Both street sections are classified as Collector Road in the District Plan (Auckland Council, 2005).



Figure 2.4 Road design and space allocation between a traffic-calmed street on Beresford Street (top) and a shared space on Fort Street (bottom) in Auckland, New Zealand.

Accordingly, the objectives of traffic calming and LATM evidently share the same goal with the shared space concept in reducing the dominance of vehicles within the urban public streets. In fact, the majority, if not all, of the guidelines and publications consider a shared space as one of the traffic calming and traffic management measures. Nevertheless, the fundamental difference between a shared space and a (vehicular) traffic-calmed street lies in the road space allocation and usage. Physical measures (e.g. speed hump, chicane and kerb extensions) are placed on the already designated vehicular space (i.e. carriageway) to slow, constrain or divert vehicular traffic. The pedestrian and community space may also be upgraded as part of the scheme, but the use of road space between the vehicle and other slower speed users is still segregated via ‘vertical kerbs with distinct footpath areas’.

Additionally, the majority of a traffic calmed street, especially on main thoroughfares, is typically allocated primarily for the motorist without an obvious design to encourage people to dwell within the space. The recent study undertaken by Biddulph (2012b) epitomises this differentiation. Comparing the two streets in the same residential neighbourhood in the UK, it was found that residents spent time, socialising and engaging in optional activities, in the home zoned street significantly more than the traffic-calmed street, and particularly the children.

As also shown in Table 2.1 in the **Calmed Street** category, there are a number of well-known techniques that give an emphasis on residential and people interaction to enhance the place function by diminishing the (vehicular) movement efficiency. These include ‘Livable Street’ (Appleyard, 1980; Appleyard et al., 1981; Oregon Department of Transportation, 2002), ‘Living Street’ (Bain et al., 2012; Los Angeles County [LAC], 2011), ‘Civilised Street’ (CABE, 2008; Lancashire County Council [LCC], 2010), ‘Complete Street’ (Kingsbury, Lowry, & Dixon, 2011; Laplante & McCann, 2008; North Carolina Department of Transportation [NCDOT], 2012), and ‘Road Diet’ (Huang, Stewart, & Zegeer, 2002; Rosales, 2006). Nevertheless, these approaches do not specifically aim at removing the segregation indicator between vehicles and pedestrians. Additionally, the following road design concepts, which are comparable to the shared space concept, are discussed below.

- ‘Self-Explaining Roads (SER)’ - the SER principle is perhaps most akin to that of shared spaces in terms of encouraging the driver to naturally adopt safe behaviour (travelling speed in particular) in response to the visual appearance of roads (Charlton et al., 2010; Theeuwes, 1998; Theeuwes & Godthelp, 1995). Mackie et al. (2013) explain that the SER concept can be applied across all public road categories, including a shared space, as long as road designs and user behaviour match their intended functions and additionally the look and feel of the roads are consistent within each category.
- ‘Context Sensitive Solution (CSS)’ and ‘Context Sensitive Design’ (CSD) – CSD is a collaborative, interdisciplinary approach used in the United States to ensure transportation projects and systems fit into the context of enhancing community values while maintaining safety and mobility (ITE, 2010). The term ‘Context Sensitive Design’ was the early terminology. The term has evolved into CSS to recognise the wider spectrum of issues that exist from planning through construction and beyond (Transportation Research Board [TRB], 2009). CSS often employs traffic calming measures to better reflect the function of the street environment and adjoining land uses.

An urban shared space therefore can be considered in the shared and calmed street continuum based not only on the segregation between vehicles and pedestrians, but also the surrounding land-use criteria, ranging from residential neighbourhoods to commercial city centres.

2.4 Review of Urban Shared Streets in Activity Centres

This section presents further discussion on non-residential shared spaces in an urban context. The evolving discourse of shared spaces can be observed, including terminology and definitions together with the ideological and practical aspects of the concept to embrace the additional place function for an urban street, and diminish vehicular dominance within the public road reserve.

2.4.1 Shared Space in Theory

What is evident in the literature about the shared space concept is the shift towards recognising a street as a destination. While the term ‘placemaking’ within a public space, including streets, is widely used in the fields of architecture and urban design (Castello, 2010; Moughtin, 2003), appropriately recognising and operating a street as a place is not a straightforward process. This is largely because the movement of all street users have in the past dominated other functions of a road space. If one compares a street to a corridor in a building, it is certainly difficult for an interior designer to justify creating a place of gathering along and within the corridor. In spite of this, it is not necessary for the designer to create a corridor if rooms, which predominantly serve the place function, can also be designed to accommodate the movement function e.g. open-plan rooms. The Buchanan Report (MoT, 1963) in fact referred to the environmental areas in residential areas, discussed in Section 2.3.1, as urban rooms.

In conventional traffic engineering and transport planning, the dominant function of movement or mobility was principally related to the efficiency of vehicular traffic. The other conflicting function in road hierarchies is accessibility, largely describing the ability of vehicles to access adjacent land-use activities. Theoretically, the movement function is the inverse of the access function. In other words, a road with a higher traffic movement function has restricted access, and vice versa. The two functions were fundamental, as demonstrated in textbooks and design guidelines (American Association of State Highway and Transportation Officials [AASHTO], 2004; Austroads, 2006; NZTA, 2000; Homburger et al., 2007; TRB, 2000; Ogden & Taylor, 2003), in designing and operating road infrastructure, thereby managing the road network. Other functions such as environmental amenity and social aspects that include pedestrians have been considered in road and street design with the objective of contributing to the overall function of the adjacent land use and surrounding areas rather than to create a place for social interaction and street activities. In *Streets and Patterns*, Marshall (2005) argues against the conventional road hierarchy as the artificially inverse relationship between ‘Mobility’ and ‘Access’ is unable to fully represent a wide range of multi-functional street types. Urban streets can be classified independently based on travelling speeds, transit-oriented arteriability (i.e. strategic contiguity or routes connected up contiguously) and urban place criteria. Furthermore, with the concept of ‘Link and Place’ status (Marshall, 2004; Jones, Boujenko, & Marshall, 2007), the two-

dimensional relationship between ‘Mobility’ and ‘Place’ functions have been promoted, and incorporated in a street planning and design process (DfT, 2007; CIHT, 2010). Although the ‘Place’ function describes a street as a location where activities take place, it also acknowledges the ‘Access’ function as Place-related activities such as loading / unloading and access for servicing. Therefore, the appreciation of the three functions of movement, access and place are all important in the design, use and management of urban streets. The shared space concept is an example of a recent trend to bring together these functions for better use of public road space in the one context of urban streets.

An additional third ‘Place’ function is introduced for shared spaces within the public road corridor along with the two more conventional functions of ‘Mobility’ and ‘Access’ (Karndacharuk & Wilson, 2010). The supplementary functions towards the surrounding area and land-use activities outside the road reserve such as economic, social, cultural, historic and environmental amenity that contribute to the formation of ‘sense of place’ within the public space, are also recognised. When these functions are considered in the planning and design phases, a holistic outcome can distinguish one street from others by its unique features, and highlights the street as the most basic unit of a neighbourhood or community. This design approach encourages a wider range of pedestrian and community activities, and thereby allows users to spend more time within the road space. Even though this three-function system can be applied to all streets in an urban area, successfully transforming a typical street to a destination or a place requires active roadside frontage in sympathy with its context of adjacent land uses (via the supplementary functions for the area outside the road reserve). A comparative study of three CBD case studies in Auckland highlights the importance of street frontage activation, coupled with a high number of pedestrians in lowering vehicle speeds and creating a safer street environment (Karndacharuk, Wilson, & Dunn, 2013a). Moreover, the street design is required to alter driver behaviour so that a wider range of human activities can be integrated in a quality ‘place’ where users can interact, even between driver and pedestrian. The idea of ‘mental speed bumps’, put forward by Engwicht (2005), including the factors of intrigue and uncertainty, can be applied for the drivers to engage with the surrounding environment and drive more slowly and attentively. In this way, a shared space is a self-regulating and ‘self-explaining’ street, which is an outcome of a context-sensitive design. It reinforces the behavioural response of low speed, and the need for caution for all road users.

Applying the shared space concept in urban activity centres, especially with the removal of traffic management measures (e.g. signage, road marking and traffic signals) poses a significant challenge for the road controlling authorities in terms of traffic safety and operation. The mixed-use shared spaces encompass a greater competing demand resulting in more conflicts from various road users from both moving and stationary activities than that of local residential streets. Conventional traffic and road safety engineering practises based on a segregation principle (as opposed to integration) have been logically employed to minimise the risk of conflicts, and this is appropriate for many road types. However, more conflicts do not necessarily result in greater frequency of injury crash, especially at low design speeds, and this is the subject of ongoing research. In fact, the shared space idea is primarily based on the perceived risk that necessitates road users to be more aware of one another, and react more carefully. Based upon the theory of ‘risk compensation’ and later ‘risk homeostasis’, Adams (2012) explains that the uncertainty of the right of way in a shared street environment enables road users’ more cautious behaviour due to their tendency to take risks and the danger they perceive.

The social cost of crashes may in fact reduce as long as driver behaviour changes, ensuring low-speed conflicts where crash severity is reduced. The legal matter of whether pedestrians have priority within a shared street in comparison to other street users is the issue for an authority to consider and decide. The shared space development process needs to very carefully enable the reduction of vehicle dominance with a goal of enhancing pedestrian priority as due to a vehicle mass it is very easy for a vehicle to dominate any road space. To achieve this, vehicular traffic speeds within a shared space must be lower than that of a normal street. When there are street pedestrian destination activities, the speed disparity between motor vehicles and other low speed ‘living, working and eating’ space users is one of the most important factors in determining the success and safety of a shared space. On the other hand, when there is little non-vehicular activity, a vehicle is still expected to behave cautiously, perhaps with higher speeds, but in anticipation of other vulnerable users. Unlike LATM, which uses horizontal and vertical physical devices to slow vehicles down, shared spaces are expected to incorporate a continuous paved surface with vehicular restrictions in space and visibility into a unique street environment so that there is uncertainty in priority for motorists, thereby reducing the dominance of motor vehicles within the space.

In addition to the goal of reducing the dominance of vehicles, the shared surface design (i.e. no kerb) for an urban shared street is part of the overall design approach to remove the demarcation between vehicles and pedestrians to encourage sharing behaviours. Without the vertical elevation difference and the material contrast between the footpath and carriageway by the removal of kerbs, a continuous level surface immediately highlights the need for the space to be 'shared' amongst all users based on the integration concept. Additionally, the design of a shared space aims to minimise traffic regulations and control devices such as signage and road marking, which are traditionally employed to define priority and behaviour of the space users as well as providing legal accountability from an enforcement perspective in urban areas. Many 'Shared Space' advocates (Hamilton-Baillie, 2008b; Methorst et al., 2007) link the shared street concept with the movement to de-clutter the street. The effort for well-designed street furniture in order to protect and enhance street amenity is not new. The UK's Design Council (1976) outlined measures to simplify street furniture design, including the coordination between various controlling organisations as well as the choice and siting of street furniture, paving surfaces and trees. Besides the aesthetic benefits of de-cluttering signage and marking (that contributes towards the place function), it is hypothesised that removing standard traffic control devices can positively create uncertainty, and in turn encourage cooperative and sharing behaviour between users. Since regulatory, warning and directional signs and markings are an essential part of road corridor operations, the removal of such traffic control devices would require careful consideration to ensure behavioural and psychological change, as earlier discussed, does occur with drivers in motor vehicles. It is hoped over time this would enable pedestrians and cyclists to be more assertive and take more control over the space.

2.4.2 Shared Space in Practice in New Zealand

The application of the shared space concept in New Zealand is largely influenced by the European Shared Space project (Shared Space, 2005; 2008a; 2008b) and the UK's Department for Transport studies (DfT, 2009; 2010a; 2010b). A shared pedestrian and vehicle street has specific legal recognition as a Shared Zone, which is defined in the Land Transport Rule 2004 simply as “a length of roadway intended to be used by pedestrians and vehicles”. The equal-priority interaction between different users is controlled under the Rule as follows:

- A driver of a vehicle entering or proceeding along or through a shared zone must give way to a pedestrian who is in the shared zone.
- A pedestrian in a shared zone must not unduly impede the passage of any vehicle in the shared zone.

The street design of city centre shared spaces incorporates a relatively level surface across the whole road corridor. With the goal of creating a distinct area with a sense of place, specially designed stone pavers are used, along with a suite of street furniture (e.g. seats, cycle racks, lighting and native trees). A shared street is deliberately designated into two major zones; Shared Zones and Accessible Routes. As shown in Figure 2.5, the central Shared Zones are designed for both temporary and permanent activities related to all types of users. In order to address concerns raised in relation to the visually impaired as discussed in many studies (Imrie, 2012; Thomas, 2008; 2011), a minimum 1.8m wide Accessible Route is provided on either side of the street. The two zones are demarcated by 600mm wide tactile delineator bands to warn the visually impaired of the risk of moving vehicles outside of the safe zone. It is therefore reasonable to point out the shift of user segregation from the conventional split of pedestrians (using footpath) and vehicles (travelling on carriageway) to a separation of those who are reluctant to share the space with motor vehicles such as the blind, the visually and mobility impaired, the elderly and young children (using the Accessible Route) and other space users, including drivers in motor vehicles.

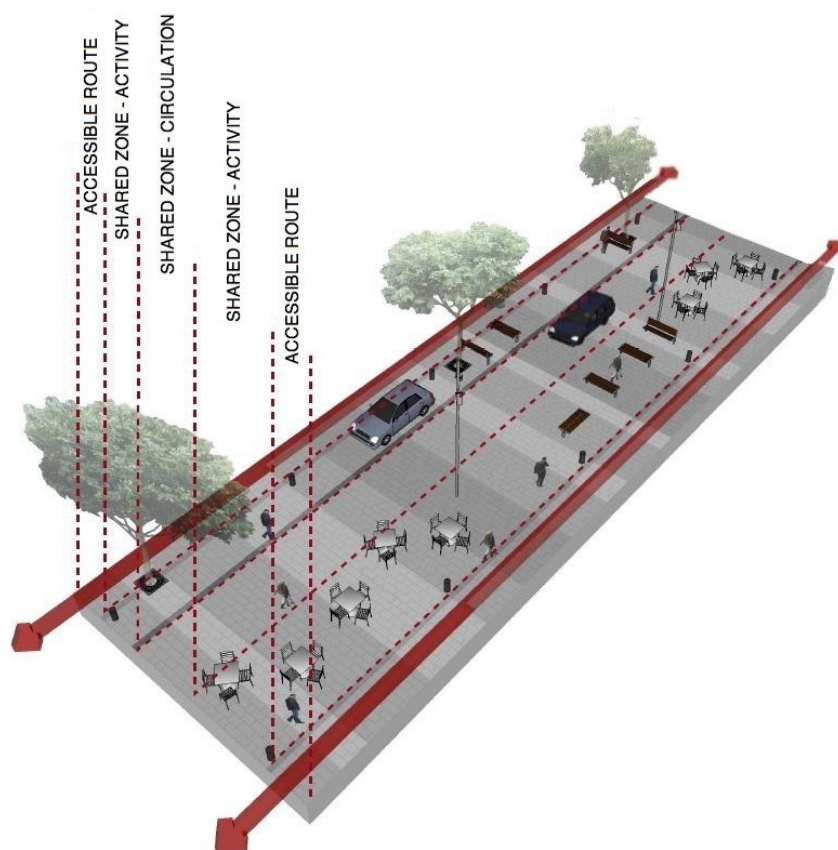


Figure 2.5 Spatial composition of shared zones in Auckland CBD, New Zealand.

Using the New Zealand design of the urban shared spaces as a reference scheme, Table 2.2 presents an outcome of a comparative analysis of design and performance of relatively recent mixed-use shared street schemes between New Zealand and six international shared space schemes in the UK, Austria, Australia and the Netherlands.

Table 2.2 Design and performance comparison between New Zealand and international shared space schemes

Country	Location	Year completed	Design features	Performance results	Authors' comments	References
<i>Reference Scheme</i>						
New Zealand	Elliott Street, Auckland	2011	(1) Level surface with stone paving continuously across the whole corridor. (2) Minimum use of traffic control devices, e.g. signage and marking. (3) Minimum 1.8 m wide safe zone with a 600 mm tactile delineator band to cater for the disabled. (4) Street furniture (e.g. trees, lighting and seating) for pedestrians. (5) Temporary activity (e.g. dining tables) to improve the Place function. (6) Shared zone signs at entry and exit points. (7) Speed limit of 10 km/h	(1) Mean and 85th percentile vehicle speeds decreased approximately 20% to approximately 16 and 21 km/h, respectively. (2) Vehicle flows drop approximately 40% to 1000 vpd. (3) Based on trajectory analysis, pedestrians walk more freely within the space. (4) No injury reported crashes as of November 2013. (5) Road user interaction and conflict study confirmed the more pedestrian-vehicle interactions, the lower vehicle speeds. Mean vehicle speed dropped as low as 12 km/h during peak activity times	(1) No stopping of vehicles permitted at all times, except in a few designated areas and for loading activities between 6 and 11 am. This restriction contributes to the shared space objectives of pedestrian priority improvement and vehicle dominance reduction. (2) Linear design of vehicular trafficable area contributed to higher vehicular speeds during off peaks when there was little land-use activity	Kamdacharuk et al. (2013a), Kamdacharuk et al. (2014) and Kamdacharuk et al. (2011)
<i>International Scheme</i>						
UK	Exhibition Road, London	2011	(1) Similar design features included a level, paved surface, minimum signage and marking, safe zone and tactile delineator provision, street furniture for pedestrians and entry and exit signage. (2) Large provision of 90° on-street parking. (3) Speed limit of 20 mph (32 km/h)	(1) 85th percentile vehicle speeds in range of 28–42 km/h depending on study areas. (2) Vehicle flows in the order of 12 000–14 000 vpd. (3) Vehicle related issues included violation of banned movements, corner cutting and safety zone encroachment. Bollards subsequently installed to address vehicle encroachment on ped zone. (4) Reduction of pedestrian-vehicle traffic conflicts, especially minor conflicts	(1) With high vehicle traffic volumes and speeds, coupled with defined pedestrian crossing points, pedestrians had less priority to freely move around when compared with the reference scheme. (2) On-street motor vehicle parking provided at the expense of pedestrian space. (3) Shared street improved pedestrian amenity, but still retained pedestrian-vehicle segregation	Kaparias et al. (in press) and RBKC (2012, 2013a, 2013b)

Austria	Sonnenfelsplatz Intersection, Gratz	2011	<p>(1) Similar design features, including a level surface, minimum use of signage and marking, safe zone and tactile delineator provision, street furniture for pedestrian occupancy and temporary trading activity</p> <p>(1) Similar design features included a level, paved surface, minimum use of signage and marking, safe zone and street furniture for pedestrian occupancy, e.g. seating and fountains. (2) Gateway treatments included 90° parking, entry plinths and stone rumble strip on entry ramps. (3) Speed limit remained at 50 km/h</p>	<p>(1) Mean vehicle speeds of approximately 15 km/h at a more constant speed. (2) Trajectory analysis showed pedestrians and cyclists following more direct paths across the intersection</p>	<p>(1) Given that combined volumes of pedestrians and cyclists were twice as much as vehicle volumes, slow-speed individuals dominated the use of space</p>	Rudloff et al. (2013) and Schönauer et al. (2012)
Australia	Hargreaves Street and Bull Street Intersection, Bendigo	2009	<p>(1) 85th percentile vehicle speeds decreased approximately 30% to 26–29 km/h. (2) Vehicle flows decreased by 30% to approximately 3200 vpd. (3) Pedestrians moved more freely within the space. (4) Increase use for formal and informal activities</p>		<p>(1) Council set the target speed of 20 km/h, was not achieved, by relying on shared space design. (2) Authority acknowledged the lack of kerbs and formal crossings as a challenge for visually impaired pedestrians, which was being monitored</p>	GSA (2012), DTPLI (2012) and Tolley (2007)
UK	Elwick Square, Ashford	2008	<p>(1) Similar design features included a level, paved surface and minimum signage and marking. (2) Majority of intersection space (approximately 72%) allocated for vehicle movement and turning with little provision for staying activities. (3) Speed limit of 20 mph (32 km/h)</p>	<p>(1) Mean vehicle speeds of 30 km/h. (2) Vehicle flow of approx 11 000 vpd. (3) The majority (56%) of pedestrians used informal crossings as opposed to moving freely along desire lines. (4) Based on perception surveys, the majority of pedestrians worried about sharing space with vehicles (72%) and preferred conventional design (64%)</p>	<p>(1) Because the majority of road space allocated for vehicle movement and turning, less space can be provided for pedestrians and the Place function. (2) Most pedestrians diverted from desire lines to avoid conflicts and gave way to drivers at informal crossings, indicating a vehicle-dominated environment</p>	DfT (2010a) and Moody and Melia (2011)

(Continued)

Table 2.2 Continued

Country	Location	Year completed	Design features	Performance results	Authors' comments	References
UK	New Road, Brighton	2007	(1) Similar design features included a level, paved surface, minimum use of signage and marking, street furniture for pedestrian occupancy, trading activity, and entry and exit signage. (2) Safe zone was provided, but in some areas conflicting with seating and trading areas. (3) Speed limit of 20 mph (32 km/h)	(1) Mean vehicle speeds of 21 km/h. (2) Vehicle flows reduced by approximately 90% to 1200 vpd. (4) Based on perception surveys, both general public (99%) and businesses (93%) supported shared street upgrade	(1) This street was comparable with the reference street in terms of reduced vehicle dominance, including speeds and volumes. (2) With some trading activity fully occupying space between building line and vehicle lane, Council acknowledged ongoing concerns related to the blind and the partially sighted	BHCC (2011a, 2011b), DFT (2010a) and Flow (2012)
Netherlands	Laweiplein Roundabout, Drachten	2003	(1) Similar design features included a level surface, minimum road signage and marking and street furniture for pedestrians such as trees, lighting and fountains. (2) Roundabout intersection with road surface marking. (3) Provision of formal (zebra) pedestrian crossings and informal crossings using speed tables. (4) Pedestrians segregated from vehicles via different surface materials	(1) Vehicle speeds comparable to the cyclist (15–25 km/h) at a more constant speed. (2) Before and after comparison shows vehicle flows increased 30% from some 1400 to 1550 vph. (3) Improvement on vehicular travel times with less delays at the intersection. (4) Based on perception surveys, the perception of road safety declined (from 30% to 45%, rating 'moderate' or 'bad') while perception of personal safety improved (from 71% to 81%, rating 'reasonable' or 'good')	(1) The majority of intersection space was allocated for vehicle movements. (2) Almost all drivers gave way to pedestrians and cyclists at informal crossing points, reflecting improved driver behaviour and reduced vehicular dominance. (3) Pedestrians and cyclists crossed at defined crossing points, reinforcing a user segregation environment. (4) Intersection design did not generally provide for the Place function	Hamilton-Baillie (2008b), NHL (2007) and Shared Space (2005, 2008a)

The common design features for the selected case studies of both road sections and intersections are a level surface, the minimisation of traffic control devices and an improved street environment for pedestrians using street furniture such as trees and lighting. The Elliott Street shared space in New Zealand also incorporates a safe zone for vulnerable users, a designated space for temporary trading activities and legal signs at the entry and exit points. Research into the operation and safety of the Elliott Street site (Karndacharuk, Wilson & Dunn, 2013a; 2014) revealed the importance of active land-use frontage, the number of pedestrians and designs that encourage pedestrian and vehicle interactions in the space. These factors contributed to the reduction of vehicular operating speeds, which were 16 and 21 km/h for the mean and 85th percentile speeds, respectively. Based on the design features and the vehicular speed outcomes, the scheme most similar to Elliott Street in New Zealand is New Road in Brighton in the UK. Both schemes achieved a similar result of reducing vehicular dominance in speed and volume as well as utilising the street space as a place. Moreover, perception surveys of the New Road scheme indicated an overwhelming support from the general public and businesses (Brighton & Hove City Council [BHCC], 2011b; DfT, 2010a).

It is therefore debatable whether a commonly referenced ‘Shared Space’ example of a busy Netherlands roundabout with traffic flows of some 20,000 vehicles per day in the Laweiplein in Drachten (Hamilton-Baillie, 2008b; NHL, 2007) functions in accordance with the shared space concept in this chapter. With this amount of vehicular traffic, the majority of road space would have to be provided and prioritised for the mobility and movement of road users as opposed to operating as a destination or ‘place’. The occupancy of road users, including vehicles, pedestrians and cyclists, would predominantly have a purpose of mobility (perhaps at appropriately low speeds, but still travelling through the road intersection space). These remarks are also applied to the Exhibition Road site (RBKC, 2012; 2013a; 2013b) and Elwick Square in Ashford in the UK (DfT, 2010a; Moody & Melia, 2013) where the high vehicular traffic volumes and speeds, coupled with defined pedestrian crossing points result in retaining pedestrian and vehicle segregation and limiting the ability for pedestrians to move around freely.

While the Bendigo scheme in Australia saw the shared space concept applied at the intersection of Hargreaves Street and Bull Street (Government of South Australia [GSA], 2012), the Sonnenfelsplatz scheme in Gratz, Austria transformed a previously implemented

roundabout into a shared space with a level surface (Rudloff, Schönauer, & Fellendorf, 2013). On the one hand, the performance of the Austrian scheme was outstanding with the mean vehicle speed of 15 km/h and a more constant speed distribution (Schönauer et al., 2012) possibly due to the slow-moving users (i.e. pedestrian and cyclists) being able to exercise control over the space. On the other hand, the Australian scheme with the 85th percentile speeds, ranging from 26-29 km/h, was unable to achieve its target operating speed of 20 km/h (DTPLI, 2012). Nonetheless, it is important to note that the space allocation for the shared spaces at intersections is, in general, prioritised for vehicle turning and movement at the expense of staying activities and achieving the place function of a street.

2.4.3 Terminology and Definition of Shared Space

Within the context of public street design, and from a perspective of a road controlling authority that is accountable for managing and maintaining a road network, simple terms such as ‘shared street’ or ‘shared zone’ are perhaps more suitable to convey the notion of supporting different street users mixing together within a public road reserve (as demonstrated in Figure 2.1). Besides, such terms have long been used in the literature (for instance, Ben-Joseph, 1995; 1997; Polus & Craus, 1988; 1996; RMS, 1987) ever since the automobile era. Additionally, the Urban Street Design Guide (National Association of City Transportation Officials [NACTO], 2013), which provides street design principles in an American urban street context, unequivocally utilises the term ‘shared street’ in place of ‘shared space’.

This is because the definition of the term ‘Shared Space’ is currently used loosely in various jurisdictions meaning different things. Besley (2010) states the term ‘shared space’ is differently understood and somewhat controversial, crossing a number of knowledge disciplines, including urban design, engineering and traffic management. The term started to gain popularity, especially in Western Europe, due to the work of a European project part of the INTERREG IIIB North Sea programme (Shared Space, 2005; 2008a). Definitions range from a way of thinking with the vision to improve the quality of public space to a street design concept for user integration. For example, the UK guideline on shared spaces in urban street environments defines a shared space as:

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 (DfT, 2011).

Yet, as earlier demonstrated, a shared space to many authors (Hass-Klau, 1990, pp. 237-238) means a traffic-calming measure whereas for Bendixson (1977, p. 216) the same expression unambiguously denotes the original shared street (*Woonerf*) configurations. The previous usage of the term counters the recent assertion (Shared Space, 2008b, p. 3) that the term ‘Shared Space’ was coined at the outset of the European Shared Space project at the beginning of the twenty first century. Moreover, as previously discussed, the scope of a shared space described in urban design and planning disciplines incorporates other areas outside of the road corridor such as public open spaces and private areas. Undoubtedly, the proponents of the concept like Hans Monderman and Ben Hamilton-Baillie would have their own interpretation of the word ‘shared space’. Nonetheless, culminating from this critical review is the following definition of a shared space in an urban street environment:

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.

2.5 Conclusions

This chapter addressed the evolving discourse of the many concepts of urban shared spaces for road user integration from a New Zealand perspective. This review sets the context of public street design within the road reserve with the emphasis of multi-disciplinary collaboration. The review challenges the view observed by ‘Shared Space’ advocates that a certain profession of traffic engineering could single-handedly create a pervasively automobile-centric street environment, and as such discusses that it was the society as a whole in the mid-twentieth century that determined the function, design and use of a public road network predominantly for motor vehicles. The realisation for integrating other road users and social activity into the public road space was documented in the influential *Traffic in Towns* that provided a critical step in the development of the shared street concepts. Influenced by the Buchanan Report, the *Woonerf* concept from the Netherlands

had come to epitomise the road user integration philosophy as well as the tangible design of residential shared streets.

Shared street, therefore, can be distinguished from calmed streets based on the intended segregation between pedestrians and vehicles within a broad spectrum of street design approaches that are comparable to a *Woonerf* street. The comparative analysis of these concepts and terminologies revealed a wider scope and application of the idea of shared street and traffic calming over time since the 1960s, particularly the expansion towards activity centres, multi-modal considerations, self-explanatory design and context-sensitive solutions. Subsequent discussion involves the principles of shared spaces in an activity centre context with the emphasis on the additional Place function and the objective of vehicular dominance reduction. Using the New Zealand example of an Auckland CBD shared zone, the application of the shared space concept can be described and compared with select international schemes. This comparative review has highlighted the importance of achieving a low speed environment via design with a provision of safe zones for the visually impaired, space reallocation for pedestrians and street furniture for the ‘staying’ activity to enable a shared street to perform multi-functions, especially to create a sense of place. In the end, the research offers a contemporary definition of an urban shared space within the road reserve for the New Zealand context, which is applicable elsewhere in order to achieve both vehicular dominance reduction and placemaking objectives.

CHAPTER THREE

METHODOLOGICAL EVALUATION FRAMEWORK

This chapter presents a framework to thoroughly evaluate the performance of a public urban road in a Shared Space environment. Utilising road space as a place for activity and reducing vehicular dominance are considered key drivers to transform a conventional street to a shared space in an activity centre. These, coupled with an aim to improve the economic vitality of the adjoining land use, form the key objectives of implementing shared spaces. With the concepts of shared space discussed in Chapter Two, this research project holistically captured the necessary data, both quantitative and qualitative, to properly evaluate shared space schemes. A framework incorporating an Analytical Hierarchy Process was proposed to analyse the processed data in order to obtain a performance index that is universally applicable to evaluating shared spaces in different street environments.

The contents of the majority of this chapter are included in Karndacharuk, Wilson, & Dunn (2013b). Section 3.4 about the qualitative analysis of the pre-implementation data is an extract from Karndacharuk, Wilson, & Tse (2011).

3.1 Introduction

As discussed in Chapter Two, the shared space concept is one of various approaches in response to the realisation of the adverse environmental and social impacts due to decades of planning and design primarily focused on the priority for motor vehicles. Even though there has been a recent surge in the use of the term ‘Shared Space’ and its applications in the past decade largely influenced by the work of a European project (Shared Space, 2005; 2008a; 2008b) and the UK’s Department for Transport (DfT, 2009; 2011), the concept of various street users sharing the same public space is not new. The road user integration concept can be traced back to the philosophical concept of an ‘environment area’ in *Traffic in Towns* (MoT, 1963) as well as the *Woonerf* concept in the Netherlands during the late 1960s (Ben-Joseph, 1995). In the form of a residential shared space, the first experiment of the *Woonerf* idea in Delft was to address the safety concerns between vehicles and children

playing in urban streets, and to integrate vehicular traffic into social residential space (Hass-Klau, 1990). Translated as ‘yard for living’ or ‘residential yard’, the *Woonerf* concept incorporates the removal of standardised road signage, marking, kerbs and barriers to reduce the motor vehicles’ influence (Hamilton-Baillie, 2008). In the United Kingdom, the concept of shared undemarcated street, which is termed Home Zone, was introduced in the 1970s for new developments with an emphasis on community and residential user integration (Ben-Joseph, 1997; Biddulph, 2003).

Comparably, traffic calming practice, which has been an established branch of traffic management, is also considered to have evolved from the *Woonerf* idea (Pharaoh & Russell, 1991). The applications of traffic calming techniques are well developed and widespread; for example, The UK’s Traffic Calming Techniques (CIHT, 2005), US Traffic Calming Manual (Ewing & Brown 2009) and Local Area Traffic Management (Austroads, 2008; Brindle 1991; 1992; 1997).

Furthermore, there has been in the past two decades a rise in the applications of the shared street concept in activity centre areas (as opposed to residential areas). A prominent person in the development of the mixed-use shared spaces was Hans Monderman (Hamilton-Baillie, 2004) who pioneered the idea as a means to influence traffic speeds and driver behaviour to address transport safety issues. Another well-known advocate in the United Kingdom for shared space schemes, who claimed to coin the term ‘Shared Space’, is Ben Hamilton-Baillie (2006). He states that a shared space is a default (*status quo ante*), which existed before the introduction of the separation of vehicles and pedestrians that later became an acceptable approach for designing public spaces.

While a shared street space in commercial or shopping areas in Australia is generally related to a Shared Zone (Austroads 2009; RMS, 2000), any shared spaces in New Zealand are to be declared specifically as Shared Zones in accordance with the Land Transport (Road User) Rule to outline the interaction between pedestrians and vehicles in an equitable manner (Karndacharuk, Wilson, & Tse, 2011).

3.2 Place function for urban road space

As mentioned before, the concept of shared space from a broad philosophical perspective can be traced to the introduction of environmental areas in the *Traffic in Town* (MoT, 1963), commonly known as the Buchanan Report. The report, which to a large degree influenced the development of the *Woonerf* concept (Clayden, Mckoy, & Wild 2006), was among the early publications to officially recognise the increasing adverse environmental impacts of transport planning and design for the automobile, especially in an urban environment. It proposes a cellular concept, as illustrated in Figure 3.1(a), to describe the relationship between the road network and environmental areas. The environmental areas must be a good environment where people can live, work, shop and move around on foot in a reasonably safe and comfortable manner. Local distributors, as shown in Figure 3.1(b), would incorporate shared spaces where the road space not only serves the functions of mobility and accessibility (i.e. an ability to access adjacent land use activities), but also functions as a destination or a place to stay and move around within an environmental area.

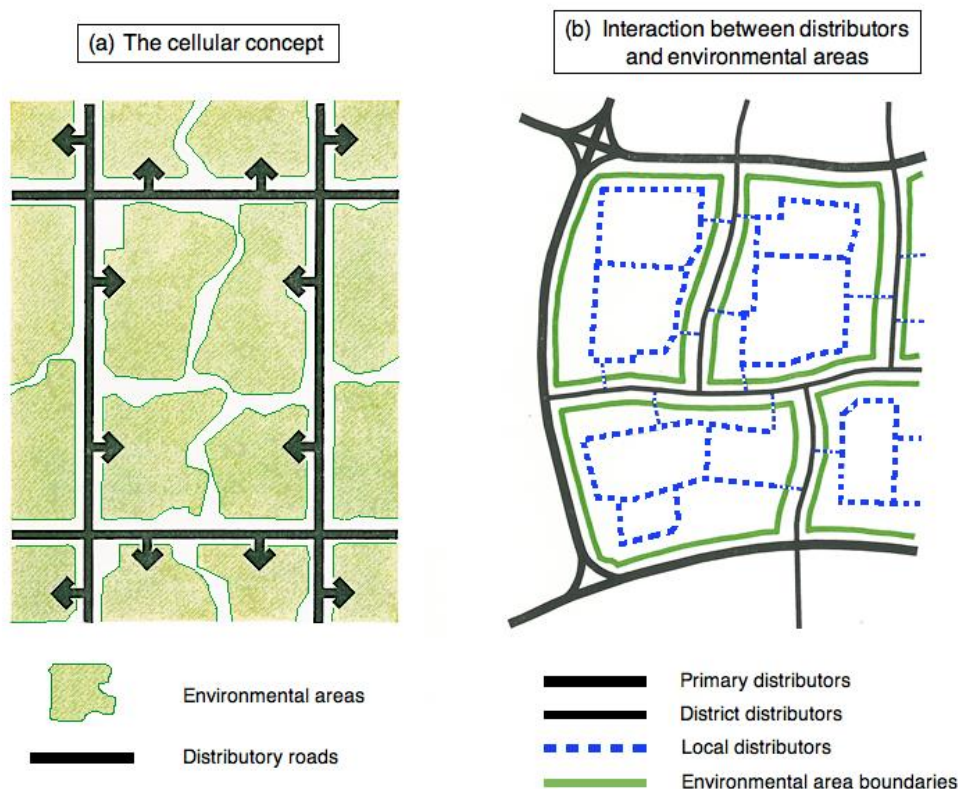


Figure 3.1 The cellular concept, comprising distributory roads and environmental areas.

(Source: Buchanan et al. 1963, adapted by the authors).

While the importance of ‘placemaking’ and ‘sense of place’ to civic spaces has long been argued in the fields of architecture and urban studies (Gehl, 1987; Jacobs, 1961; Whyte, 1980), the shared space concept introduces an additional ‘Place’ function for urban road spaces in the areas of transportation engineering and planning. The two more conventional functions of ‘Mobility’ and ‘Access’ have been fundamental in street design and classification as demonstrated in textbooks and design guidelines (NZTA, 2000; Ogden & Taylor, 2003; AASHTO, 2004; Austroads, 2006; Homburger et al., 2007; TRB, 2010). These two competing functions gave rise to two distinct types of ‘designed’ streets; traffic routes serving primarily mobility, and local streets serving primarily property access (Brindle, 2003). The recently developed concept of ‘Link and Place’ status (Jones & Boujenko 2009; Jones, Boujenko & Marshall 2007; Marshall 2004) with the two-dimensional relationship between ‘Mobility’ and ‘Place’ function has been adopted in the UK’s *Manual for Streets* (CIHT, 2010; DfT, 2007).

By embracing the place function, the shared space concept brings a new notion that is divergent, but adds to current approaches of traffic engineering practice and management. Figure 3.2 depicts the three functions of a shared space as a public urban area situated exclusively within the road reserve. The diagram also takes into account the adjacent land use activities located outside of the road reserve and the complementary street functions of economic, social, cultural, historical and environmental amenity, that contribute to the formation of ‘sense of place’ within the public space.

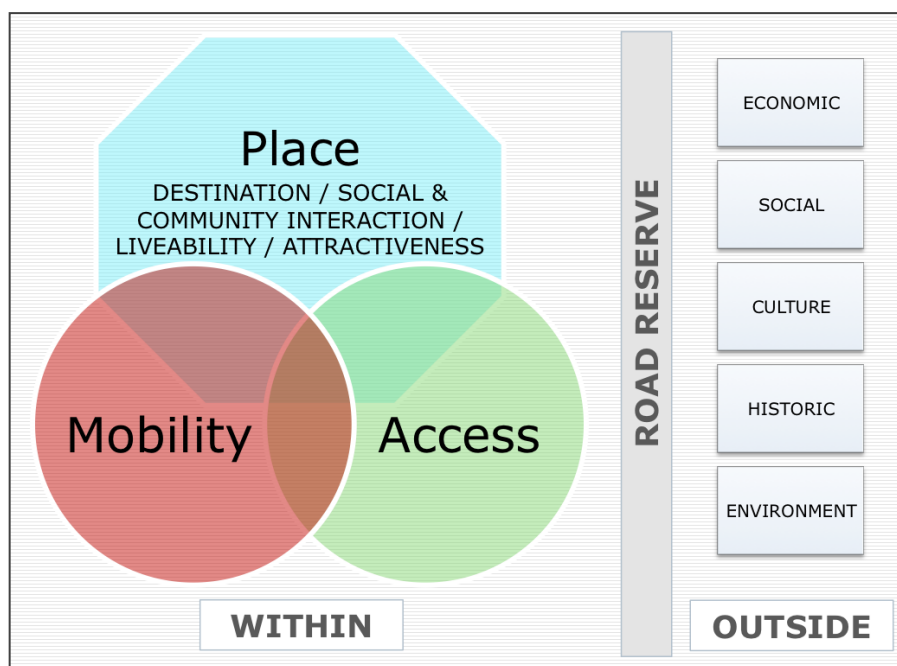


Figure 3.2 Place function and how it links to other functions outside the road reserve.

Shared spaces have distinct design features of a level surface continuous across the road reserve without an obvious or no vertical elevation difference (i.e. kerb) between what would normally be the road carriageway and the footpath areas. Similar paving materials and colours between the vehicle zone and the rest of the street space should be used to promote pedestrian movements over the full width of the street environment. With the use of street furniture (e.g. trees, art works, bollards and lighting) and traffic calming measures (e.g. lateral shifting of horizontal alignments and street closures), the schemes would limit vehicular volumes, speeds and dominance as well as encourage a wider range of pedestrian and community activities, thereby allowing users to spend more time within the road space.

3.3 Development of Evaluation Framework

The importance of developing an appropriate evaluation process, taking into account various attributes that influence the effective use of the public space, cannot be overemphasised. One of the significant challenges for a road controlling authority when implementing a shared space or allowing the shared space concept to be applied within public road reserve is how to manage the safety and operational risks and liabilities appropriately. This is especially so when the concept is new to users. This transitional period requires special consideration until behavioural change occurs, which may differ

from country to country and region to region. The uncertainty is whether the new road environment would trigger such behavioural change required for safe and integrated traffic operations. The importance of performance monitoring is also highlighted in the UK Department for Transport's recent publication on Shared Space (DfT, 2011).

A review of the literature and relevant studies revealed a knowledge gap on a suitable approach in assessing the effectiveness of shared spaces schemes. It should be noted that the term 'shared space' is differently understood and somewhat controversial, crossing a number of knowledge disciplines, including urban design, engineering and traffic management (Besley, 2010). In urban design and planning, the focus of a performance evaluation in the literature is generally around pedestrian activities and subjective values of users and stakeholders and the use and effectiveness of streetscape elements as well as user opinions and perceptions. On the other hand, an engineering based evaluation predominantly captures traffic data based on movement and access functions e.g. traffic flow and speed, pedestrian crossing and accident data. More importantly, the majority of shared space data collection and analysis is based on a site-specific consideration. Besides a consistency issue, this means raw data is not typically converted to a standardised unit that can be used for comparison / benchmarking with other schemes or between pre and post implementation. Additionally, it has been identified that a small, limited number of schemes are properly evaluated based on crash data and public perception (Quimby & Castle, 2006). These highlight the need for a holistic evaluation mechanism based on clearly defined multi-objectives of a shared space, particularly creating a high quality place.

Therefore, in order to address this gap, an all-encompassing process was proposed, using both quantitative and qualitative research methodologies, for the performance evaluation that is conforming to the purposes of city centre shared space. Figure 3.3 illustrates the performance evaluation framework.

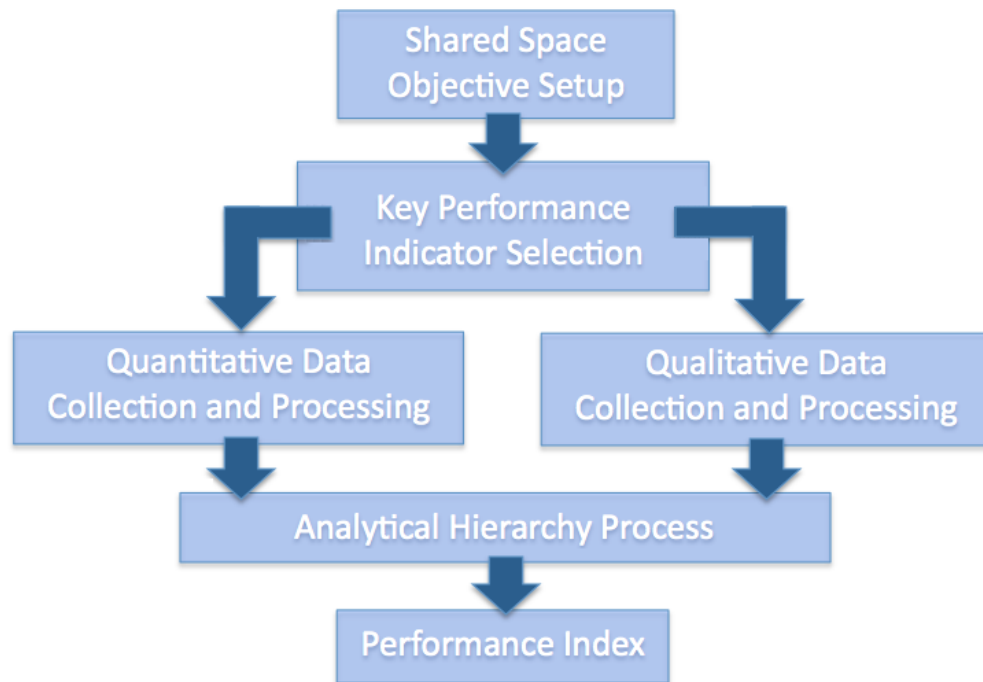


Figure 3.3 Shared space evaluation framework with a goal of performance index.

3.3.1 Shared Space Objective

The objectives of shared spaces in an urban area were firstly established along with relevant key performance indicators in order to enable an appropriate development of data collection and analysis methodologies. It is acknowledged that motivations and corresponding purposes of developing a shared space scheme are context sensitive; therefore vary for different locations. Nonetheless, the performance of a shared space can be determined based on how successful the public space performs its functions of place, mobility and access. In general accordance with what was suggested in a report prepared for the UK Department for Transport (DfT, 2009), the primary objectives of shared spaces and corresponding performance measures can be discussed as follows:

Placemaking: The street should provide better use of public space via a lively quality of the environment that attracts users to spend time within the space. It is also reflected in a wider range of street activities. Performance measures include number of users dwelling in the area and time spent in the area or user dwell time. Both are a possible measure to indicate that the zone functions as an origin/destination rather than a through route. Other measures are use of facilities provided, type of activity occurring (e.g. eating, chatting etc.) and user perceptions.

Pedestrian Focus: This objective involves an environment with improved pedestrian priority and the ability to walk along and across as well as freely roam the street. The performance measures include space allocation, pedestrian number, density, flow, trajectory / crossing zone where there is a potential encounter with other modes of transport (e.g. vehicle and cyclist) and user perceptions.

Vehicle Behaviour Change: A goal is to reduce the current dominance of the motor vehicle and the driver in the environment. This change of priority should enable the driver of a vehicle to be more aware of other road users and to drive at appropriate speeds. The performance measures include traffic volume and speed reductions, travel time increase through the zone and observed sharing behaviour. The traffic data (SCATS) on the surrounding road network at signalised intersections were collected to be able to determine the impact of a shared space on the surrounding environment as it cannot be taken in isolation.

Economic Impetus: A road space should complement the operation and prosperity of the surrounding businesses. Conversely, the presence of business related users would enhance the range and type of activity in the public space. The performance indicators include property and leasing values, retail occupancy rates, number of users accessing the adjacent land use, active frontage and user perceptions.

Safety for All Users: Shared spaces are to provide a safer environment for all users, including cyclists, the elderly and children. The performance indicators include crash history, injury severity and costs, user demography, number of user conflict and user perceptions.

3.3.2 Key Performance Indicator and Data Acquisition

Key performance indicators (KPIs) for each objective were carefully selected from the aforementioned performance measures to form an analysis model (which is discussed in Section 3.3.3). As displayed in Table 3.1, quantitative performance indicators are those indicators that can be measured objectively such as type, number, speed and density of street activities / space users. The main method of quantitative data collection was a video survey from which pedestrian and vehicular data can be extracted along with the use of

space and streetscape facilities based on various time periods of the day and week, and weather conditions. Other sources of data comprised a vehicle traffic survey using tube counters, economic data surveys, Crash Analysis System (CAS) and council databases.

Table 3.1 Quantitative key performance indicators and data sources.

Objective	Quantitative KPI	Unit	Data source
Place	Pedestrian Occupancy Ratio	-	Video survey
	User dwell time	sec	Video survey
Pedestrian	Pedestrian density	ped/m ²	Video survey
	Crossing zone	m ²	Video survey
Vehicle	Motor vehicle speed	km/h	Traffic counter
	Motor vehicle volume	veh/h	Traffic counter
Economic	Active frontage	m	Measurement
	User accessing adjacent land use	ped/h/m	Video survey
Safety	User conflict	conflict	Video survey
	Reported crash history	crash	CAS database

As shown in Table 3.2, the quantitative data collection of the video surveys was undertaken at the three shared space sites between 2010 and 2013. To give an example of the quantitative data acquisition from the video surveys, the process to obtain the Pedestrian Occupancy Ratio (POR) is explained as follows (refer to Karndacharuk, Wilson, & Dunn, 2013 for a more detailed discussion and analysis of quantifying various pedestrian activities). The video survey data of pedestrian activity was examined for every 15-minute interval over a 24-hour period. The pedestrian data were then classified into two different groups: Pedestrian Movement (PM) and Pedestrian Occupancy (PO).

Table 3.2 Summary of video data collection.

Scenario	Year	Month				
		Aug	Sep	Oct	Nov	Dec
Before	2010	25 FORT	8 ELLIOTT	4	17 LORNE	1
	2011		21 F	28 E	5 L	12
After	2012		21 FORT	5 ELLIOTT	12 LORNE	26 9
	2013		18 F	25 E	2 L	9

The PM group represents the pedestrians who walk along and across the space for transport movement functions (i.e. Mobility and Access) whereas the PO group includes people who

spend time within the shared space, and generally use the space for the ‘Place’ function. A review of a 10-second period immediately before and after the 15-minute snapshot was required to clearly differentiate the two groups. The POR is a ratio of the PO volume over the total number of pedestrians at a particular time.

For the qualitative performance data collection, an on-street perception survey has been developed as the main method. The survey was designed to be filled in on-site at the three CBD case studies. The participants were obtained from volunteer pedestrians travelling through or dwelling within the space, property and/or business owners and employees of businesses adjacent to the space. The sample of pedestrians was checked against the 2013 census data for Auckland Central (Statistics NZ, 2014) to determine the extent of the representativeness of the space users.

A 6-point Likert rating scale, ranging from ‘strongly disagree’ to ‘strongly agree’ was used in both perception surveys to measure the participants’ opinion toward the following five statements, which are consistent with the established shared space objectives:

- Place - *“I like spending time in this street.”*
- Pedestrian - *“I can freely move around on the street.”*
- Vehicle - *“Driver behaviour is appropriate in this street.”*
- Economic - *“This street complements the economic activity.”*
- Safety - *“I feel safe and secure in this street.”*

Without a neutral or mid-point in the 6-point Likert scale, the participants were required to make a choice whether they tend towards ‘liking’ or ‘disliking’ the shared space objectives and then how strong that opinion is. It is, nevertheless, acknowledged that there was inherent bias due to the fact that the participants may genuinely be indifferent to the survey questions which could lead to nonresponse. The Likert scale departs from the originally proposed continuous scale of 0 to 5, which has been used for other purposes in measuring pavement serviceability or ride quality of road sections (Karndacharuk, Wilson, & Tse, 2011). Further, general participant and demographics data (e.g. purpose of the trip, age, gender and ethnicity) was collected in both surveys. The outcome of the qualitative perception survey was the median value of the rating scores, which is the KPI for each objective. The shared space objectives and KPIs were used as criteria for the following analysis process.

3.3.3 Analytical Hierarchy Process

It is proposed to utilise a concept known as the Analytical Hierarchy Process (AHP), which is one of the Multi-Criteria Decision Analysis methods, to determine the relative weights of selected key performance indicators in order to obtain an overall performance index. Developed by Thomas Saaty (1980), the AHP is a systematic method to compare a list of objectives or alternatives, and facilitate a complex multi-criteria decision-making process. The goal is to select the best from a number of alternatives based on various criteria and sub-criteria. It is able to capture both quantitative and qualitative evaluation measures into numerical scores for comparison. The AHP has been used in a wide range of disciplines, including engineering, social sciences, and economics (Saaty & Vargas, 2001) as well as in prioritising major transport projects (Su, Cheng, & Lin, 2006).

Unlike the majority of AHP applications that employs relative pairwise comparisons among alternatives (relative measurement), shared space schemes were evaluated against a standard or baseline using absolute measurement. Saaty and Vargas (2001) explain that absolute measurement, sometimes called scoring, is applied to rank the alternatives (e.g. shared space schemes) with regard to either the criteria (e.g. shared space objectives and quantitative performance indicators) or the ratings of the criteria (e.g. median survey ratings).

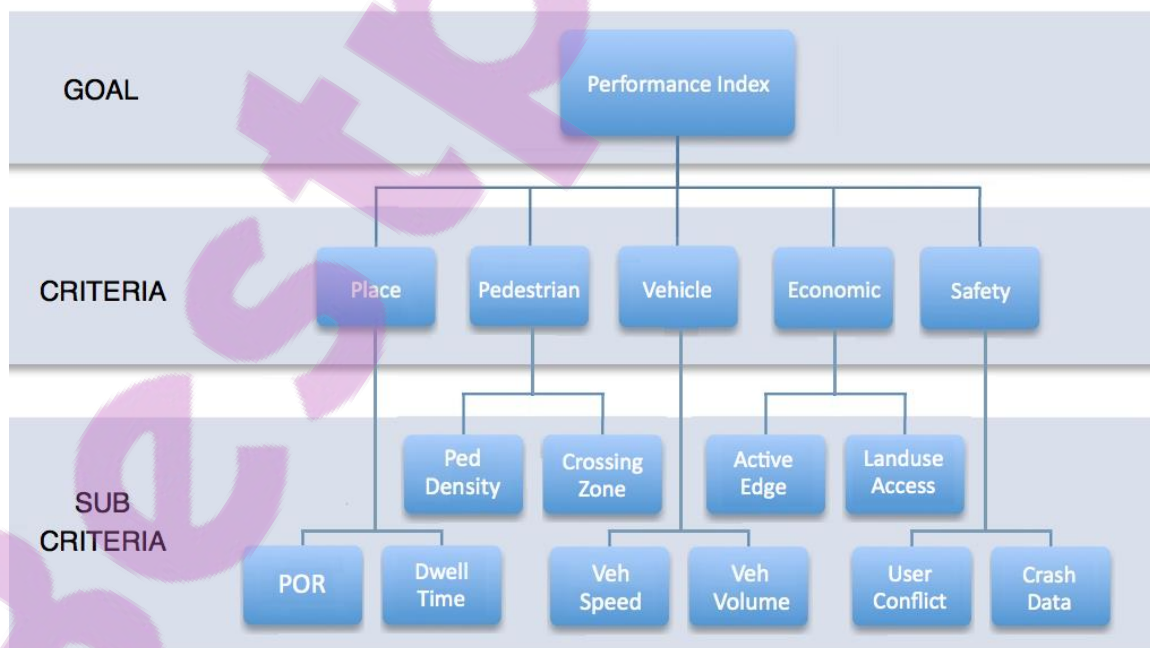


Figure 3.4 Quantitative performance hierarchy.

The first and most important part of decision making is to structure a hierarchy. The basic principle is to work down from the goal and ensure elements of same level are homogeneously comparable. Figure 3.4 illustrates a shared space evaluation hierarchy, incorporating the goal of the performance index, criteria and subcriteria for a quantitative model. It is noted that the quantitative model can later be updated to reflect the aim of the evaluation: criteria (objectives) and subcriteria (KPIs) might be added or removed. For the qualitative model, the hierarchical structure only contains the goal and criteria because the median rating value from the perception surveys is the KPI for each shared space objective at the Criteria level.

After the hierarchy is established, the importance (priority or weight) of each decision criteria or subcriteria can be determined. Pairwise comparisons of homogeneous elements are made in a matrix with a 1-9 scale to represent the intensity of importance. A value of 1 is when two criteria are equal in importance. The intensity of 9 is when criterion *i* is absolutely more important than criterion *j*, and reciprocally criterion *j* must be absolutely less important when compared with *i* with the reciprocal value of $1/9$.

Table 3.3 Pairwise comparison matrix for shared space performance criteria.

Criteria	Place	Pedestrian	Vehicle	Economic	Safety	Importance
Place	1	1/2	1/3	2	1/3	0.111
Pedestrian	2	1	1/2	3	1/2	0.185
Vehicle	3	2	1	3	1/2	0.265
Economic	1/2	1/3	1/3	1	1/4	0.073
Safety	3	2	2	4	1	0.367
Consistency Ratio = 0.029						

In determining the importance of shared space performance criteria based on the aforementioned hierarchy, a 5x5 matrix as displayed in Table 3.3 can be constructed. The intensity of importance for each pairwise comparison was initially decided by the author and checked against the consistency ratio once the matrix was complete to ensure consistent judgements. In addition, the validity of the output (priority or weight of each performance

criteria) was further evaluated via the qualitative study of expert interviews, and to a lesser degree, perception surveys, discussed in Chapter Six.

There are ten comparisons to be made for each triangular matrix where the (i, j) element is the reciprocal of the (j, i) element. Considering the Safety criterion on the last row for example, it is determined that Safety contributes stronger than other criteria in achieving the goal of the performance index at the importance intensities of 3, 2, 2 and 4 when compared with Place, Pedestrian, Vehicle and Economic, respectively. The relative importance (weight) of the criterion is then derived by normalising the intensity values of each column and averaging the values of each row. The weight of 0.367 for the Safety criterion is calculated as follows;

$$W_{safety} = \frac{1}{5} \left[\frac{3}{\left(1+2+3+\frac{1}{2}+3\right)} + \frac{2}{\left(\frac{1}{2}+1+2+\frac{1}{3}+2\right)} + \frac{2}{\left(\frac{1}{3}+\frac{1}{2}+1+\frac{1}{3}+2\right)} + \frac{4}{(2+3+3+1+4)} + \frac{1}{\left(\frac{1}{3}+\frac{1}{2}+\frac{1}{2}+\frac{1}{4}+1\right)} \right]$$

where, W_{safety} is the normalised eigenvector for Safety criterion.

The next step is to calculate a Consistency Ratio (CR) to measure how consistent the judgements have been in relation to samples of purely random judgements. Saaty (1990) suggests the value of CR should be less than 0.1 (i.e. an inconsistency of 10 percent or less) or otherwise the comparisons should be revised. For the matrix of performance criteria, the ratio is calculated as;

$$CR = \frac{CI}{RI} = \frac{\left(\frac{\lambda_{max} - n}{n - 1}\right)}{RI} = \frac{\left(\frac{5.128 - 5}{5 - 1}\right)}{1.12} = 0.029$$

where,

CI is the consistency index

RI is a random matrix (1.12 for n=5)

λ_{max} is the maximum or principal eigenvalue of the matrix

n is the number of criteria



3.3.4 Performance Index

The process of setting priorities for the subcriteria (quantitative KPIs) by comparing them in pairs was then undertaken for each parent criterion (shared space objective). The alternatives (shared space schemes) was rated and scored at the subcriteria level and weighted by the priority of the criterion. A radar chart in Figure 3.5 illustrates the importance of the criteria with the Safety criterion having the highest value of 0.367. A total ratio scale score, the performance index for each scheme, was derived from summing up the scores of these criteria.

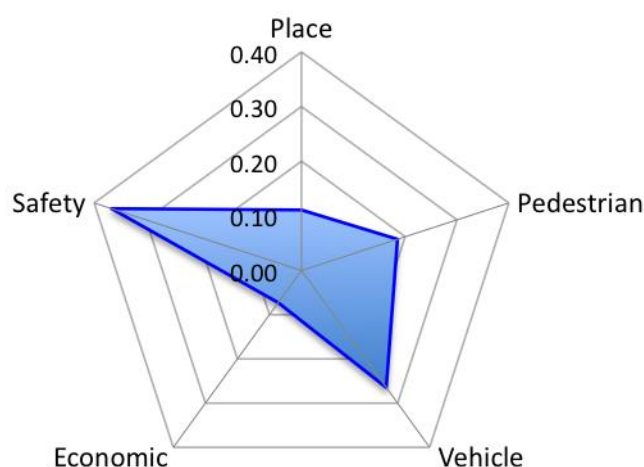


Figure 3.5 Priority of each shared space objective.

3.4 Quantitative Analysis of Pre-Implementation Data

The analysis process first considered the existing street and neighbouring environments of all study areas in order to better understand how each street was being used, and to acknowledge the spatial and physical characteristics as well as the surrounding land use. The Elliott Street study area was selected to demonstrate how the quantitative analysis was conducted using the 'before' data from the video surveys and traffic tube counts. Finally, a comparison of the pre-implementation data of the three case studies based on pedestrian density and active frontage is shown and discussed.

The result of this preliminary analysis was presented in the Institution of Professional Engineers New Zealand (IPENZ)'s Transportation Group Conference (Karndacharuk, Wilson, & Tse, 2011).

3.4.1 Street Characteristics

All of the three sites were located in the Queen Street Valley Precinct designated under the Operative District Plan (AkCC, 2005). The precinct consisted of the most intensive retail activities within Auckland and a significant portion of commercial offices, thereby having the highest level of pedestrian activity within the Auckland region. The diversity of architectural character of the buildings (e.g. ages, style, levels of detail and height), and the streetscape contributed to a sense of place. The street characteristics of each study area, exclusively within the road reserve, can be summarised in Table 3.4 below.

Table 3.4 Street characteristic summary for the three study areas.

Study Area		Street Characteristic							
Street	Sub-section	Classification	Corridor		Vehicular Traffic			Pedestrian Traffic	
			Width (m)	Length (m)	Traffic Operation	Carriageway Width (m)	On-Street Parking	Footpath Width (m)	Extra Ped Facility
Elliott	Elliott St Nth	Local Rd	14.2	60	One-way NB	10	Vehicle	2.4	-
	Elliott St Sth	Local Rd	14.2	130	One-way NB	4-8	Vehicle	3.6	Verandah, seating & waiting area
Lorne	Lorne St	Local Rd	17.6	100	One-way NB	7-11	Veh & motorbike	3	Verandah & waiting area
Fort	Jean Batten Pl	Collector Rd	12.4	40	One-way NB	4	Prevented	4	-
	Fort St	Collector Rd	20	90	Two-way	12	Veh, taxi & police	4	Verandah
	Fort Lane	Local Rd	6	100	One-way NB	6	Veh & motorbike	-	-

Elliott and Fort Street areas were further divided into sub-sections in order to recognise their unique existing functions for vehicular and pedestrian traffic. The street classification was based on the current road classification hierarchy under the Central Area District Plan.

It was observed that the inner city streets of Jean Batten Place and Fort Lane had narrower road reserve widths than the standard guidelines in the District Plan in accordance with its classification i.e. minimum of 17m and 14m for Collector and Local roads respectively. With the 6m-corridor width on the Fort Lane section, pedestrians currently shared the space with other users such as cars and service trucks. Unlike other spaces, the Jean Batten Place section did not accommodate on-street parking, which was evident by the presence of broken yellow lines or the no stopping at all times restriction.

Additionally, all road sections, except Fort Street had a one-way traffic operation, which was historically introduced to primarily accommodate the Mobility function of vehicular traffic in these areas. Although the one-way arrangement could be seen to significantly

contribute to the vehicle dominance within the (road) space, there was another key contributing factor being the use of the private land abutting the street and how it actively interacts with the public space. This is further explored in the following section.

3.4.2 Adjacent Land Use with Active Frontage

Table 3.5 gives a summary of the adjacent land-use activities along with the frontage measurement for both day and night time periods. Active frontages / edges can be defined in a number of ways. In this research, it was defined as a distance along a property boundary that provides transparent frontage so that the activity generated within the property (i.e. building) can be visible from the street at relatively the same levels. There must be at least one pedestrian access off the street for each property.

Table 3.5 Adjacent land-use and frontage summary for the three study areas.

Study Area		Adjacent Landuse				
Street	Sub-section	Overall Frontage (m)	Daytime (6am-6pm)		Nighttime	
			Active Edge (m)	Activity	Active Edge (m)	Activity
Elliott	Elliott St Nth	125	30 (24%)	Retail, takeaway & public parking	5 (4%)	Takeaway & public parking
	Elliott St Sth	245	220 (90%)	Retail, café, restaurant, takeaway & hotel	55 (22%)	Café, restaurant, hotel & bar
Lorne	Lorne St	180	80 (44%)	Library, café, restaurant & unused theatre	10 (6%)	Restaurant & bar
Fort	Jean Batten Pl	80	40 (50%)	Retail	0 (0%)	-
	Fort St	165	135 (82%)	Retail, café, takeaway, convenience store, backpacker & police	50 (30%)	Takeaway, convenience store, backpacker
	Fort Lane	200	15 (8%)	Retail, café, restaurant & public parking	25 (13%)	Restaurant & bar

Only sections of Elliot Street South and Fort Street had active frontage greater than 80% of the overall frontage length, reflecting the diversity of adjacent land-use activities on the streets in comparison to the others. Furthermore, the active frontage of the Fort Lane section at night was greater than that of the daytime, which is because of the bar and night club activities.

The relationship between the active frontage of the adjacent land-use and the pedestrian and vehicular data is further discussed in the following sections.

3.4.3 Pedestrian and Vehicle Data Analysis

Using the Elliott Street case study as an example of the quantitative data analysis process, Figure 3.6 below illustrates the results of the pedestrian and vehicle data analysis for a typical day on 27 September 2010 in good weather conditions. The pedestrian density is a ratio of the pedestrian numbers (p) relative to the area (m^2) allocated for pedestrians (e.g. footpath, seating and waiting area). Subsequent analysis examines the pedestrian density taking into account the whole road space of the shared spaces.

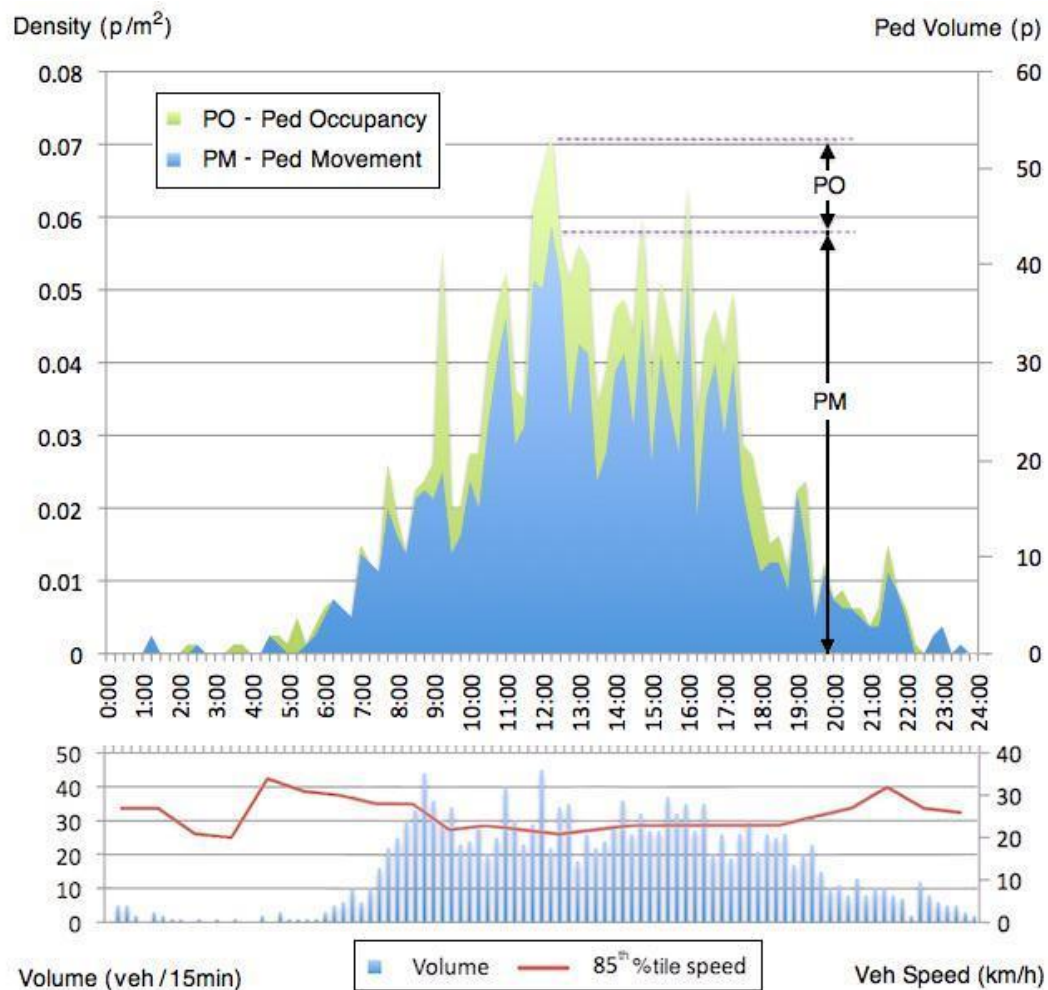


Figure 3.6 Result of ‘before’ data analysis for Elliott Street area.

The pedestrian traffic volume and the corresponding density peaked at 12.15 pm, which reflected the high demand of the space for transport functions during the typical business lunchtime period. However, it was 9.15 am when the Occupancy portion outweighed the amount of pedestrians using the space for Movement functions (at a split of 56/44 for PO and PM respectively). It is observed from the video footage that the seating and waiting

areas are well utilised for social street activities (e.g. eating and chatting in a group) during these peak hour periods.

The overall percentage of Occupancy pedestrian traffic out of the 24-hour total was 22%, which is indicated by the green area of Occupancy in the upper graph. It was anticipated that with the implementation of the Shared Space concept to enhance the 'Place' amenity, the Occupancy proportion will increase significantly, especially during the day.

For the vehicular traffic, the 15-minute one-way northbound traffic volume (based on the tube counters) was similar to the pedestrian profile, reaching a highest peak at lunchtime with a similar morning peak at 8.45 am. The five-day average daily one-way traffic was 1,800 vehicles per day with a peak of 150 vehicles per hour. This is reasonably typical for a local one-way street in a built-up CBD area; even though based on the surrounding land-use catchment, the majority of the vehicular traffic used the street as a thoroughfare rather than to access the adjacent land use (which is the primary function of a local road).

It is interesting to note that the current 85th percentile speed over the 24-hour period was 26 km/h given that it was a relatively short, one-way street with a posted speed limit of 50 km/h. This in itself demonstrates that the 50 km/h speed limit was inappropriate. It also had a relatively low traffic volume, and the majority of the street had 'no stopping at all times' restrictions. Additionally, the peaked pedestrian density of 0.07 p/m² (or pedestrian space of 14.3 m²/p at LOS A) was very low based on the theoretical capacity in accordance with Highway Capacity Manual's pedestrian Level of Service assessment (TRB, 2000).

Without any vertical speed calming devices such as speed humps, the vehicular travelling speeds were naturally suppressed by the existing use of unique paving surfaces as well as the diverse adjacent land-use activities with active frontages. The very active edges on the Elliott Street South section during daytime periods generated frequent demand for crossing movements for pedestrians, and in turn evidently reduced vehicle speeds.

3.4.4 Before Pedestrian Data Comparison

Figure 3.7 depicts the early ‘before’ data comparison for the three case study streets during the daytime period between 6 am and 6 pm in normalised density. The normalised density is the number of pedestrians averaged over the 15-min snapshots before and after a particular time per square metre of allocated pedestrian area within the road reserve. The average normalised density for the Elliott, Lorne and Fort Street areas were 0.039, 0.023 and 0.020 p/m² respectively.

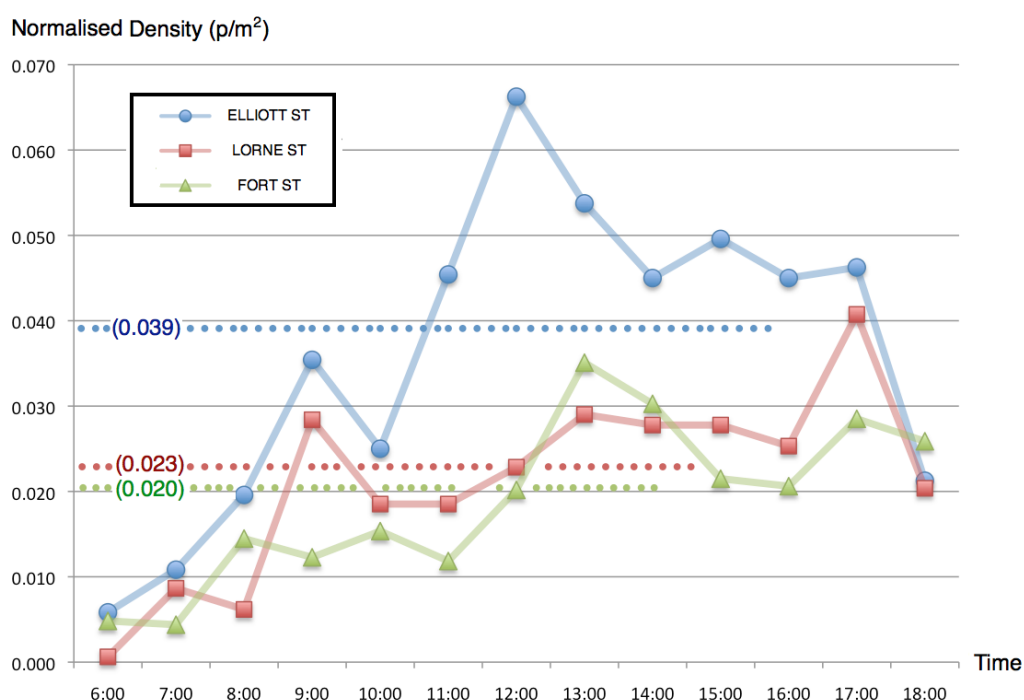


Figure 3.7 Preliminary comparison of pre-implementation pedestrian data.

As discussed earlier for the density profile and the adjacent land use, the Elliott Street area had a much stronger and active frontage with an average of 68% in comparison to Lorne Street and Fort Street of 44% and 43% respectively. The 68% average for Elliott Street is calculated by dividing the total active edge (30m+220m) by the total frontage (125m+245m) as per the data shown in Table 3.5. Based on the pedestrian data comparison, the level of active land-use frontages had, as would be expected for a vitalised CBD area, a high correlation with the amount of pedestrians within the street corridor.

3.5 Conclusions

This chapter puts forward a multi-faceted performance evaluation process. It takes into account three functions of an urban road space, namely Mobility, Access and Place. The framework incorporates the identification of objectives and key performance indicators and the collection of both quantitative and qualitative data. The Analytical Hierarchy Process (AHP) was used as an analysis and evaluation tool to achieve a universal performance index. By modifying objectives and revising the analysis model, the framework was able to accommodate schemes with visions and motivations differing from those being discussed in the chapter.

The research utilised quantitative and qualitative data obtained from the three shared space projects in the Auckland CBD, being the Elliott, Lorne and Fort Street areas. The qualitative data, using the video survey, were collected between 2010 and 2013 at the same relative time periods. The ‘before and after’ analysis of the 2010 and 2011 data was undertaken (Karndacharuk, Wilson, & Dunn, 2013) with an emphasis on pedestrian performance measures. The qualitative data collection of the on-street and expert interview surveys was undertaken in 2013 along with the testing of this multi-faceted evaluation framework in producing a reliable shared space performance index.

With the established evaluation framework, there was an intention during the analysis stage to correlate a quantitative with a qualitative AHP model to determine whether the quantitative matrices alone could consistently produce the performance index, thereby allowing the evaluation process to primarily rely on objective data without the need for subjective interviews and perception surveys.

CHAPTER FOUR

QUANTITATIVE STUDY: PEDESTRIAN PERFORMANCE EVALUATION

Given the variety of shared space user groups, pedestrians emerge as one of the most important groups in the evaluation process, not only because of the shared space objective to provide for better pedestrian level of service and amenity, but also, as demonstrated in this chapter, the leading role of pedestrians in enabling a shared street to be successful, particularly creating a sense of place.

This chapter, therefore, presents a study of pedestrian-related performance measures developed under the multi-faceted methodological framework, discussed in Chapter Three, to quantitatively evaluate the successfulness of shared space schemes based on the study areas in Auckland's city centre. The analysis of the 'before and after' implementation data revealed a positive result to pedestrian performance across all sites based on 24-hour pedestrian profiles, pedestrian trajectories, dwell times and stationary activities. A comparative analysis of the 'after' data highlighted the importance of the active frontage in enabling a lower (vehicular) speed environment in relation to the number of pedestrians within the shared space.

Some background information and discussion documented in Chapters Two and Three is presented again in this chapter to provide a contextual framework, specifically for this quantitative study. The results of the study are included in Karndacharuk, Wilson, & Dunn (2013a).

4.1 Introduction

A shared space is a road space where all road users (including pedestrians, cyclists, drivers and people with disabilities) are encouraged to occupy and share the same public space with little physical segregation, particularly between pedestrians and vehicles. Unlike a conventional road with carriageway and footpath, distinct design features of a relatively

level surface with minimum use of traffic control devices (signage and marking) are employed to reduce the dominance of the automobile. Similar to a pedestrian mall, a design approach for shared spaces aims to create a lively quality of the street environment. It encourages a wider range of pedestrian and community activities to spend time within the space (public right-of-way) that functions as a destination in addition to serving the transport corridor purposes.

The shared space concept is one of many approaches developed in response to the dominance of the automobile and the realisation of the adverse environmental and social impacts due to decades of planning and design primarily focused on the priority for motor vehicles. Like traffic calming principles, the concept of shared space evolved from the *Woonerf* idea. The *Woonerf* concept was first introduced in 1965 by Niek De Boer, Professor of Urban Planning in the Netherlands who advocated the street as a living area for neighbourhood residents. The initial experimental application of the *Woonerf* idea was in the form of residential shared streets (Woonerven) undertaken to integrate vehicular traffic into social residential space (Hass-Klau, 1990). The idea was also contemporary with, and arguably influenced by the notion of environmental areas in the 1963 *Traffic in Towns*, commonly known as the Buchanan Report (Southworth & Ben-Joseph, 2003). An environmental area, being a good environment where people can live, work, shop and move around on foot in a reasonably safe and comfortable manner, incorporates a network of local distributors and access roads where up to a point, a mixture of pedestrians and vehicles is not seriously harmful (MoT, 1963).

The idea of road user integration was subsequently embraced in many countries such as Denmark, Germany, the United Kingdom (UK), Switzerland, Japan and Israel (Ben-Joseph, 1995) along with the United States (Bain, Gray, & Rodgers, 2012; Hiatt & Supawanich, 2010), Australia and New Zealand (NZTA, 2009), generating a number of similar terms to describe a shared (road) space, including, shared street, living street, festival street, encounter zone, shared zone and home zone. In the UK, a residential shared space is called a home zone with one of the initial schemes implemented in 1969 (Biddulph, 2003). Although the applications of the *Woonerf* concept were extended to town centres and shopping areas in the 1980s in Western Europe (Pharaoh & Russell, 1991), there has been in the past few decades a rise of the applications of the shared street concept in inner city areas. A prominent figure in the recent development of the concept is Hans Monderman

who pioneered the idea as a means to influence traffic speeds and driver behaviour to address transport safety issues (Hamilton-Baillie, 2008a, Kaparias et al., 2010). The UK Department for Transport published a guideline document on Shared Space (DfT, 2011). Although Moody and Melia (2011) discussed some shortcomings of the published guideline, the document provides useful information on design considerations and the process of developing shared space schemes.

4.2 Study Background

In this section, the place function of an urban street is briefly discussed. Place-making is one of the main objectives in transforming a street into a shared space along with an aim to reduce vehicular dominance in the road environment. Since the operation and behaviour of various road users influence one another, a methodology for evaluating pedestrian performance is integrated into the shared space performance evaluation. This evaluation consists of the identification of the shared space objectives, performance indicators and quantitative data collection and analysis.

Data used for the analysis in this chapter is part of this doctoral research project at the University of Auckland with support from Auckland Transport. The goal of the research is to develop a multi-faceted performance evaluation framework for shared spaces based on both quantitative and qualitative measures and ‘before and after’ implementation data (Karndacharuk, Wilson, & Tse, 2011).

4.2.1 Place Function

It has been recognised that besides enhancing pedestrian priority and level of service, one of the key objectives of creating a shared space is to use the road space as a destination or a place for street and social activities. Consequently, as depicted in Figure 3.2 in Chapter 3, a shared space as a public urban area exclusively situated within the road reserve performs the three functions of Place, Mobility and Access. The diagram also recognises supplementary functions of a street towards surrounding areas and land use activities outside the road reserve such as economic, social, cultural, historical and environmental amenity that contribute to the formation of a greater sense of place within the road space. It is noted that the three-function system is divergent from the conventional street design and classification (with only ‘Mobility and Access’ functions) typical of traffic engineering

practices and management (for instance; Ogden & Taylor, 2003; Homburger et al., 2007). The more recently developed ‘Movement and Place’ functions (CIHT, 2010) as incorporated in Figure 3.2 is used to characterise streets based on the degree of through movement and the interaction of the space users between themselves and with their surroundings.

4.2.2 Shared Space Objective

In order to enable an appropriate performance evaluation of pedestrians and vehicles within a shared space environment, the objectives of shared spaces required establishing. It is acknowledged that the motivations and corresponding purposes for developing a shared space scheme are context sensitive; therefore vary for different locations. Nonetheless, the effectiveness of a shared space can be determined based on how successful the public space performs its functions of place, mobility and access. In general accordance with what was suggested in a report prepared for the UK Department for Transport (DfT, 2009), the primary objectives of shared spaces in an inner city area can be outlined as follows:

- **Placemaking:** the street should provide better use of public space via a lively quality of the environment that attracts users to spend time within the space. It is also reflected in a wider range of street activities.
- **Pedestrian focus:** this objective involves an environment with improved pedestrian priority and the ability to walk along, across and freely roam the street.
- **Vehicle behaviour change:** a goal is to reduce the current dominance of the motor vehicle and the driver in the environment by way of low vehicle speeds and volumes. This change of priority should enable the driver of a vehicle to be more aware of other road users.
- **Economic impetus:** a road space should complement the operation and prosperity of the surrounding businesses. Conversely, the presence of business related users would enhance the range and type of activity in the public space.
- **Safety for all users:** shared spaces are to provide a safer environment for all users, including cyclists, the elderly and children.

4.3 Study Methodology

4.3.1 Pedestrian Performance Indicator

With the aforementioned shared space objectives, meaningful and measurable key performance indicators (KPIs) can be determined to evaluate how successful a shared space is in relation to a number of activities such as those of pedestrians, vehicles and adjacent land uses. Pedestrian performance can then be measured by considering how well pedestrian activity contributes towards fulfilling shared space objectives in ‘before and after’ implementation analysis based on a scheme-specific consideration. Table 4.1 exemplifies selected KPIs for shared spaces together with corresponding units and data sources.

Table 4.1 Shared space key performance indicators and data sources.

Objective	Key Performance Indicator	Unit	Data source
Place	Pedestrian Occupancy Ratio	%	Video survey
	User dwell time	min	Video survey
Pedestrian	Pedestrian density	p/m ²	Video survey
	Pedestrian trajectory	-	Video survey
Vehicle	Motor vehicle speed	km/h	Traffic counter
	Motor vehicle volume	veh/h	Traffic counter
Economic	Active frontage	m	Measurement
	User accessing adjacent land use	p/h/m	Video survey
Safety	User conflict	# of conflicts	Video survey
	Reported crash history	# of crashes	CAS database

Owing to the place function of a shared space and the space allocation where pedestrians are able to access virtually the whole area within the road reserve, some of the pedestrian level-of-service (LOS) methodologies set out in the Highway Capacity Manual (TRB, 2010) to evaluate an urban street segment in terms of its service to pedestrians are not by themselves applicable, and in some cases in conflict with the placemaking objective. For example, while examining footpath activities in Hawaii, Kim et al. (2006) conclude that street entertainers and buskers had a negative impact on pedestrian LOS whereas the same impediments to the pedestrian movements and footpath capacity could be considered positive in a shared space environment. Nonetheless, some performance measures in the HCM are relevant to the shared space study such as average or peak pedestrian space (m²/p), which is an inverse of pedestrian density (p/m²).

4.3.2 Study Area

The research was undertaken in Auckland, New Zealand's largest city with a population of approximately 1.5 million. Three road sections in the city centre were used for the analysis in this chapter.

- Elliott Street (between Darby Street and Wellesley Street West)
- Lorne Street (between Wellesley Street East and Rutland Street)
- Jean Batten Place (between Fort Street and Shortland Street)

Each section was selected from the above three shared spaces. Figure 1.2 illustrates the location of each section in relation to the three shared spaces. Refer to Section 3.4 for spatial and physical street characteristics of the three shared spaces along with the surrounding land-use zoning.

4.3.3 Street Design as Shared Space

The three shared space schemes were designed with an aim to reduce visual sign clutter in the streetscape. The lateral cross-section was relatively flat without an obvious vertical elevation difference (i.e. kerbs) to separate the carriageway from the footpath. The level surface incorporated specially designed stone paving to create a distinct space with the sense of place by offering vitality, texture and interest.

The design of the shared space considered the need of the visually impaired, mobility impaired and all road users (including young and old) by placing a 600mm wide tactile delineator band between the central Shared Zone and the marked Accessible Route (pedestrian and scooter only zone). This accessible route on either side of the street was a minimum of 1.8m wide to warn the visually impaired about the possibility of moving vehicles. Refer to Figure 2.5 in Chapter Two for spatial allocation of the CBD shared spaces.

4.3.4 Data Acquisition Methods

As indicated in Table 4.1, the main data collection methods in this chapter were a video survey using cameras from which pedestrian and vehicular data can be extracted along with the use of space and a vehicle traffic survey. The 'before and after' data were collected in relatively the same time periods in the spring months from September to November in 2010 and 2011.

Video Survey

A number of network cameras were used to continuously record pedestrian and vehicle activity. Various automated analysis techniques using video data have been developed for pedestrian-vehicle conflict studies (for example; Ismail, Sayed, & Saunier, 2010), however most methods are not transferable and are designed for a specific purpose or video camera setup. For this research, it was imperative to ensure that the placement and setup of the cameras resulted in the appropriate capture of the required movements and interaction of shared space users. As illustrated in Figure 4.1 using the Fort Street area for example, four cameras were placed on the mezzanine floor of the downtown Police Station.

Vehicle Traffic Tube Counter

During the time of the camera recording, a traffic survey using tube counters was implemented on all sites to obtain the vehicular based traffic speed, volume and composition data.

Crash History

Recorded crash data were obtained from the Crash Analysis System (CAS), managed and maintained by the New Zealand Transport Agency. The CAS system is a geographic based system and integrates three primary sources of road safety data: crash reports, diagrams of crashes and traffic data. The crash data collection is based on Police reported fatal, injury and non-injury crashes. Multiple contributing crash factors are categorised under Human, the Road Environment and Vehicle factors, allowing detailed crash analysis to be undertaken.

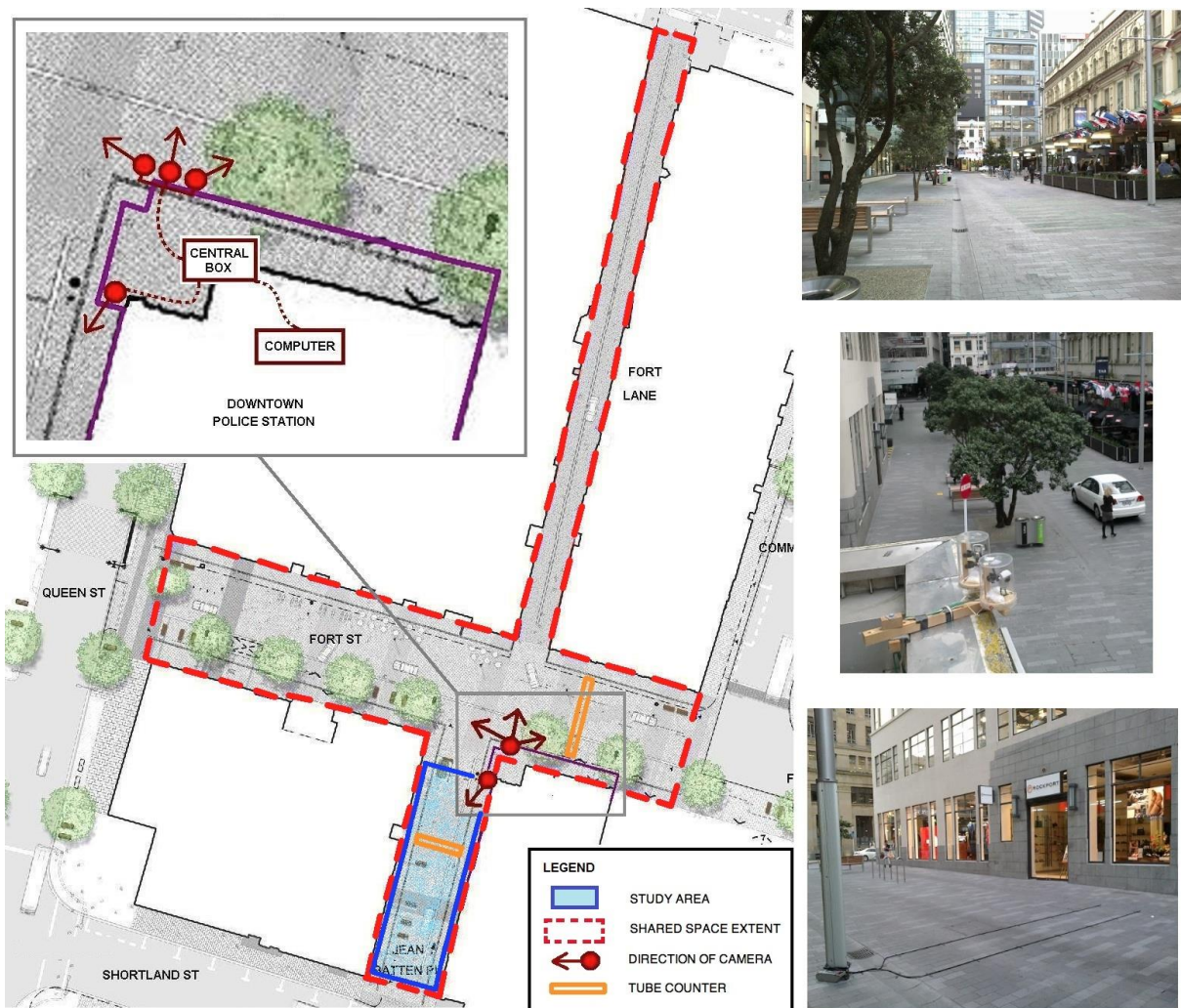


Figure 4.1 Data collection in Fort Street area.

4.3.5 Pedestrian Analysis

The ‘before and after’ pedestrian performance data were extracted from the video surveys. In this analysis, video footages on a Thursday with generally good weather conditions were selected to represent a typical use of the street. Vehicle data from automated traffic counters were used in the comparative analysis between the three sites. The analysis of the pedestrian data for each site from macro to micro time period processing can be explained in the following steps:

1. **24-hour profile:** the video footage was examined for every 15-minute interval over a 24-hour period to produce a general profile of pedestrian demand. The pedestrian data were classified into two different groups: one is Pedestrian Movement (PM) and the other Pedestrian Occupancy (PO). The PM group represents the pedestrians

who walk along and across the space for transport movement functions (i.e. Mobility and Access) whereas the PO group includes people who spend time within the shared space, and generally use the space for the 'Place' function. A review of a 10-second period immediately before and after the 15-minute snapshot is undertaken to clearly differentiate the two groups. The overall percentage of the PO group (PO_{24h}) represents the number of stationary pedestrians out of the 24-hour total.

2. **15-minute peak zone:** a peak period of 15 minutes, which was identified from the 24-hour profile of the 'after' scenario, was then used for detailed analysis. The analysis zone, which is the same for both the 'before and after' scenarios, was limited to approximately 40m in corridor length (although the width varies from site to site) that exhibited the greatest pedestrian activities during the peak period. In order to understand user behaviour in the 'before and after' shared space implementation, pedestrian trajectories for the PM group and the dwell times and stationary activities of the PO group are manually extracted from the footage at 5-minute intervals. In other words, the pedestrians who occupy the road space within the 40m zone at the zero, fifth, tenth and fifteenth minutes of the peak period are observed and tracked. The observations were also extended backwards in time to determine the dwell time.

In order for a comparison of similar shared space environments to be made, relevant pedestrian analysis data were converted to a standardised unit that can be used for benchmarking purposes. For example, the 24-hour profile employs the pedestrian density, which is a ratio of the pedestrian numbers (p) relative to the corridor area (m^2). Although only footpath areas are theoretically useable for pedestrian spaces in the 'before' situation of a conventional road, the whole road space is used for the density calculation in the 'before and after' analysis to enable a common comparison.

4.4 Results and Discussion

This section first presents a summary of the analysis results for each street section. The discussion of pedestrian performance aims to assess how well the post-implementation outputs contribute to fulfilling the shared space objectives previously mentioned. Subsequently, the results of the three sites were compared to show the extent of the effects from other factors such as vehicle speeds and volumes on pedestrian performance.

With limited time and therefore limited recorded crash data since implementation, the ‘after’ safety scenario had not yet been able to be thoroughly investigated. However, positively as of November 2012, there were no recorded injury related crashes for the three study areas since the practical completion in August 2011.

4.4.1 Elliott Street Pedestrian Performance

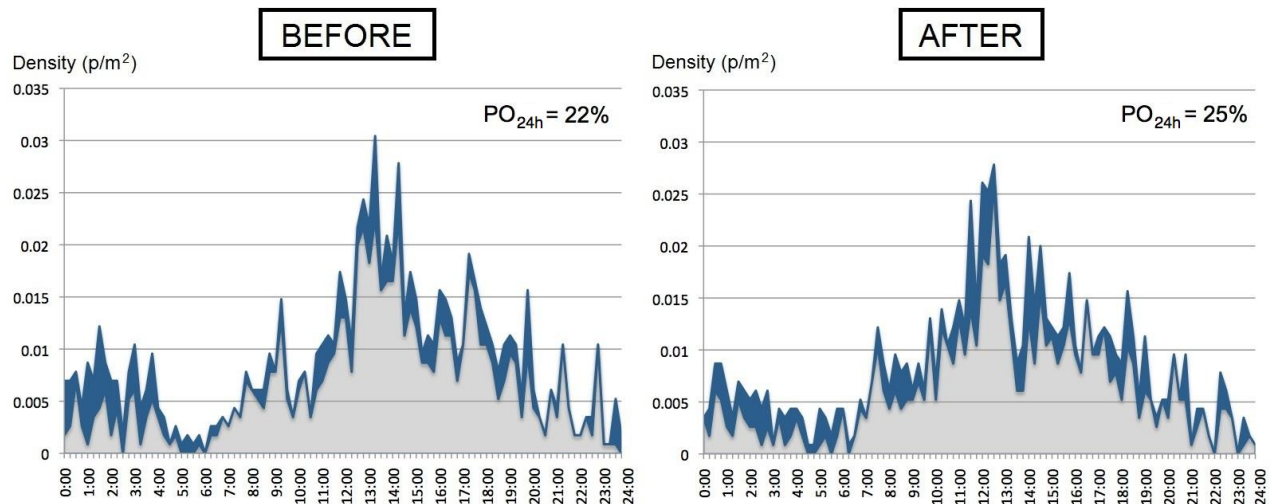
Apart from being a key north-south pedestrian connection (serving the Mobility function), this section of Elliott Street plays an important role in providing pedestrian access to retail outlets, cafes, and eateries in the daytime along with restaurants, bars and clubs at night. Consequently, pedestrian performance for the Elliott Street study area was influenced by both daytime and night-time land use activities. Additionally, under the New Zealand Historic Places Act, there are scheduled heritage buildings that have frontage access from Elliott Street. The previous design of this one-way street in the ‘before’ period comprised the use of paved surfaces for a staggered carriageway and pedestrian area with mountable kerbs and bollards for separation.

The ‘before’ and ‘after’ pedestrian data for the Elliott Street section were based on the video surveys on 23 September 2010 and 29 September 2011 with generally fine weather conditions. The results of the analysis are illustrated in Figure 4.2. As shown on the pedestrian profiles in Figure 4.2(a), the shared space upgrade does not generally change the pedestrian usage over the 24-hour period with peaks during the lunchtime period. Figure 4.2(b) illustrates the pedestrian trajectories of the PM group during the peak period of investigation (12.15-12.30) with the small orange circles indicating the location of where people (PO) stayed within the period. The ‘after’ diagram reveals an improved environment

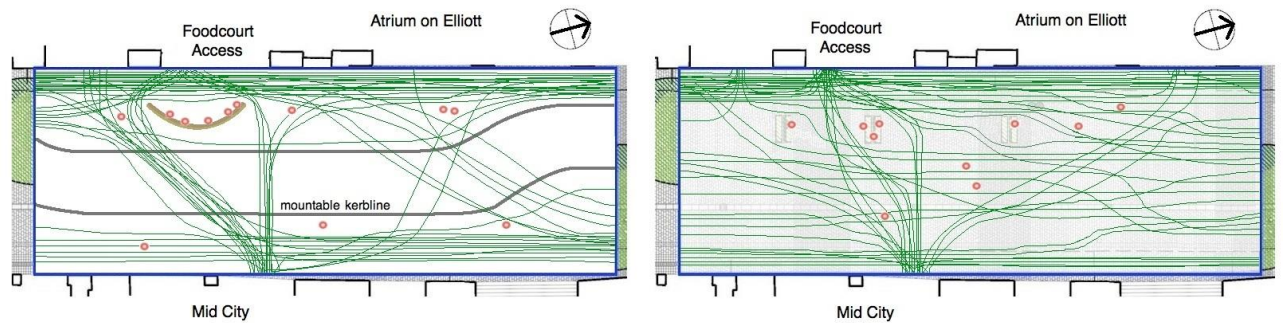
where pedestrians are more comfortable to walk along and across within the whole space, especially in the area allocated for the vehicular travelling lane.

The overall percentage of the PO group (PO_{24h}), as indicated in Figure 4.2(a), increases from 22% to 25%. The removal of the large curved seatings and the reduction of freestanding benches within the 40m-long selected area certainly contribute to a lower portion of the 'Sitting' activity in Figure 4.2(c). Unlike the Lorne Street and Jean Batten Street sites, only 'Sitting' and 'Standing' activity types can be identified from the footage review as the cameras were set up on the sixth floor of the nearby building. Figure 4.2(d) shows an average dwell time increase of 36 seconds for the PO group after the shared space implementation.

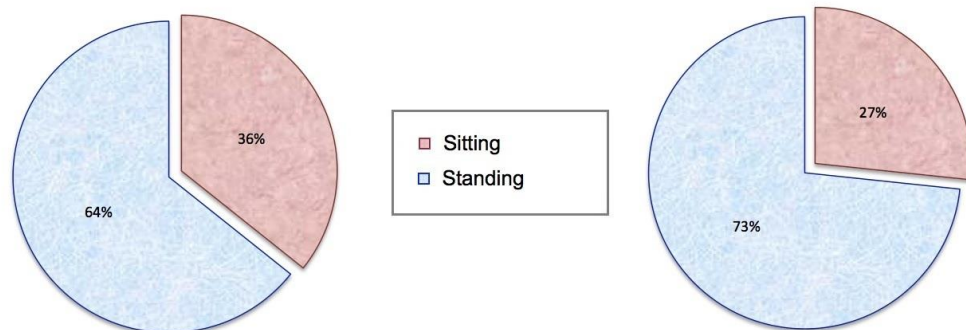
It important to note that while the PM trajectories indicated an improvement on pedestrian priority in the Elliott Street, other measures of the PO ratios and dwell times did not entirely show a positive transformation because these changes were relatively small and may not be statistically significant.



(a) 24-hour pedestrian profile (PM lower area in grey / PO upper area in blue)



(b) Pedestrian Movement (PM) trajectory during the peak period (12.15-12.30)



(c) Pedestrian Occupancy (PO) activity during the peak period (12.15-12.30)



(d) Pedestrian Occupancy (PO) dwell time during the peak period (12.15-12.30)

Figure 4.2 Pedestrian performances in Elliott Street section.

4.4.2 Lorne Street Pedestrian Performance

Pedestrian performance for the Lorne Street study area predominantly involved trips related to the central city library, which takes up one complete side of the street frontages. On the opposite side, the unoccupied St James Theatre building currently generates no pedestrian demand. The main design element of the shared space transformation besides the paved level surface is the conversion of retaining walls and adjacent on-street parking spaces on the library side to sitting steps, which provide spaces for informal outdoor seating.

The ‘before’ and ‘after’ pedestrian data for the Lorne Street section were based on the video surveys from 25 November 2010 and 6 October 2011 with good weather conditions. The results of the analysis are illustrated in Figure 4.3. As shown on the 24-hour profiles in Figure 4.3(a), the shared space upgrade has altered the overall profile of pedestrian demand, particularly during lunchtime hours (11 am to 2 pm) where the number of pedestrians almost doubled. The PO_{24h} increased from 26% to 36%, which is a very positive result based on the placemaking objective. It is noted that the peak at 9 am for both scenarios reflects people who waited for the library to open.

Figure 4.3(b) illustrates the pedestrian trajectories of the PM group during the peak period of investigation (13.30-13.45). Although the majority of movements occurred on the eastern side along the central library frontage, it is observed that like in the Elliott Street case study, pedestrians in the ‘after’ scenario moved around more freely than the ‘before’ scenario. Figures 4.3(c) and 4.3(d) display pedestrian activities and dwell times of those under the PO group and occupied the space as indicated in the small circles in Figure 4.3(b). The social activity of ‘Chatting’ type increased significantly from 29% to 47% along with more variety of the activity types. ‘Using laptop’ teenagers who utilised the library’s free internet access contributed the most to the dwell time increase from 3 minutes 48 seconds to 20 minutes 54 seconds.

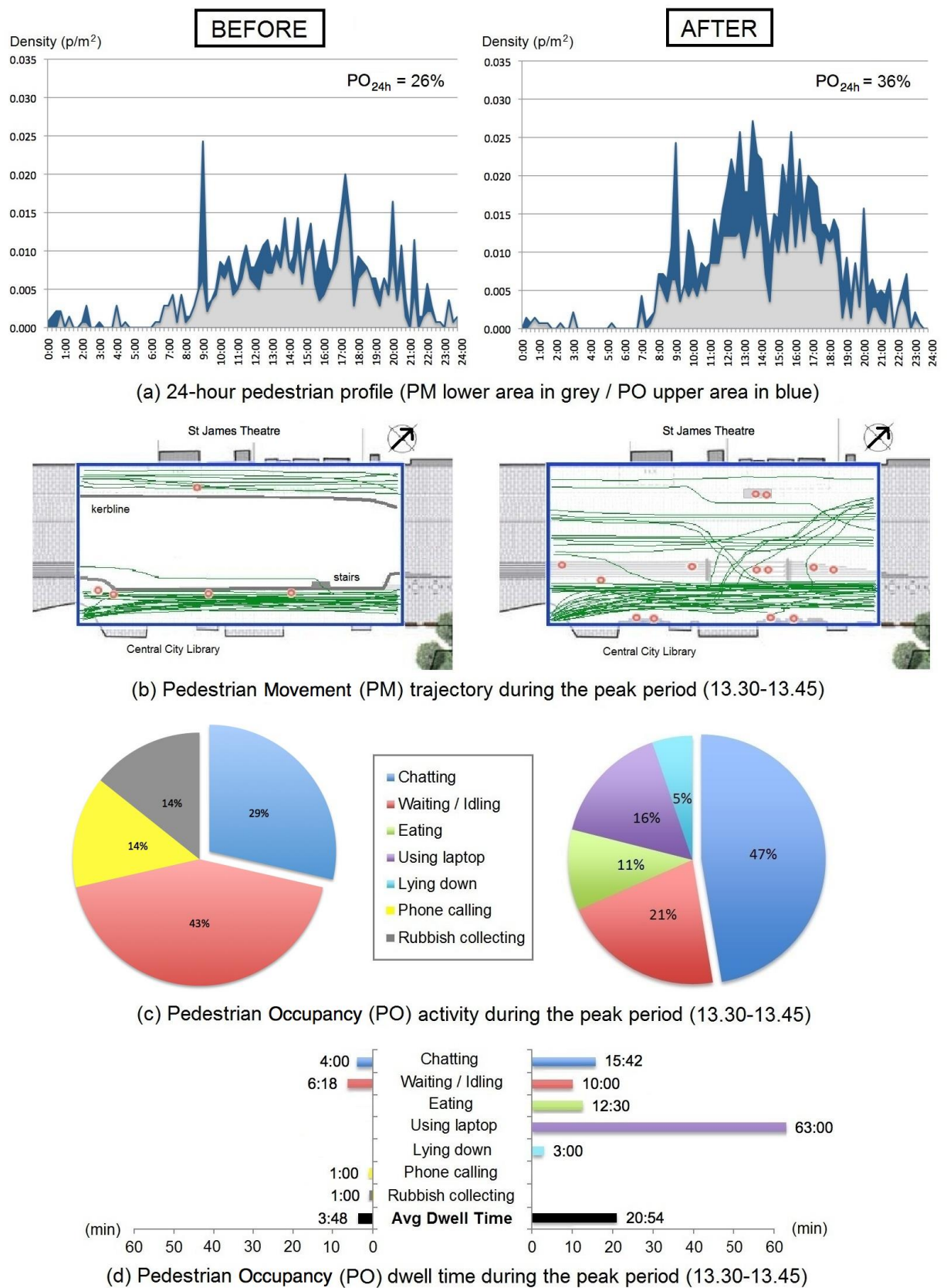


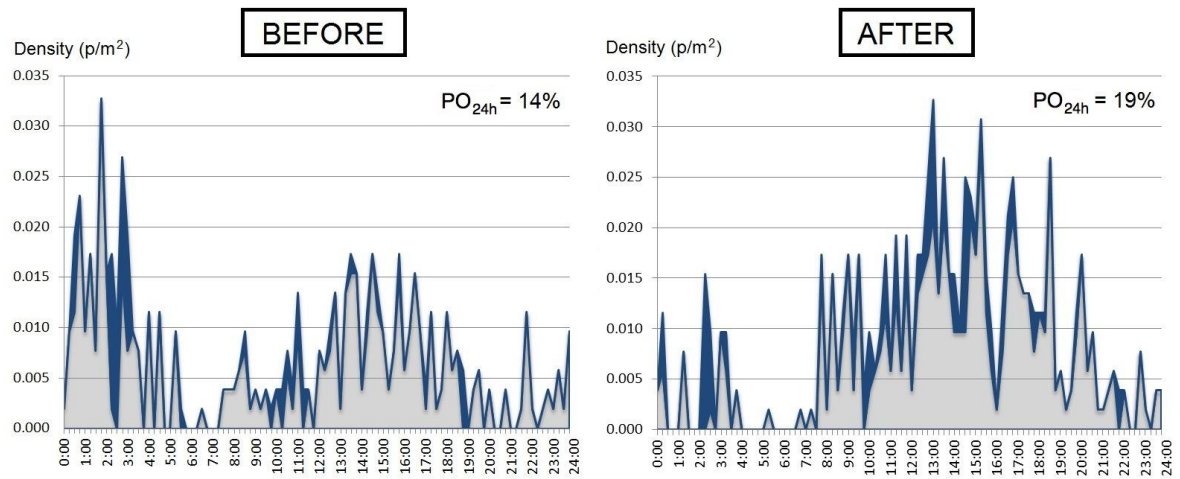
Figure 4.3 Pedestrian performance in Lorne Street section.

4.4.3 Jean Batten Place Pedestrian Performance

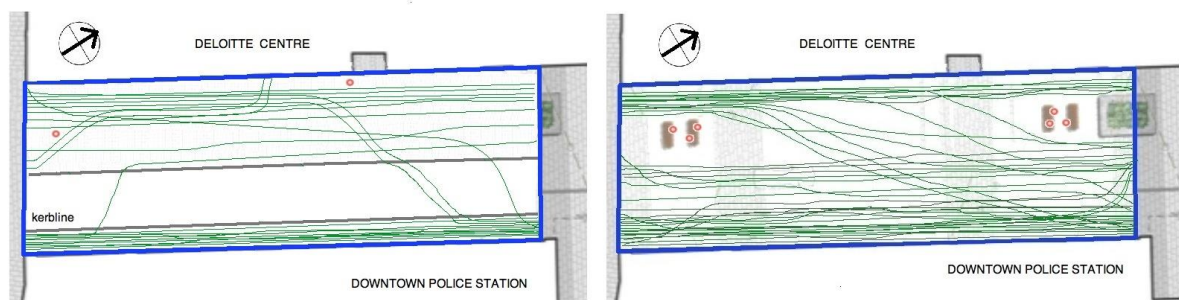
The ‘before’ and ‘after’ pedestrian data for the Jean Batten Place section were based on the video surveys on 2 September 2010 and 22 September 2011 with good weather conditions. The results of the analysis are illustrated in Figure 4.4. As illustrated in Figure 4.4(a), the pedestrian performance for the ‘before’ scenario was dominated by night-time activities. Pedestrians associated with the popular nightclubs on Fort Lane along with other bars and clubs in adjacent areas occupied a wider footpath on the western side next to the Deloitte Centre site. The decrease of night-time pedestrians in the ‘after’ scenario is likely due to the shared space upgrade in the Fort Street area where more high-quality pedestrian areas have been created closer to the destinations but outside the study area. In the daytime, there was a noticeable increase of pedestrians in the area with a peak period between 12.45 and 13.00. The overall PO (PO_{24h}) also increases from 14% to 19%.

Like the other two study areas, the shared space environment in Jean Batten Place enhances the pedestrian priority and the ability to freely move along the street as displayed in the trajectory plot in Figure 4.4(b). It is observed that almost half of the pedestrians moving within the 40m-long study zone occupied a certain part of their trips, if not all, in the spaces that also cater for vehicles. With little demand for accessing the adjacent land uses, the shared space design with the level surface results in better space utilisation for pedestrians walking along the street.

For the pedestrians who occupied the space, Figures 4.4(c) and 4.4(d) demonstrate more diverse activities (i.e. the addition of ‘Chatting’ and ‘Eating’) and the longer average dwell time of the ‘after’ scenario. Most of the pedestrians in the PO group sit at the freestanding benches.



(a) 24-hour pedestrian profile (PM lower area in grey / PO upper area in blue)



(b) Pedestrian Movement (PM) trajectory during the peak period (12.45-13.00)



(c) Pedestrian Occupancy (PO) activity during the peak period (12.45-13.00)



(d) Pedestrian Occupancy (PO) dwell time during the peak period (12.45-13.00)

Figure 4.4 Pedestrian performance in Jean Batten Place section.

4.4.4 Shared Space Findings and Data Comparison

It can be established based on the ‘before and after’ analysis that pedestrian performance was improved by transforming a conventional street with kerb and footpath into a shared space with a level paved surface in the following aspects:

- From the placemaking perspective, the design with formal and casual seating resulted in an increase of the stationary pedestrian activities; even with the reduction of the seating capacity as in the Elliott Street case. Furthermore, the shared space environment attracted the pedestrians to stay longer within the road space.
- From the pedestrian priority improvement perspective, the pedestrians, to a large degree, better utilised the road space for both Mobility and Access purposes. A noticeable amount of the pedestrians were comfortable to walk within the space that is allocated for vehicular movement.

In addition to the above, one of the shared space research objectives aimed at understanding the user impact of the scheme in different land-use environments with the focus on the performance of pedestrians relative to motor vehicles. In order to discover any correlation between pedestrian and motor vehicle characteristics, vehicular speeds and volumes in both pre (2010) and post (2011) implementation were examined.

Vehicular Traffic Volume and Speed

As demonstrated in Table 4.2, there were significant reductions of vehicle speeds and volumes across all streets with the Lorne Street section having the greatest percentage reductions on all parameters considered. While the ‘after’ 24-hour volume of 397 vehicles was the lowest of all sites, the mean and 85th percentile speeds (20.7 and 27 km/h, respectively) were both higher than the other two sites. With similar design elements for vehicles (e.g. linear alignment and stone paving), this could have raised a concern that lower vehicular flows in a shared space environment would result in increasing speeds, but when comparing the Elliott Street and Jean Batten Place sections, this is not the case. The Elliott Street vehicular data (both speed and volume) in every aspect were lower than that of the Jean Batten Place section. Consequently, there are certainly other factors that contribute to a lower speed environment such as pedestrian density and activity.

Table 4.2 Vehicular traffic information pre and post shared space implementation.

Parameter		Unit	Elliott St			Lorne St			Jean Batten Pl		
			Before	After	Change	Before	After	Change	Before	After	Change
Volume	24-hour	veh/day	1,928	1,139	-41%	1,065	397	-63%	3,112	2,031	-35%
	AM peak	veh/h	130	94	-28%	66	38	-42%	218	160	-27%
	PM Peak	veh/h	142	74	-48%	93	40	-57%	237	139	-41%
Speed	Mean	km/h	19.3	15.6	-19%	31.2	20.7	-34%	21.2	16.9	-20%
	V85	km/h	25.0	21.0	-16%	46.0	27.0	-41%	27.0	22.0	-19%

Nevertheless, it is fair to conclude that based on the three sites transforming a conventional road to a shared space helps in reducing the dominance of the automobile in terms of its volumes and speeds. It is noted that at the time of the traffic surveys, no speed limits were posted in the areas.

Pedestrian Density vs Vehicle Speed

The ‘after’ implementation data of pedestrians and vehicles for the three sites were empirically inspected to find a relationship between variables such as time of day, pedestrian densities and vehicle speeds and volumes. Scatter plots in Figure 4.5 illustrate the degree of association between a (total) pedestrian normalised density and a mean vehicular speed between 8 am and 6 pm for the three sites. A linear regression was employed to calculate the coefficient of determination (R^2), which indicates the overall tightness of the two parameters. The normalised density is the number of pedestrians (both PM and PO) averaged over the 15-min snapshots before and after a particular time per square metre of the study area.

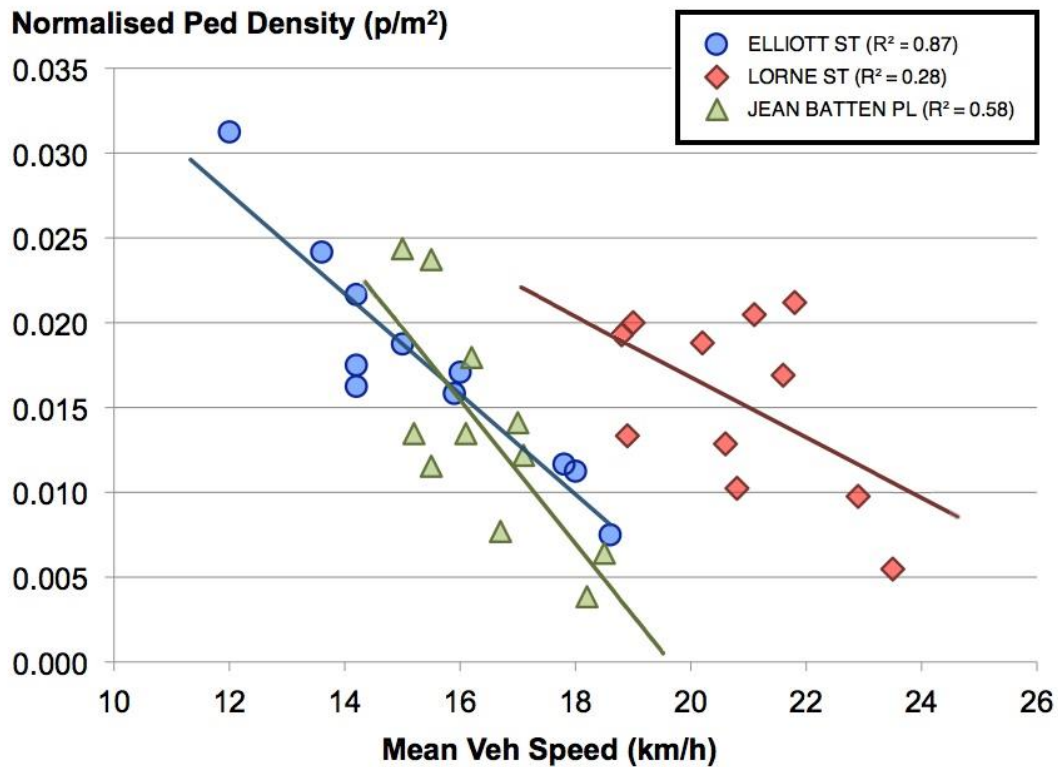


Figure 4.5 Normalised pedestrian density (p/m^2) versus mean vehicular speed (km/h).

An inverse relationship can be generally observed in Figure 4.5 for all study areas during the daytime period from 8 am to 6 pm. In other words, the greater the value of the normalised pedestrian densities, the less the value of the mean vehicle speeds. Out of the three sites, the Elliott Street section has the highest correlation ($R^2 = 0.87$) between the normalised pedestrian density and the mean vehicular speed, followed by the Jean Batten Place and Lorne Street sections with the R^2 value of 0.58 and 0.28, respectively. The very high degree of association between the two parameters for the Elliott Street site reflects the influence of pedestrians on the vehicle speeds within the street that has the highest length of overall active frontage of cafes, shops and eateries in the daytime as previously discussed in Section 3.4.

4.5 Conclusions

This chapter presents a pedestrian performance analysis of the three study areas that have been transformed into shared spaces in the central business district of Auckland in New Zealand. The main conclusions of this thesis chapter are:

- With an increase in pedestrian activity and dwell time, the shared space design enables a public street to better perform the place function.
- Shared spaces fundamentally create a road environment where there is enhanced priority for pedestrians (including the visually and mobility impaired) to safely move around and interact with the surrounding environment.
- Mean vehicle speeds decrease as pedestrian density increases in shared space zones.
- Although data are limited in the ‘after’ period, injury-related reported crashes to date have not increased.

This chapter also proposes a new methodological analysis process in assessing the complexity of pedestrian performance and characteristics within a shared space environment. The 24-hour profile using a 15-minute snapshot interval gives a sound representation of pedestrian demand for those who both travel and stay within the space. The 15-minute peak zone analysis provides a systematic evaluation procedure for the ‘before and after’ analysis.

The additional analysis of the pedestrian and vehicle data resulted in a very strong correlation between pedestrian density and vehicular speed at the Elliott Street site with an R^2 value of 0.87. When comparing with the other two sites, this section of Elliott Street had the highest portion of active edges in the daytime (as discussed in Section 3.4). In other words, active land-use frontages, coupled with high pedestrian volumes contribute towards lower vehicle speeds and therefore a safer shared space environment.

Future research tasks involved a more detailed safety analysis of crash history, safety risks and user conflicts. It was also proposed to investigate the quantitative pedestrian performance using perception surveys. These formed part of a multi-faceted evaluation framework to produce a performance index that is adaptable to cater for shared space schemes with different design motivations and surrounding land use activities.

CHAPTER FIVE

QUANTITATIVE STUDY:

SAFETY PERFORMANCE EVALUATION

Road users in a shared space are expected to travel at low operating speeds or very near walking speeds. This expectation is to ensure an urban street functions as a 'place' and that the dominance of the vehicular traffic is neutralised. The implementation of a shared space concept in a public road requires a safety evaluation, especially for vulnerable road users like pedestrians and cyclists. However, this evaluation is more difficult as there are potential traffic conflicts across the whole road corridor (public right-of-way), except the designated areas that are free of vehicles.

This chapter presents the results of a safety analysis of a shared zone in Auckland, New Zealand. Along with the recorded crash history, the before (2010) and after (2011 & 2012) data were systematically collected using video surveys and traffic counters. The vehicle speeds, volumes and road user interactions were processed and analysed. The outcome of the vehicle speed study highlights the need for traffic calming to be incorporated into the shared space design in order to restrain the vehicle operating speed, especially for off-peak periods. Further, this study challenges the traditional notion and application of the continuum of traffic events where potential conflicts (termed 'interactions' in this study) and uninterrupted passages are the foundation of the number of injury or fatal crashes, specifically in a shared pedestrian and vehicle space environment.

Contents of this chapter were presented at the *Transportation Research Board's* Annual Meeting in January 2014, and have been accepted for publication in the *Transportation Research Record* journal (Karndacharuk, Wilson, & Dunn, 2014b).

5.1 Introduction

The safety performance of a road entity (e.g. intersection, highway section or local road network) is primarily manifest in crash and casualty figures based on a crash database for a specific time period. The goal of the Decade of Action for Road Safety, proclaimed by the United Nations General Assembly, is to save an estimated five million lives over the period of 2011-2020 (World Health Organization, 2013; United Nations, 2010). Consistent with the international strategy, New Zealand's Safer Journeys with a Safe System approach utilises records of road deaths and serious injuries to track national road safety performance (MoT, 2010). Further, a rate of road deaths per head of population, vehicle kilometres travelled or registered vehicles is used for international comparisons (Organisation of Economic Co-operation and Development, 2008; 2013).

The limitations of reported crash data, particularly non-injury collisions, in safety performance analysis are well recognised in the literature (Chin & Quek, 1997; Ismail, Sayed, & Saunier, 2010; Elvik et al., 2009). Given the low rate and multi-factored nature of road crashes, it is, in many cases, difficult to draw any statistically significant inferences from these rare and sometime stochastic events. Furthermore, many collisions, involving no injury often go unreported. More importantly, with the post hoc, deductive nature of crash investigation and reporting, the details of crash records are inherently incomplete and inconsistent. Lord (1996) states that not all crashes are reportable and the ones that are reportable are not always reported.

This chapter sets out to present the analysis process and outcome of a quantitative safety study of a Central Business District (CBD) shared space in Auckland, New Zealand's largest city, using traffic conflicts and interactions as well as vehicular speeds as safety performance indicators. It formed part of a research project at the University of Auckland with support from Auckland Transport to develop a multi-faceted evaluation framework of shared spaces based on both quantitative and qualitative performance measures (Karndacharuk, Wilson, & Dunn, 2013a; 2013b).

5.2 Study Background

In order to provide a context for a safety evaluation, two topics are reviewed and summarised; the first, the traffic conflict analysis and the second, the implementation of shared space concepts in New Zealand.

5.2.1 Traffic Conflict Analysis

The traffic conflict analysis method is a surrogate safety measuring tool that has come a long way since the original conflict study conducted in the late 1960s by Perkins and Harris (1969) and the joint international calibration study of traffic conflict techniques in 1983 (Asmusse, 1984). An internationally recognised definition of a traffic conflict is:

“an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged” (Amundson & Hyden. 1977).

A number of quantitative conflict indicators (e.g. time to collision, post encroachment time and gap time) have been developed to objectively measure the conflict severity (Ismail, Sayed, & Saunier, 2011). Additionally, with the development of computer vision techniques, the automation of undertaking traffic conflict analysis is now possible (Ismail et al., 2009).

According to Svensson and Hyden (2006), the interaction between road users is a continuum of safety related events, and can be illustrated in pyramid form in Figure 5.1. This pyramid of traffic events is based on a hypothesis that there is a close relationship between conflicts and crashes. The uninterrupted passages and potential conflicts are at the bottom whereas the crashes (accidents) are at the very top of the pyramid.

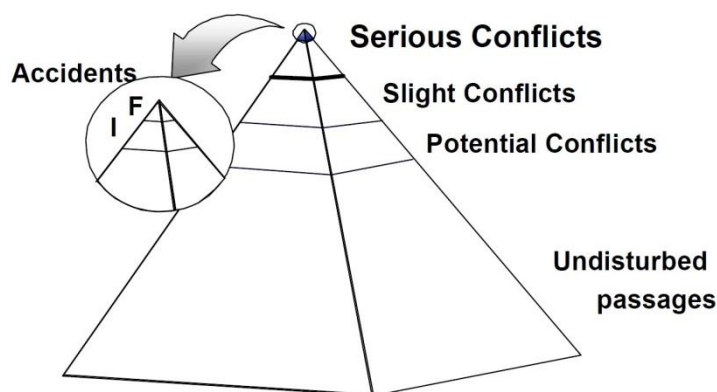


Figure 5.1 The pyramid – the interaction between road users as a continuum of events
(Source: Hyden, 1987).

Consistent with this concept of the continuum of traffic events, the results of a Pedestrian-Vehicle Conflicts Analysis (PVCA) method for an urban street in the United Kingdom, that has been redesigned with some elements of ‘Shared Space’, show that the number of conflicts reduces with increasing severity (Kaparias et al., 2013). The PVCA method, using video data, has been developed and refined to evaluate shared pedestrian and vehicle spaces, and is employed in this research.

5.2.2 Shared Space Concept in New Zealand

There has been a recent surge in practice and literature of the use of the term ‘Shared Space’ and its applications in the past decade. This has been influenced by the work of a European Shared Space project and the UK’s Department for Transport studies (Karndacharuk, Wilson, & Dunn, 2013b); however, the concept of road user integration that forms an integrated part of the shared space principles is not new. From a broad philosophical perspective, the shared street concept can be traced back to the introduction of ‘environmental areas’ in the *Traffic in Towns* (MoT, 1963). The concept was then fully embodied in the form of a residential shared street in the Netherlands via the implementation of *Woonerf* in the late 1960s (Hass-Klau, 1990). Design for a public road space in town centre and shopping areas was treated with a shared space design as early as in the late 1970s (Pharaoh & Russell, 1991; Kraay & Dijkstra, 1989). The *Woonerf* concept subsequently evolved into a number of similar, but interrelated road design approaches, including for example, traffic calming, self-explaining roads, liveable streets and Local Area Traffic Management.

In New Zealand, a form of shared space design has specific legal recognition as a ‘Shared Zone’. A shared zone is defined in the Land Transport (Road User) Rule as simply “a length of roadway intended to be used by pedestrians and vehicles”. The interaction between different users is controlled as follows:

- *A driver of a vehicle entering or proceeding along or through a shared zone must give way to a pedestrian who is in the shared zone.*
- *A pedestrian in a shared zone must not unduly impede the passage of any vehicle in the shared zone.*

To achieve this, Auckland Transport, a regional transport agency and road controlling authority in New Zealand, developed operational design principles for new or modified shared space schemes (Karndacharuk, 2013). The principles aim to provide details of fundamental aspects that should exist in the shared space environment to maximise the potential of the space operating successfully. The key design principles include, for example, the following:

- a. The design should be context-sensitive, taking into account the surrounding land use and the complementary street functions of economic, social, cultural, historical and environmental amenity.
- b. The scheme should attempt to limit vehicular dominance, volumes, and speed. Based on the walking speed criteria, the recommended design speed is 10 km/h.
- c. The design should be self-explaining to reduce the need for traffic control devices. Such devices should be used sparingly or avoided within the zone.
- d. Street furniture (e.g. trees, lighting and art works) should be used to define the various zones within the shared space and act as traffic calming measures.
- e. Designs will typically consist of a level surface continuous with similar paving materials and colours across the road reserve.
- f. The entry and exit points to the zone should be clearly marked. A gateway treatment should be implemented at the zone transition.
- g. Any scheme should be accompanied by extensive education of the public to inform what is expected of them when using a shared space.

Accordingly, a shared space utilises a public road space where all road users are encouraged by design to legally occupy, interact and share the same public space with little physical segregation (e.g. traffic control devices). It is noted that the terms ‘shared street’, ‘shared zone’ and ‘shared space’ are used interchangeably in this chapter within the context of public street design because such terms have long been used in the literature (for instance, Ben-Joseph, 1995; Polus & Craus, 1988 RMS, 1987) since the beginning of the automobile era.

5.3 Study Methodology

This section describes the study scope and methodology, including data collection and analysis methods.

5.3.1 Study Area

The Elliott Street area, which was one of the three CBD case studies in the shared space research project (Karndacharuk, Wilson, & Tse, 2011), was selected for the detailed safety analysis. Elliott Street operates as a one-way, northbound road with the surrounding land use of a mixture of commercial activities, particularly retail, offices, cafes and restaurants. The road space of Elliott Street has been transformed into a shared street with stone paving across the full corridor width. Any obvious delineation that indicates the exclusive use for motor vehicles (e.g. kerbing, sinuous carriageway alignment and broken yellow lines) has been removed.

The street section between Darby Street and Wellesley Street was legally declared a Shared Zone by the Traffic Control Committee (Auckland Transport, 2011), and construction completed in July and August 2011, respectively. Road safety audits were undertaken together with a comprehensive public consultation, particularly with the Royal New Zealand Foundation for the Blind. A 1.8m wide safety zone free of vehicles is provided on either side of the street, which is delineated by a 600mm wide tactile delineator strip. Stopping of vehicles is not permitted at all times in the zone, except bicycle and motorcycle parking in a designated area. Loading activities are permitted between 6 am and 11 am to a maximum parking time of 5mins.

5.3.2 Safety Data Collection

As part of the study quantitative data collection strategy, ‘before and after’ data were collected from three sources, that is, the national crash database, video surveys and traffic tube counters (Karndacharuk, Wilson, & Dunn, 2013a). Video cameras and traffic tube counters were located at approximately the same location for the three-year data collection from September to October in 2010, 2011 and 2012.

Crash Database

New Zealand’s road crash analysis tool is called the Crash Analysis System (CAS), which is managed and maintained by the New Zealand Transport Agency. The CAS integrates three primary sources of road safety data: crash reports obtained from Traffic Officers reporting on a crash, diagrams of the crash (from 1996 on) and crash contributing factors, including road user, the vehicle and road environment data. The crash data collection is categorised into fatal (within 30 days), injury and non-injury crashes reported by the New Zealand Police. The mid-block section of Elliott Street between Darby Street and Wellesley Street was selected for the crash data analysis undertaken in this study.

Video Survey

The changing behaviour of road users due to the road infrastructure improvement was detected via a video survey. The analysis of video surveys was considered an appropriate monitoring method to observe and understand the interaction behaviour between users in the ‘before and after’ street implementation environments.

The behaviour of the Elliott Street users was video recorded via a number of network cameras as shown in Figure 5.2. The video data were continuously recorded for a minimum of one week by the four cameras, and was transferred via a central box to a computer located inside the building. Set up on the sixth floor of the Smith & Caughey’s building, the cameras were able to satisfactorily capture the movements and interactions of the users within the study area.

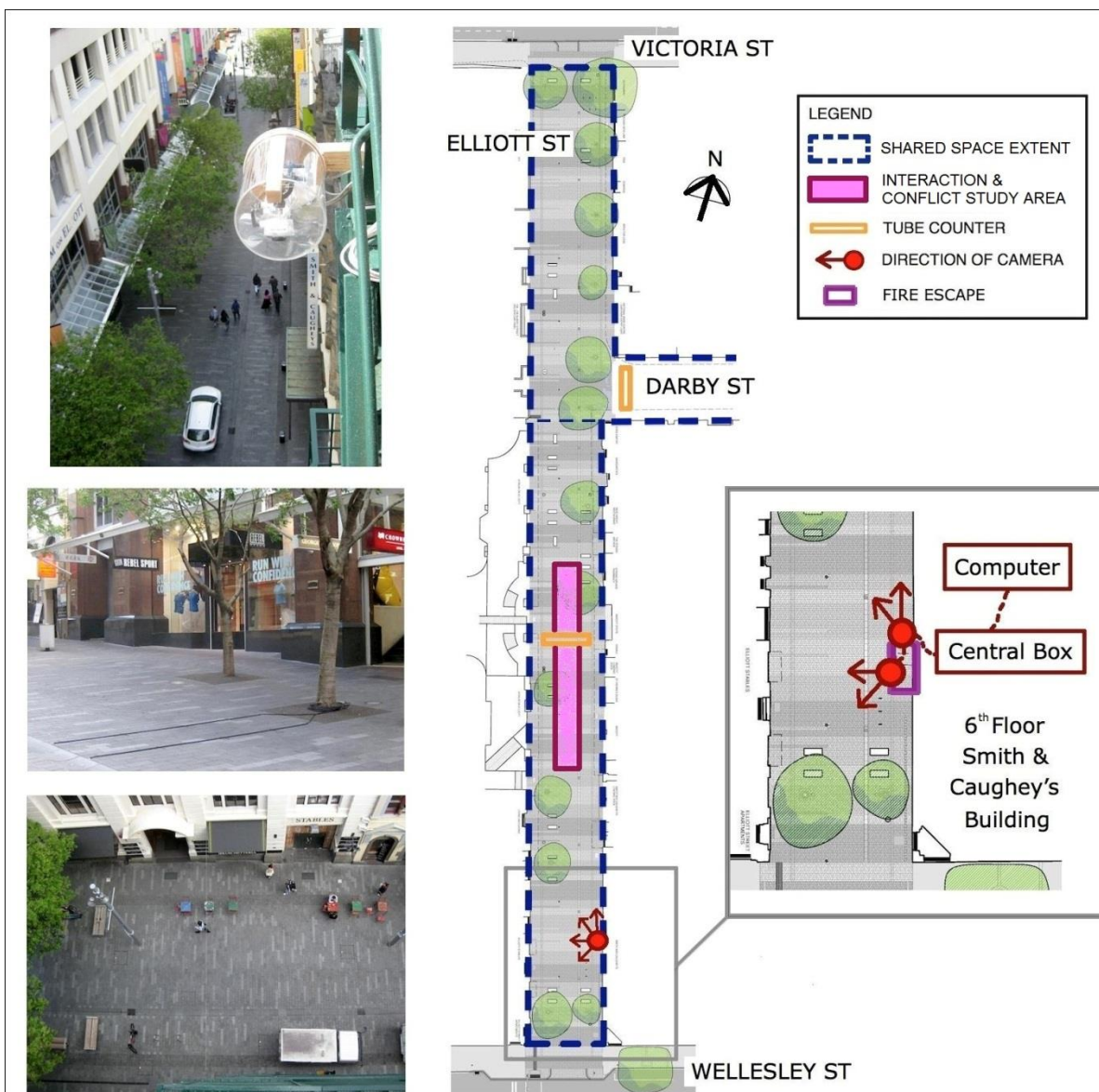


Figure 5.2 Data collection and analysis in Elliott Street area.

Vehicle Traffic Tube Counter

Vehicular traffic speeds and volumes during the time of the camera recording were collected using tube counters. Figure 5.2 displays the location of the tube counter on Elliott Street and Darby Street.

5.3.3 Safety Analysis Methods

As anticipated in a slow-speed, local street environment, the crash data analysis for this mixed-use section of Elliott Street (between Darby Street and Wellesley Street) during an approximately three-year period pre and post shared space implementation (2008-2013)

revealed little crash occurrence. As of July 2013, there were two non-injury crashes recorded within the study area; one in the ‘before’ period in 2008 and the other ‘after’ in 2011. However, when investigating further by reviewing the detailed police reports and collision diagrams, the location of the 2008 crash was misreported by some 60m and was outside of the study area. This epitomises the reliability concern of the non-injury crash reporting as has been discussed previously. Further, contributing factors that caused the 2011 were ‘hit parked vehicle’ and the Police further noted ‘speed misjudgement’ and that the vehicle was a stolen vehicle. These crash factors were unlikely to be related to the shared space, and reflect the stochastic nature of crashes.

As it was not possible to make a meaningful crash data comparison within the selected Elliott Street section, an evaluation of the safety performance impact of the shared space implementation was made by examining the interaction and conflict among road users and vehicular speed. Vehicle impact speed and severity of injury have been shown to be highly correlated (Elvik et al., 2009) and therefore the interaction between vehicles and especially pedestrians was further investigated.

Vehicle Speed Study

In a shared street environment where the mixing of various road users is encouraged, vehicle speed is considered one of the most important parameters in safety evaluation. Hauer (2009) reaffirms that if other conditions (e.g. vehicles, roads and medical services) remain unchanged, accidents will be more severe as speed increases; resulting in more crashes being reported. Given kinetic energy is the product of the mass and the speed, crash severity (i.e. energy resulting from a crash as per Sobhani et al., 2011) is for the most part contributed by the larger-mass and higher speed of the vehicle as opposed to a pedestrian or cyclist.

It was therefore proposed to study vehicle speeds pre and post shared space environment in terms of speed variation and distribution. The mean operating speed at each hour over a 24-hour period was examined along with the speed ranges of all vehicles for the speed distribution analysis.

Road User Interaction and Conflict Study

The ‘before and after’ Road User Interaction and Conflict Study (RUICS) was proposed as an analysis tool to quantify the safety performance of shared spaces. This research demonstrated its application to the implementation of shared spaces in Elliott Street by observing video footage and the change of user behaviour particularly of pedestrians and vehicle drivers.

The following dates on Tuesday, Thursday and Saturday with generally good weather conditions before and after the shared space treatment were selected for the RUICS safety analysis:

- 28, 30 September and 2 October 2010 (Before)
- 29 September, 1 and 4 October 2011 (After)
- 16, 18 and 20 October 2012 (After)

A road user interaction is defined in this study as “an event in the vehicle travelling zone where at least one road user (i.e. pedestrian or vehicle driver) modifies their travel path and/or speed due to the existence of the other user(s) and if an evasive action was not taken, the event would have led to a collision”.

This effectively means that a traffic conflict (as discussed for example in Kaparias et al., 2013) with an evasive action taken by force is also identified as an interaction. Figure 5.3 demonstrates the identification process of road user interaction and conflict. The first step is to ensure that the interaction event occurs exclusively in the vehicle travelling zone (e.g. excluding designated vehicle loading or motorbike parking areas). For this Elliott Street study, the RUICS study area of some 40m in length is defined in Figure 5.2. The trajectory of the identified users is then projected based on travelling speed and direction. The risk of collision is then considered if the movement(s) remains unchanged. While an interaction can be identified if the traffic event would lead to a collision without any change to user behaviour, a conflict is distinguished where the evasive action is taken by force of situation rather than by choice or willingly. It is noted that an event may involve a vehicle interacting with a group of pedestrians, and is still considered one interactive event. This is the case when a driver in a vehicle responds to the movement of pedestrians in a group (i.e. not an individual) and vice versa.

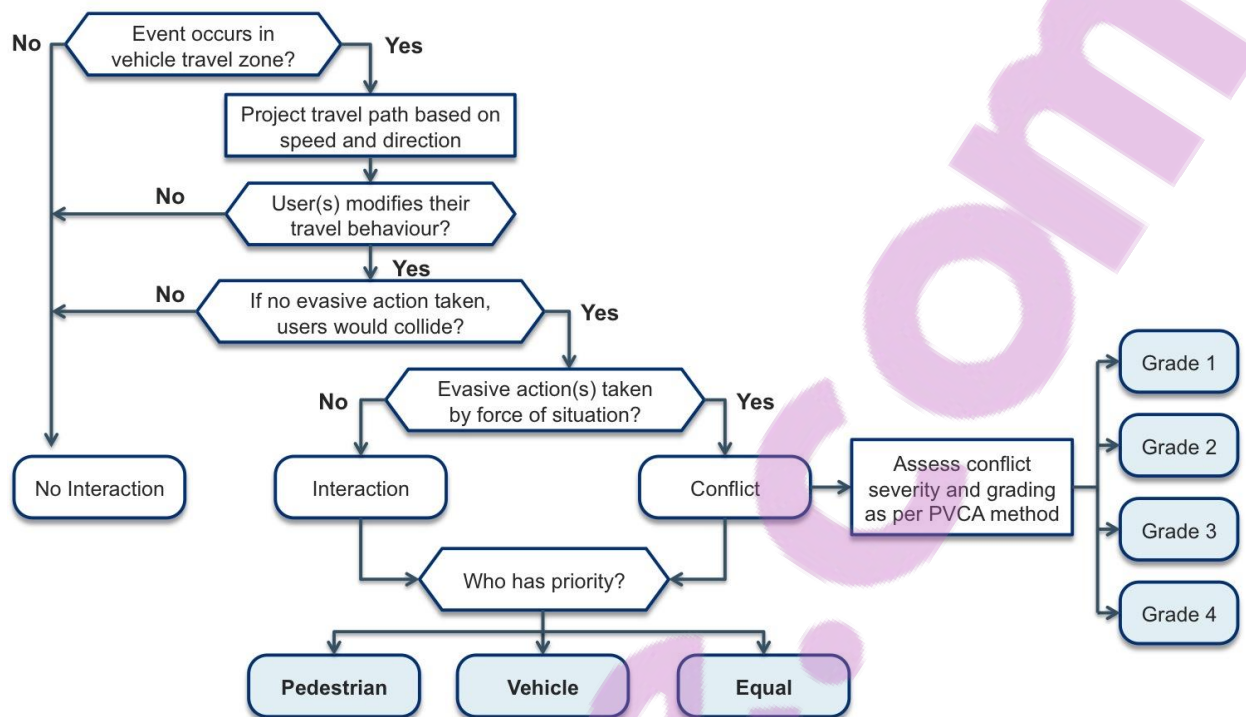


Figure 5.3 Decision flowchart for interaction and conflict identification.

As shown in Figure 5.3, the traffic interaction and conflict events can be classified based on the behavioural interactions between the two road users by the following three categories:

- Pedestrian Priority – a driver in a vehicle gives way to a pedestrian by adjusting vehicle speed and/or travelling path.
- Vehicle Priority – a pedestrian gives way to a vehicle by keeping away from the vehicle travelling path.
- Equal Priority – both users give way to each other and react to the event by modifying their travel path and/or speed.

Since the focus of the RUICS analysis was on the pedestrian-vehicle interaction event within a shared zone, traffic conflicts were examined by classifying the severity of a conflict occurrence based on a Pedestrian-Vehicle Conflict Analysis (PVCA) method (Kaparias et al., 2013). Embraced in the RUICS process, and as shown in Figure 5.3, the PVCA method employs four quantitative factors to characterise a conflict. These factors include Time to collision, Severity of evasive action, Complexity of evasive action and

Distance to collision. The output of the conflict analysis is a severity Grading from 1 to 4 from slight to a most serious conflict, respectively. Refer to Kaparias et al. (2013) for the quantification of the conflict severity grading process.

5.4 Results and Discussion

5.4.1 Vehicle Speed Variation

Figure 5.4 displays the 24-hour operating speeds averaged out over a one-week period for each hour on Elliott Street within the study area. The volumes of vehicles per hour at the bottom of Figure 5.4 are shown to demonstrate how the implementation of a shared space has effectively diverted traffic away from this zone. A speed reduction for the 2011 and 2012 ‘after’ scenarios is shown during the daylight hours between 8 am and 6 pm. Without any significant land use changes in the area, the infrastructure upgrade of the shared space implementation has played a major role in reducing the vehicle speeds, together with increasing pedestrian use and occupancy as discussed in the previous study (Karndacharuk, Wilson, & Dunn, 2013a) and in Chapter Four.

A rebound of approximately 20 km/h of the mean operating speeds in 2012 from those of the 2011 data can also be seen in Figure 5.4 during night periods when traffic and pedestrian numbers are low. Even though a higher vehicle speed can be anticipated during a period with low pedestrian density and little street activity, the speed difference between the 2011 and 2012 ‘after’ data between midnight and 8 am raises a major safety concern.

A key shared space goal is to keep the operating speeds (of all road users) at a minimum. This is encouraged by using a 10 km/h design speed; however, it is evident from this research that relying on driver behaviour alone without pedestrian activity is ineffective in speed control and management during the off-peak hours. This is especially so with a straight street alignment with unobstructed sightlines of some 200m (between Wellesley Street and Victoria Street). To reinforce the self-explaining design of a low-speed street, the use of vehicular traffic restraining measures such as a lateral shifting of the horizontal alignments or the use of strategically placed street furniture (e.g. trees, lighting, art works and bollards) are encouraged.

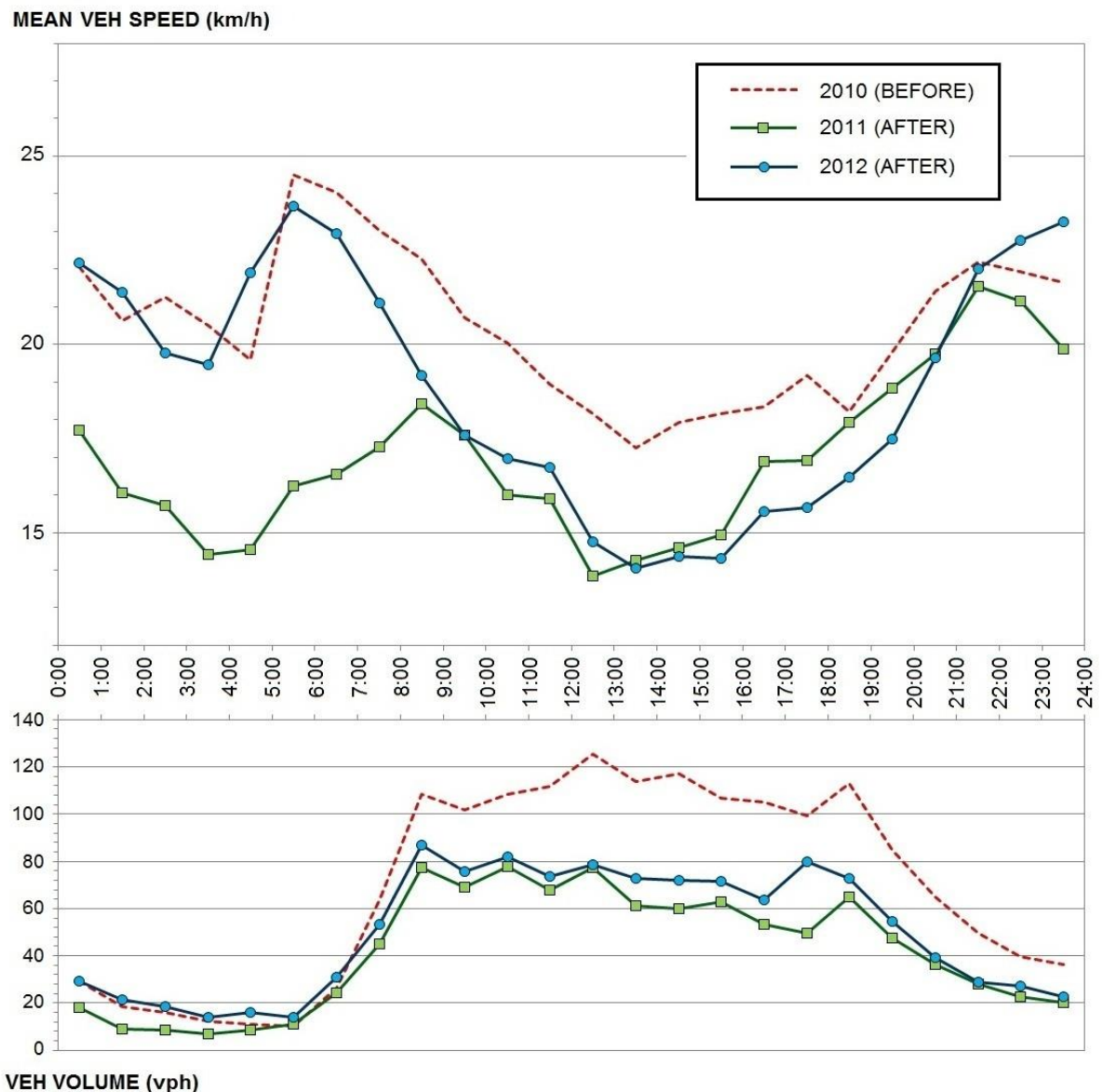


Figure 5.4 Mean operating speeds and vehicle volumes averaged over one week.

5.4.2 Vehicle Speed Distribution

The distribution of drivers' speeds by year is displayed in Figure 5.5 and demonstrates a shift towards lower speeds following the shared space implementation. This reflects a positive safety outcome involving the majority of vehicles. Based on the 2012 speed profile, more than 70 percent of the drivers chose to travel at the speed range of 0-20 km/h. The 10 km/h speed limit sign posted early in 2012 at the entry to the shared zone, coupled with user's better understanding of appropriate speeds following education campaigns, certainly contributed to this speed reduction. The speed distribution profile was best fitted based on the traffic data from the tube counters over the one-week period.

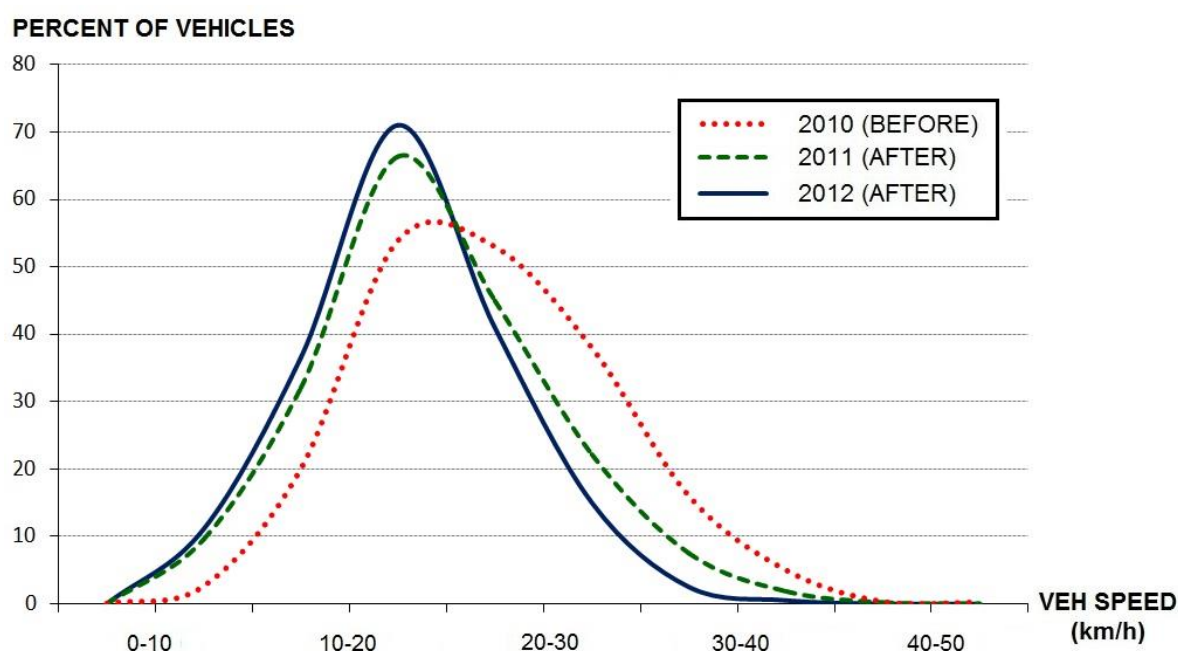


Figure 5.5 Distribution of vehicular speeds before and after the shared space upgrade.¹

5.4.3 Road User Interaction and Conflict Study Results

Table 5.1 summarises the safety performance indicators discussed earlier for the before and after Elliott Street case study, including the RUICS interactions and the observed PVCA conflicts. The most salient behavioural change when comparing the before (2010) and after (2011 & 2012) scenarios was the overall priority outcome of the RUICS interactions. Based on the 2010 data analysis, the overwhelming portion (greater than 90%) of vehicle drivers maintained their dominance over the carriageway when interacting with crossing pedestrians, resulting in a very high number of vehicles having priority. Very little equal priority interactions were observed in the before scenario. However, in the 2011 and 2012 RUICS analysis, pedestrians had reclaimed the space that has previously been allocated for travelling vehicles with a dominant amount of the ‘Pedestrian and Equal Priority’ interactions (i.e. 57% and 60% in 2011 and 2012, respectively).

¹ The speed distribution diagram is different from that presented at the TRB 93rd Annual Meeting because it is updated in light of an Auckland Transport-wide automatic traffic count problem identified in January 2014 where the reporting software omitted the 0-10 km/h speed bins, resulting in incorrect labels in the speed columns. This, however, did not affect the mean and 85th percentile speed data.

Table 5.1 Safety performance indicators of interactions and conflicts before and after shared space implementation.

Year	Date	PVCA					RUICS				
		Conflict Grade				Total	Interaction Priority			Total	Grand Total
		1	2	3	4		Ped	Veh	Equal		
2010 (Before)	Tue (28 Sep)	1	0	0	0	1	98	868	0	966	2727
	Thu (30 Sep)	0	0	0	0	0	95	926	3	1024	
	Sat (2 Oct)	1	0	0	0	1	58	679	0	737	
2011 (After)	Tue (4 Oct)	4	3	0	0	7	442	384	83	909	2608
	Thu (29 Sep)	3	2	0	0	5	585	415	46	1046	
	Sat (1 Oct)	4	1	1	0	6	324	308	21	653	
2012 (After)	Tue (16 Oct)	2	1	0	0	3	431	291	85	807	2859
	Thu (18 Oct)	2	1	1	0	4	466	413	69	948	
	Sat (20 Oct)	3	3	1	0	7	606	431	67	1104	

With respect to the PVCA conflict analysis, there were more conflicts in the 2011 and 2012 ‘after’ periods than those of the 2010 ‘before’ situation. These results were, to a large degree, expected given the shared street was designed to encourage the mixing of various road users at a low speed. All of the 2011 & 2012 traffic conflicts in the shared space occurred approximately evenly across the 6 am to 8 pm period, reflecting the time of street activities and interactions on Elliott Street.

An example of the PVCA conflict identification process method follows to demonstrate the overall assessed grade for a serious conflict that occurred on 20 October 2012. A vehicle moderately decelerated to avoid a collision without change in course and came to a complete stop to allow two pedestrians to cross. The time to collision was more than 2sec and the distance to collision was approximately one and a half vehicle lengths with the deceleration in the range of 2-3.45 m/s². The rating result was 1,2,1,2 for Factors A to D, respectively. Based on the conflict grade matrix presented in Kaparias et al. (2013), this conflict event occurred at the time of 12hr 47min 50sec on the video footage, and was classified as a Grade 2 conflict.

As part of the RUICS interactions over a 24-hour period on Thursday, 18 October 2012, Figure 5.6 shows a varying magnitude of pedestrian and vehicle interactions based on the ‘after’ data. The majority of the interactions occur in the street between 8 am and 8 pm. This corresponded well to the period of high vehicle flows (as discussed earlier) and

consistent with the period of high pedestrian demand as presented in the previous study (Karndacharuk, Wilson, & Dunn, 2013) and in Chapter Four. As shown in the diagram, it is very positive to see the majority of the interactions having either an equal or pedestrian priority over the 24-hour day period. This achieves the shared space objectives of improved pedestrian priority and level of service as well as a safer street environment with reduced vehicle dominance.

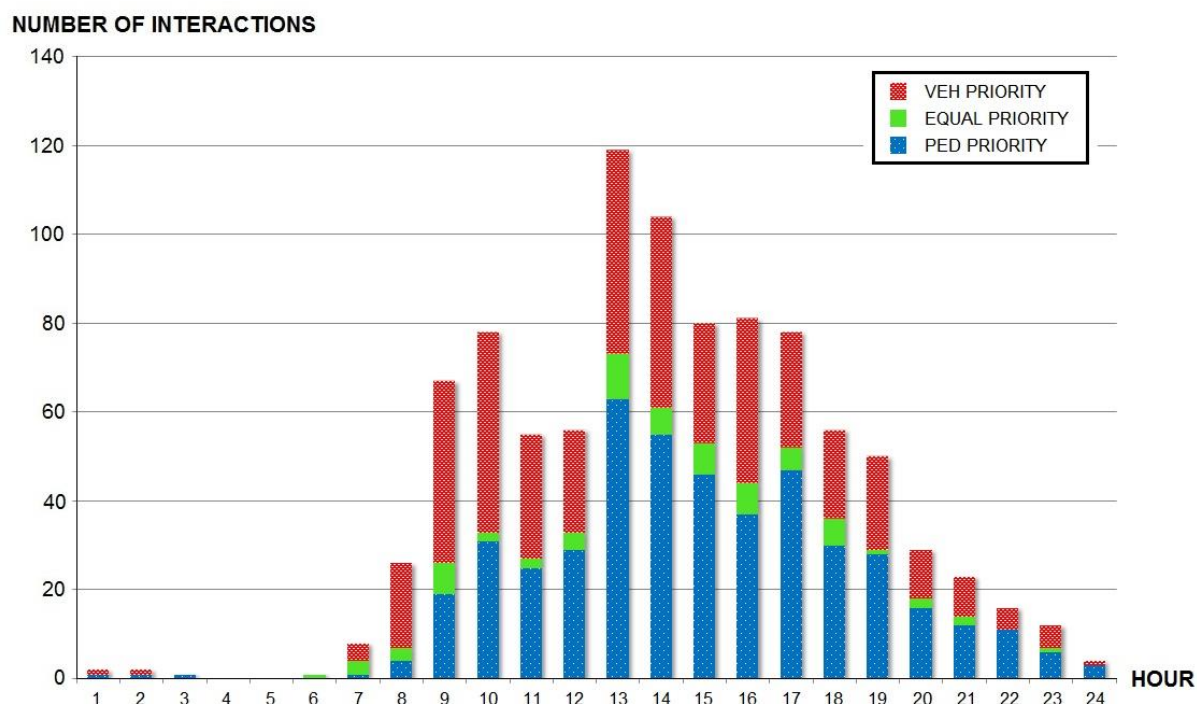


Figure 5.6 RUICS interaction and priority over 24-hour period in 2012.

5.4.4 Road User Interaction vs Vehicle Speed

The safety investigation of the vehicle speed and road user interaction described has shown that the shared space treatment does contribute to a positive behavioural modification (decrease in speed) of the road users, and especially to road vehicle drivers within the shared space zone. In order to determine whether the vehicle speed is influenced by the level of the pedestrian-vehicle interactions, scatter plots were constructed for the three-day after implementation data of the 2012 RUICS interactions against the mean vehicular speeds for every hour as shown in Figure 5.7. As a result, a very high degree of association ($R^2 = 0.81$) can be observed between the number of road user interactions and the vehicle speed in a shared street environment. It is concluded from this data that lower measured speeds are the result of more pedestrian-vehicle interactions in the shared zone.

Consequently, the public road space should be designed to attract more people, which will result in more user interactions where the event of increasing low-speed conflicts is allowable. This, coupled with the pedestrian demand generated from the adjacent land use activities over the 24-hour period, is critical to the successful operation of an urban shared space.

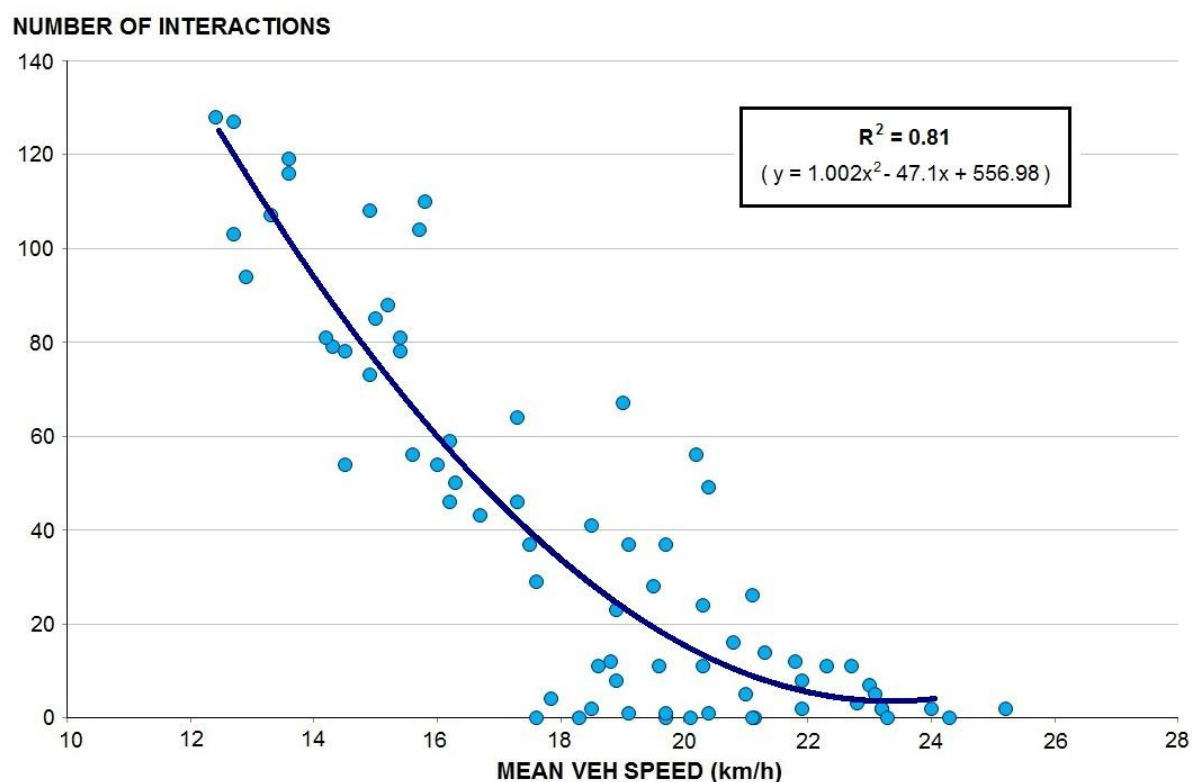


Figure 5.7 RUICS interaction versus mean vehicle speed in 2012.

5.4.5 Safety Observations from Video Footage

Based on the review and comparison of the 2011 and 2012 data, two traffic safety and operational issues in the Elliott shared zone were observed and identified. The first issue was related to on-street parking. Even though only 5min loading activities are allowed within the 6am-11am period, the video footage shows vehicles parked for a considerably longer period and extended beyond the time limit as well as in the areas that are designed for other activities such as pedestrian space or temporary street activities. Furthermore, two of the identified conflicts in the 2012 PVCA analysis involved restricted sight distances for both the crossing pedestrian and travelling vehicle due to parked cars and delivery trucks.

Secondly, given the one-way operation of Elliott Street, some vehicles (including cars, motorbikes and bicycles) travelled in the wrong direction. The 2012 video review of the three-day period saw 59 ‘wrong-way’ incidents. In contrast, there were 17 incidents observed in 2011 with no incidents at all in the ‘before’ (2010) scenario. This could be due to a wider effective width of a vehicle travelling lane when compared to the previous narrow carriageway.

The safety risk of the wrong-way crashes and limited visibility due to parked vehicles can be minimised by an on-going Street Management Plan. The Plan should be prepared specifically for each shared zone in order to detail how various street activities are to be managed, including the use of on-street parking and loading spaces, traffic operational monitoring and enforcement, temporary street furniture rearrangement and activation of street edges at different times.

5.5 Conclusions

This chapter investigated the ‘before and after’ safety data of a public street that has been transformed into a shared pedestrian and vehicle space in Auckland, New Zealand. The safety performance analysis of the Elliott Street section was based on the reported crash history, vehicle speed characteristics and the study of road user interactions and conflicts. The key conclusions of the safety study presented in this chapter can be summarised as follows:

- The normal crash database analysis revealed little useful information for the shared space safety evaluation due to statistically low numbers.
- Based on the vehicle speed study of the Elliott Street shared zone, the shared space implementation contributes to a significant reduction of operating speeds for the majority of vehicles. However, with the linearity of the street design, the safety concern was raised during the night-time period when there were few road user interactions and little land use activity. Vehicular traffic calming measures have therefore been recommended to be incorporated into the design of shared space schemes.
- Additionally, with the decrease in vehicle volumes in the ‘after’ shared space implementation scenarios, the risk of crash involvement has been reduced based on crash predictive models (AASHTO, 2010; Turner, 2001).

- A new RUICS safety analysis method that incorporates a PVCA method has been developed to evaluate safety performance of shared spaces.
- There is a high correlation between the number of interactions and operating vehicle speeds based on this safety study of the lower-speed shared zone. It is evident that the more interactions, the lower vehicle speeds, thereby resulting in decreased kinetic energy and likelihood of injury severity in the event of a crash.
- A specific Street Management Plan is recommended for each shared street to address any ongoing safety and operational concerns as well as to outline the ongoing monitoring and enforcement process.

In summary, this research has shown that for shared space environments, more road user interactions (potential conflicts), particularly between vehicles and pedestrians, do not translate into more injury or fatal crashes. The study therefore challenges whether the conventional pyramid of traffic events can or should be applied to a shared street environment.

The reduced vehicle speeds via the interactions of various users are also central in achieving the other shared space objectives such as placemaking, improved pedestrian level of service and vehicle dominance reduction. With the ‘before and after’ data methodologically collected during the three year period for a minimum of one continuous week, there is an opportunity to further analyse, using the RUICS method, the safety performance of the other shared spaces (i.e. Fort and Lorne Streets). It is recommended that future shared space research investigates the correlation between the interaction priority and the number of pedestrians in a group, observing the ‘Safety in Numbers’ concept (Jacobsen, 2003)

CHAPTER SIX

QUALITATIVE EVALUATION STUDY

This chapter presents the findings of a qualitative analysis using on-street perception and expert interview surveys of city centre streets that have been transformed into shared spaces in Auckland, New Zealand. To explore the ability of shared streets in performing movement, access and place functions, five assessment criteria were established, which are the key objectives of shared space schemes.

Each shared space site at the Elliott, Lorne and Fort Street areas was measured against these performance criteria of Placemaking, Pedestrian Focus, Vehicle Behaviour Change, Economic Impetus and Safety for All Users. With respect to on-street perception surveys, a total of 360 survey responses (120 per site) were used in this study, together with an additional set of 40 responses from a survey of a control site in O'Connell Street that remained as a traditional street. Fifteen professionals with background in transportation and urban planning participated in semi-structured expert interviews.

6.1 Introduction

Qualitatively, the perception of the road users towards the shared space objectives is a direct indicator of how well the space is servicing end users. In other words, the measurement of these subjective values reveals how successful the street space is in accomplishing each objective, resulting in a qualitative performance indicator. The following paragraphs present a review of relevant qualitative evaluation of shared space schemes in the UK and New Zealand.

Kaparias et al. (2012a) undertook on-street surveys to evaluate the street environment in the South Kensington area. Forming part of the Exhibition Road project, the street has been redesigned to incorporate a shared, level surface, and recognised as a shared space in the UK. Adapted from the previous pedestrian auditing tools of 'Pedestrian Environment Review System (PERS)' (Allen, 2005) and 'Pedestrian Environment Data Scan' (Clifton et al., 2007), the survey questionnaire consisted of ten questions. As shown in Figure 6.1, the

first three questions were designed to collect participants' demographic data (age, gender and frequency of visit) while the remainder assessed pedestrian experience. Consistent with the PERS system, a 7-point rating scale ranges between -3 (very bad) and +3 (excellent) with a middle point of 0 (neutral). Besides some interdependence among pedestrian crossing criteria, the research suggests that there is a strong positive correlation between 'comfort' and 'ease of movement' performance attributes.

Imperial College London *Study of South Kensington Station area improvements*

1. **Age:** Under 21 ☐ 21–30 ☐ 31–40 ☐ 41–50 ☐ 51–60 ☐ 60+ ☐

2. **Gender:** Male ☐ Female ☐

3. **How often do you visit the South Kensington Station area?**
 first visit ☐ infrequently ☐ at least once a month ☐
 at least once a week ☐ at least 5 times a week ☐

4. **How do you rate the visual environment of the area? (street furniture, paving, cleanliness, etc)**
 -3 -2 -1 0 +1 +2 +3
 Comments: _____

5. **How easy do you find moving around in the area? (obstructions, congestion, signage, etc)**
 -3 -2 -1 0 +1 +2 +3
 Comments: _____

6. **How do you rate the comfort of the area? (noise, seating, shelter, etc)**
 -3 -2 -1 0 +1 +2 +3
 Comments: _____

7. **How do you rate the safety of the area?**
 -3 -2 -1 0 +1 +2 +3
 Comments: _____

8. **How do you rate the positioning of the pedestrian crossings? (are they out of your way? would you rather cross elsewhere?)**
 -3 -2 -1 0 +1 +2 +3
 Comments: _____

9. **How do you rate the waiting times of the crossings?**
 -3 -2 -1 0 +1 +2 +3
 Comments: _____

10. **How do you rate the capacity of the crossings? (width, congestion, obstructions, etc)**
 -3 -2 -1 0 +1 +2 +3
 Comments: _____

Figure 6.1 On-street questionnaire design developed by Kaparias et al. (2012a).

It is observed from the last three questions that the street design in the South Kensington area incorporated designated pedestrian crossing points whereas, as discussed in Chapter Two, a genuine shared space design does not necessarily require a designation of pedestrian crossing areas. This is because pedestrians in a shared space should be able to comfortably cross the street at any location.

In addition to these on-street pedestrian surveys, Kaparias et al. (2012b) also implemented web-based surveys to determine the factors contributing to driver's willingness to share and pedestrians' comfort in moving around a shared space. The outcome of the online surveys suggests, while the presence of children and elderly, pedestrian density and lighting level were most important for the willingness of drivers to share the space with pedestrians, the amount of vehicle traffic, provision of safe zones and lighting level had statistically significant effects on the comfort of pedestrians in sharing the road space with vehicles.

To provide the basis for continuing the shared space implementation into the next stage of the area upgrade of Fort Street (between Custom Street East and Gore Street), a preliminary evaluation of the completed Stage 1 Fort Street area was undertaken (Nazla, & Williamson, 2012). The study included perception surveys of pedestrians, drivers and business owners, however was primarily based on 'after' implementation data with limited 'before' data. Relating to traffic and personal safety, the perception survey outcome indicated 83% and 53% of participants rated safety as either 'very good' or 'excellent' during the day and at night, respectively. The evaluation report also included the results of user perceptions on amenity, distinctiveness, cleanliness and willingness to work, visit and spend time within the street. Without the information on the participant characteristics, especially the total number of participants, it is debatable whether the data are statistically significant.

6.2 Previous Work

As discussed in Chapters Four and Five, the quantitative data collection and analysis were undertaken within a multi-faceted evaluation framework using both quantitative and qualitative performance measures.

The initial proposal for the qualitative study involved a web-based survey (Karndacharuk & Wilson, 2010; Karndacharuk, Wilson, & Tse, 2011) with a continuous rating scale. The

survey was designed to be filled in by selected groups (to represent both the general public and persons with knowledge in transportation or urban design) after they had viewed a common video of the ‘before’ and ‘after’ shared street environments. However, the survey design of the qualitative study was later changed to instead assess actual user’s perception within the study areas in order to obtain a better indicator of estimating the subjective performance values.

6.2.1 Conceptual Evaluation Framework

The methodological framework has been developed to evaluate the public shared streets (Karndacharuk, Wilson, & Dunn, 2013a; 2013b) by measuring how the urban space performs its functions of place, mobility and access. Acknowledging the context-sensitive nature and self-explanatory design, the overall performance criteria (variables) chosen were based on the key five objectives of shared spaces, that is:

- Placemaking: the quality of the street environment and its attractiveness to pedestrians to spend time within the space
- Pedestrian Focus: an environment with improved pedestrian priority to enable pedestrians to freely roam the street
- Vehicle Behaviour Change: street design to reduce the dominance and priority of the motor vehicle and driver within the space
- Economic Impetus: a street space that complements surrounding land uses, particularly economic activities in an activity centre
- Safety for All Road Users: a safer environment for all users, including the elderly, the disabled and children

In addition to quantitative performance measures (e.g. pedestrian density & occupancy, vehicle speeds & volumes, and reported crash history), the framework incorporates a qualitative evaluation of user perceptions. The primary method of collecting the qualitative data is an on-street perception survey, including a questionnaire of the five performance measures. The following section discusses the design and implementation of the perception surveys.



6.3 Study Methodology

The perception survey has been developed with a goal to measure the degree to which a shared street meets the five established objectives. In accordance with the previous work (Karndacharuk, Wilson, & Tse, 2011), three sites of the Elliott, Lorne and Fort Street areas in Auckland's Central Business District (CBD) were qualitatively evaluated in 2013. All of the sites were transformed into a shared space with a level, paved surface continuous across the road reserve, and practically completed in July 2011. This allowed sufficient time for road users to become familiar with the shared street environment, reflecting normal use and behaviour within the road space. A survey of a control site with a standard street environment (including the carriageway and footpath separated by vertical kerbs) on nearby O'Connell Street was also included in this study. Figure 6.2 displays the location of the study areas of the on-street perception survey.

To supplement the main surveys of pedestrian perception, 'expert' interviews were carried out with transportation, urban design and planning professionals who had varying degrees of shared space experience and involvement. This was undertaken in order to gain professional practitioners' perception towards how the three CBD schemes performed and to recognise factors affecting their performance.

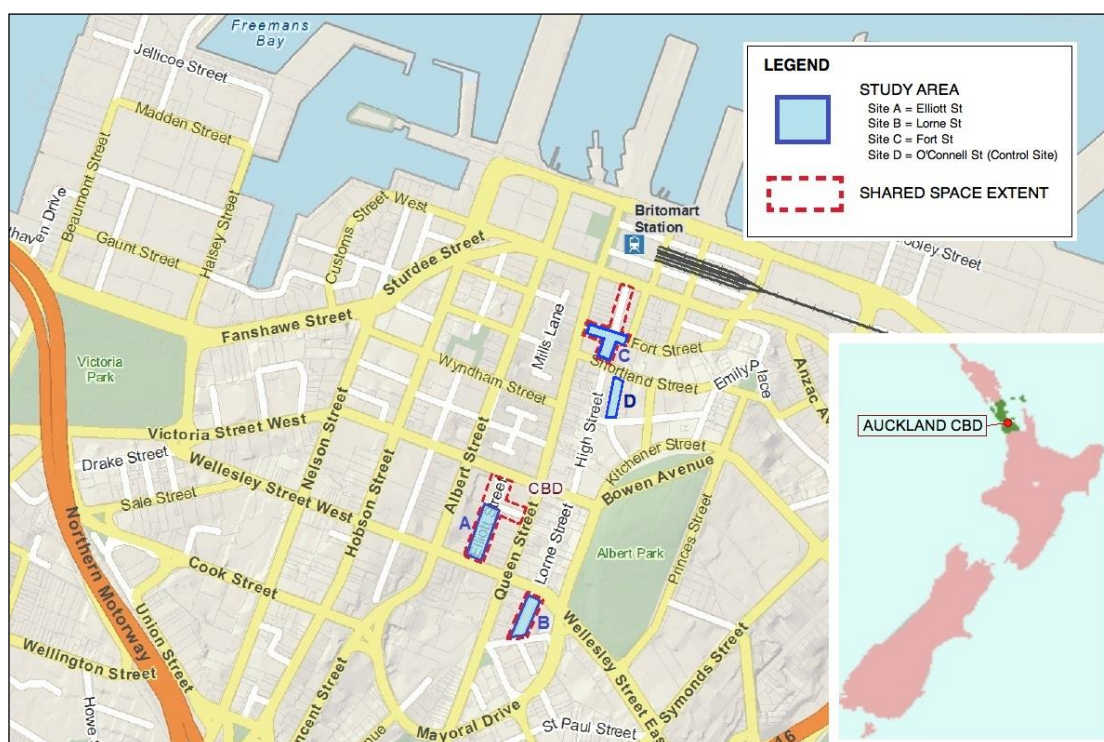


Figure 6.2 Locality plan for on-street perception surveys
(Source: Auckland Council GIS Viewer).

6.3.1 Survey Design and Development

Given that the research involved human participants, the design of the on-street survey and expert interview process was reviewed and approved by the University of Auckland Human Participants Ethics Committee (Reference number 7342). A Participant Information Sheet (PIS) and Consent Form (CF), incorporated in the ethics approval, provided the participants with the information on research purposes, survey procedures, intended use of the results, the confidentiality and anonymity of the responses and researchers' contact details. Appendix C contains the ethics approvals and a copy of the PIS and CF.

On-Street Perception Survey: Questionnaire and Rating Scale

Auckland Transport
An Auckland Council Organisation

THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

The Development of a Multi-Faceted Evaluation Framework of Shared Spaces

Sheet A : On-Street Perception Survey
Please circle the option best describes your opinion towards the following five statements.

	Strongly Disagree	Disagree	Tend to Disagree	Tend to Agree	Agree	Strongly Agree
1) "I like spending time in this street"	-3	-2	-1	1	2	3
2) "I can freely move around on this street"	-3	-2	-1	1	2	3
3) "Driver behaviour is appropriate in this street"	-3	-2	-1	1	2	3
4) "This street complements the economic activity"	-3	-2	-1	1	2	3
5) "I feel safe and secure in this street"	-3	-2	-1	1	2	3

Please further provide us with your impression about this street space and your background information

6) Of the five statements above, which are the most important (.....) and least important (.....) ?

7) Of the five statements above, which do you feel could be most improved, and why?
.....

8) What, in particular, do you like most about this street space?
.....

9) How often do you visit this street?
☐ First visit / Very Infrequently ☐ Around once a month
☐ Around once a week ☐ Multiple times a week

10) Why have you visited this street today? (e.g. passing through, shopping or eating)
.....

11) Age: ☐ Under 20 ☐ 20 – 34 ☐ 35 – 49 ☐ 50 – 65 ☐ Over 65

12) Gender: ☐ Male ☐ Female

13) Ethnic group: ☐ NZ European ☐ Maori / Pacific Islands ☐ Asian
☐ Other

Figure 6.3 On-street perception survey questionnaire (Sheet A).

The questionnaire was carefully developed to capture the perceptions of road users towards the three study areas and one control street, together with variables that were expected to

influence the user perceptions. The questionnaire consists of two parts: the first part (Sheet A) designed to be filled out by participants and the second part (Sheet B) designed to be filled out by trained surveyors with respect to site-specific information and observations.

As shown in Figure 6.3, the following five statements were developed to measure the road users' opinions towards the five performance criteria. To minimise the halo effect where the respondent's overall impression of an object being evaluated (i.e. a shared street) influences a particular attribute of the object (Hutchinson, 1964), the survey questions and statements were designed with an aim for accuracy and exactness in definitions.

Place:	<i>I like spending time in this street</i>
Pedestrian:	<i>I can freely move around on the street</i>
Vehicle:	<i>Driver behaviour is appropriate in this street</i>
Economic:	<i>This street complements the economic activity</i>
Safety:	<i>I feel safe and secure in this street</i>

The survey design of the performance questions incorporated a 6-point Likert rating scale, ranging from 'Strongly Disagree' at the value of '-3' to 'Strongly Agree' at the value of '3'. As suggested by Bradburn, Sudman, & Wansink (2004) to minimise incongruous and unreliable responses, each response point along the continuum was defined with a clear and accurate label. A mid-point to express a neutral position was intentionally excluded in order for the participants to be more thoughtful about their opinions on each declarative statement while enabling a choice, either positively or negatively, to be made.

Moreover, the participants were asked to indicate, out of the five, the most and the least important aspects. Two additional open-ended questions were included to investigate their perceived area for improvement as well as any positive aspects of the street environment. Finally, the demographic and personal questions (including frequency of visit, age range, gender and ethnicity) were placed at the end of the survey questionnaire to enable a stronger focus on the main survey questions because the respondents tend to be more attentive at the start of a survey (Frery, 1996).

Expert Interview: Semi-structured Interview Process

The interview was organised in a semi-structured manner mostly with open-ended questions to obtain personal information and the experts' opinion towards the five shared space objectives, the definition of a shared space and the importance of the five objectives. To ensure a diversity of perspectives, participants with various backgrounds and professional experience were sought, including traffic and transport practitioners, urban planners and designers and academics from both public and private organisations. For example, the following main objective-based questions were raised in the interview.

- | | |
|-------------|--|
| Place: | <i>Do you believe that the shared spaces are attractive? Do the current schemes adequately provide for a wider range of street activities?</i> |
| Pedestrian: | <i>Do pedestrians have adequate freedom to roam the current shared spaces? Are the current legal regulations around priority sufficient?</i> |
| Vehicle: | <i>Are drivers currently behaving appropriately in the current shared space schemes? What is an acceptable operating speed for the Shared Space Schemes?</i> |
| Economic: | <i>Do the existing shared space schemes adequately complement the operation and prosperity of the surrounding businesses? How much active frontage is needed for shared spaces to be successful?</i> |
| Safety: | <i>Do the current shared spaces provide a safe environment for all users? Have the mobility and visibility impaired been adequately catered for in the existing shared space schemes?</i> |

While maintaining a free-flowing conversation, the participants were asked which scheme (out of the three case studies) performed better or worse and how the particular aspect in question can be improved. With an interview time allocation of maximum one hour, additional questions may be asked regarding key design elements (e.g. level surface), the adequacy of the concept understanding in New Zealand and the suitability of shared space applications in residential settings. The interview questions and format are included in Appendix C.

6.3.2 Data Collection Process

For consistency with previous research (Karndacharuk, Wilson, & Dunn, 2014b) and to better understand any temporal variations in space use and performance, the on-street perception surveys were conducted only on Tuesday, Thursday and Saturday for weekday and weekend samples, and during peak activity periods of 7-9 am, 11 am-2 pm and 4-6 pm. For the expert interview, participants were selected from professional contact of the author and the research supervisors. Both on-street perception and expert interview surveys were conducted between August and September 2013 with assistance from two final year undergraduate engineering students.

On-Street Perception Survey Procedure

To ensure proper and consistent implementation by surveyors, survey procedures and instructions were established. First, surveyors were required to be familiar with the survey objectives and how the objectives fit within the overall evaluation framework of shared spaces so as to be able to clarify any questions raised by the participant. Second, each survey session was conducted in pairs with one surveyor at each end of the surveying area during the identified peak periods. Next, the surveyors approached the 5th pedestrian that walked into the study area from their side in order to prevent sampling bias. If willing to participate, the pedestrian was provided with the ethically approved PIS, and asked to fill out the questionnaire. Last, while conducting a survey session, the surveyors were to ensure the information required in Sheet B was complete, including survey period, weather conditions, number of refusals to participate and whether there were vulnerable road users (including the disabled, children and cyclists), and any other observations that may influence the survey outcome.

After a pilot test at the Fort Street area and minor adjustments to the survey questionnaire, the perception surveys were undertaken at the three shared space sites and the control street during a transitional period from winter to spring between August and September 2013. A total of 400 responses were collected and used for analysis; 120 from each shared space site (Elliott, Lorne and Fort Street) and 40 for the control site (O'Connell Street).

On-Street Survey Participant Characteristics

Table 6.1 summarises the demographic information of the participants. For a benchmarking purpose, the 2013 census data are also included in the table. While the gender and age group data were based on the Auckland Central residents, the available census data for the ethnic groups were pertaining to the (wider) Auckland Region. A good balance of men and women participated in the surveys with fifty-two percent being male respondents. Almost 90% were between 20 and 65 years old with the largest age group of 20-34 years (55.7%). It is observed that the gender and age profiles of the samples are largely consistent with the census benchmark.

Table 6.1 Demographic characteristics of perception survey participants.

Participant Characteristic	Study Area (%)				Total (%)	2013 Census (%)
	Elliott St	Lorne St	Fort St	O'Connell St		
No. of participants	120 (30.0)	120 (30.0)	120 (30.0)	40 (10.0)	400 (100.0)	
Gender						
Male	58 (48.3)	65 (54.2)	64 (53.3)	22 (55.0)	209 (52.2)	(52.0)
Female	62 (51.7)	55 (45.8)	56 (46.7)	18 (45.0)	191 (47.8)	(48.0)
Age group						
Under 20	7 (5.8)	11 (9.2)	16 (13.3)	1 (2.5)	35 (8.8)	(12.4)
20-34	74 (61.7)	57 (47.5)	64 (53.3)	28 (70.0)	223 (55.7)	(56.0)
35-49	21 (17.5)	29 (24.2)	25 (20.8)	4 (10.0)	79 (19.7)	(15.2)
50-65	13 (10.8)	19 (15.8)	15 (12.5)	7 (17.5)	54 (13.5)	(11.6)
Over 65	5 (4.2)	4 (3.3)	0 (0)	0 (0)	9 (2.3)	(4.8)
Ethnic group						
European	48 (40.0)	53 (44.2)	64 (53.3)	22 (55.0)	187 (46.8)	(56.4)
Maori / Pacific Islands	10 (8.3)	10 (8.3)	8 (6.7)	0 (0)	28 (7.0)	(19.8)
Asian	49 (40.8)	44 (36.7)	26 (21.7)	11 (27.5)	130 (32.5)	(22.0)
Other ethnicity	13 (10.8)	13 (10.8)	22 (18.3)	7 (17.5)	55 (13.7)	(1.7)
Frequency of visit						
First visit / infrequently	13 (10.8)	13 (10.8)	16 (13.3)	8 (20.0)	50 (12.5)	
Once a month	17 (14.2)	18 (15.0)	22 (18.3)	5 (12.5)	62 (15.5)	
Once a week	30 (25.0)	22 (18.3)	22 (18.3)	8 (20.0)	82 (20.5)	
Multiple times a week	60 (50.0)	67 (55.8)	60 (50.0)	19 (47.5)	206 (51.5)	
Purpose of visit						
Passing through	60 (50.0)	48 (40.0)	91 (75.8)	28 (70.0)	227 (56.8)	
Dwelling / accessing adjacent land use	60 (50.0)	72 (60.0)	29 (24.2)	12 (30.0)	173 (43.2)	

Note: Percentages may not add due to rounding

The majority of participants were Europeans (46.8%), followed by Asians (32.5%) and Maori (indigenous people of New Zealand) / Pacific Islanders (7.0%). When compared to the census data of the Auckland Region population, the ethnic profiles of the participants

sampled from the CBD sites had a much less portion of Maori / Pacific Islanders and a greater diversity in ‘other’ ethnicity (13.7%). Nevertheless, the sample’s representativeness deems appropriate for the study because the ethnic data primarily reflected the CBD as a multicultural city centre and a gateway to tourism.

Most respondents (51.5%) were regular visitors to the street and the surrounding areas with multiple visits per week. Additionally, when considering the total responses of all four sites, 56.8% of the participants travelled through the street without a prior intention to stop in and around the street, reflecting the dominating Movement function. On the contrary, the majority of the respondents (60%) in the Lorne Street area walked to the street to access the adjacent land uses, or temporarily stayed in the street space, reflecting the major attraction of the Auckland Central City Library to users.

Expert Interview Procedure and Characteristics

The expert participant was initially contacted and if interested in the interview, an electronic copy of the PIS and Consent Form (CF) was provided. Once the participant confirmed the participation, and signed the CF, an interview time and location were arranged. With consent, the interview was audio recorded and subsequently transcribed. The transcript was later sent to the participant for review and to ensure the interview transcription accurately reflected the views expressed. The characteristics of the fifteen professional participants are summarised in Table 6.2.

Table 6.2 Participant characteristics of expert interviews.

Gender	Female (4)	Male (11)		
Highest Qualification	PhD (2)	Masters (6)	Bachelor (3)	Diploma (4)
Professional Sector	Private (3)	Public (12)		
Expertise	Urban Planning & Design (7)		Civil & Transport Engineering (8)	
Involvement in CBD Shared Spaces	Direct (12)			Indirect (3)

While the majority of professional experts were male and employed in a public sector such as local government and university, the group of specialists had a balanced cross-section of expertise and an excellent range of highest qualification from doctorates to graduate

diplomas. Twelve experts had a direct involvement in some aspect of the CBD shared spaces, varying from planning and design development, project management and implementation, safety and operation monitoring of the schemes, whereas the remaining participants had some understanding of or experience with the study areas.

6.3.3 Data Analysis Strategy

The statistical software package IBM SPSS for Windows (IBM Corp, 2014) was employed for data analysis of the on-street survey outcome, and the qualitative analysis software suite QSR NVivo 10 (Nvivo, 2014) was utilised to analyse the expert interview transcripts to explore common themes and responses. In order to methodologically analyse the survey data, an analysis strategy was developed, and divided into the following three parts.

Part 1: Analysis of Performance Measures of Shared Spaces

Given the main goal of this perception survey study was to qualitatively measure and evaluate how well a road space served the user perception of the five performance criteria, the effectiveness of a shared street can be expressed as an average value of users' subjective perception ratings. The three main measures of central tendency of Mean, Median and Mode were calculated and presented for the three shared streets as well as the control street. Given that the Likert scale produces ordinal survey data and the mean and standard deviation are not appropriate for the analysis of the ordinal data, the primary numerical value that represents the performance of a shared space towards each performance aspect is the median, which is termed 'Median Perception Rating' (MPR) in this study.

In accordance with the subjective-estimate methods described in Torgerson (1958), the computation of the MPR value can be outlined in the following steps. Using the Elliott Street (Pedestrian) data as an example, Figure 6.4 demonstrates the computation process.

1. Calculate the proportion of survey responses that each performance criterion was rated below the upper boundary of each rating category. A table of cumulative proportions can be constructed.
2. Plot the cumulative proportions against each category boundary. The top rating category (rating scale 3) has no upper boundary.
3. Determine the MPR scale value for a given performance measure by considering where the curve crosses the 0.50 level on the ordinate.

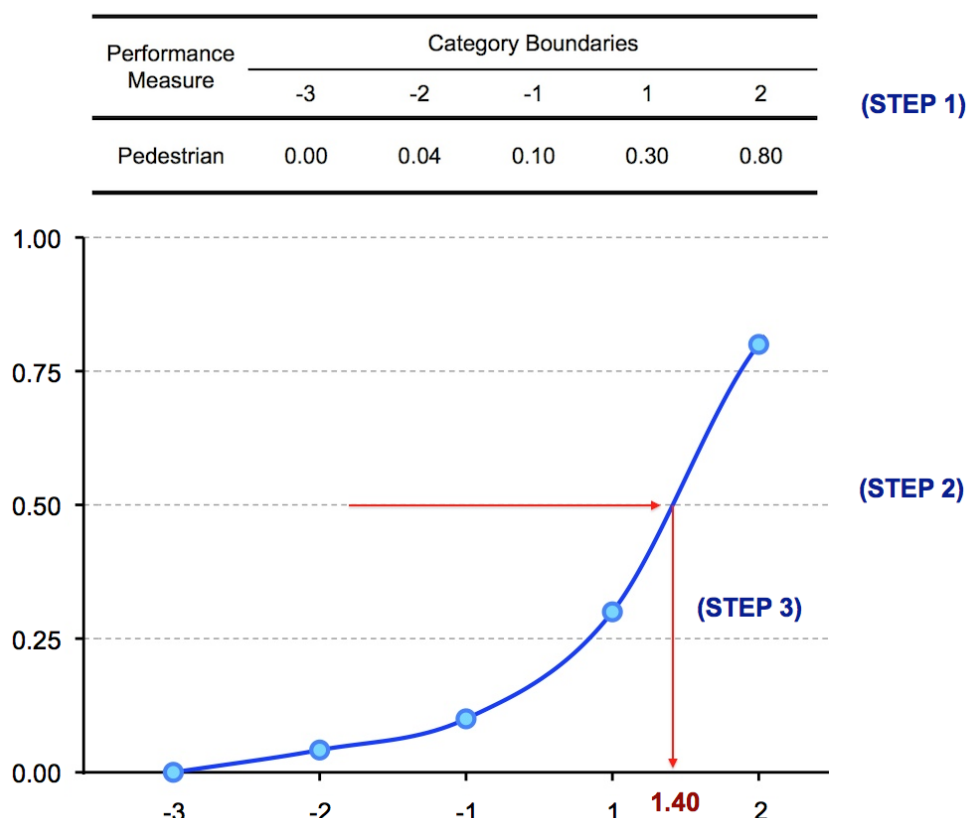


Figure 6.4 MPR computation steps.

Moreover, in order to determine whether the MPR difference between the three shared spaces was statistically significant, a paired-wise analysis of Wilcoxon signed-rank test was undertaken. Other statistical measures (including standard deviation, skewness, kurtosis and Cronbach's alpha) were also calculated. Furthermore, to investigate the interrelationship between different performance measures (variables), nonparametric (Spearman's rank) correlation coefficients were calculated along with parametric (Pearson) correlation coefficients. The outputs of the statistical significance were of a two-tailed test.

Part 2: Comparison with Control Site and Other Contributing Factors

The comparison of the survey outputs between the shared street and control sites was aimed at determining whether a shared space performed differently than a conventional street in meeting the established objectives. It was also undertaken to test the suitability of the survey design in measuring the differentiation of the two street types. Besides the evaluation of the MPR and other statistical values presented in the first part, a Mann-Whitney U test was employed to compare the perception outcomes between the shared

space and control sites. The responses to the additional survey questions (Items 6-8) and the effects of demographic variables were also investigated and discussed.

Part 3: Discussion of Expert Interview Results

As an evaluation outcome to complement the perception survey results, the in-depth viewpoints from the expert interview were reviewed and discussed against the five shared space objectives. The audio recordings were listened to and a search made for underlying commonalities and connection between narratives across interviews. The NVivo software was used to extract the most frequently occurring words spoken during the interview. Additional insight into the shared space design, development and management was also summarised and discussed.

6.4 Results and Discussion

The results presented in the following three sub-sections correspond to the three parts of the data analysis strategy and methods discussed earlier.

6.4.1 Analysis of Performance Measures of Shared Spaces

Table 6.3 presents the main results of the on-street perception surveys (Items 1-5) for the three shared space sites (Elliott, Lorne and Fort Streets) as well as the control site (O'Connell Street). Based on the full sample ($n = 120$), Cronbach's alpha for the Elliott, Lorne and Fort Street areas were 0.677, 0.758 and 0.740, respectively, which indicated good internal consistency. The distribution of responses was negatively skewed with a varying degree of kurtosis, resulting in a non-normal distribution.

The analysis of all shared spaces yielded positive central tendency measures of Mean, Median (Median Perception Rating, MPR) and Mode. The MPR as the key performance indicators of the shared spaces are discussed with respect to each performance objective, together with other statistical characteristics as follows. The results of the O'Connell Street as a control site are discussed in the following comparative analysis section.

Table 6.3 Median Perception Rating (MPR) and other statistics of performance measures.

Performance Measure	Study Area	Mean	MPR	Mode	SD	Distribution of Responses (%)						Skewness	
						-3.0	-2.0	-1.0	1.0	2.0	3.0	Value	SE
Place	Elliott St	1.51	1.26	2	1.216	.8	3.3	5.8	29.2	45.8	15.0	-1.488	.221
	Lorne St	1.09	1.02	2	1.495	3.3	6.7	8.3	30.8	42.5	8.3	-1.264	.221
	Fort St	1.14	1.27	2	1.497	1.7	8.3	9.2	27.5	42.5	10.8	-1.133	.221
	O'Connell St	.53	.23	2	1.664	2.5	17.5	12.5	30.0	35.0	2.5	-.661	.374
Pedestrian	Elliott St	1.66	1.40	2	1.220	.0	4.2	5.8	20.0	50.0	20.0	-1.521	.221
	Lorne St	1.60	1.35	2	1.170	.0	4.2	5.0	24.2	50.8	15.8	-1.543	.221
	Fort St	1.53	1.42	2	1.438	1.7	2.5	11.7	17.5	43.3	23.3	-1.294	.221
	O'Connell St	.75	1.06	2	1.765	.0	17.5	17.5	12.5	42.5	10.0	-.512	.374
Vehicle	Elliott St	.73	.42	2	1.715	7.5	6.7	13.3	31.7	32.5	8.3	-.864	.221
	Lorne St	.95	.67	2	1.505	1.7	8.3	13.3	31.7	36.7	8.3	-.906	.221
	Fort St	.55	.31	2	1.704	4.2	14.2	15.0	27.5	34.2	5.0	-.615	.221
	O'Connell St	.80	.23	1	1.436	.0	5.0	25.0	32.5	30.0	7.5	-.451	.374
Economic	Elliott St	1.30	1.16	2	1.400	3.3	4.2	5.8	30.0	45.8	10.8	-1.561	.221
	Lorne St	.69	.31	1	1.623	4.2	9.2	15.8	32.5	31.7	6.7	-.746	.221
	Fort St	1.41	1.18	2	1.357	1.7	4.2	6.7	31.7	38.3	17.5	-1.333	.221
	O'Connell St	-.18	-1.00	-2, 1	1.810	7.5	27.5	15.0	27.5	20.0	2.5	-.026	.374
Safety	Elliott St	1.31	1.22	2	1.533	4.2	1.7	11.7	25.8	37.5	19.2	-1.232	.221
	Lorne St	1.17	1.20	2	1.605	3.3	5.8	12.5	20.8	42.5	15.0	-1.082	.221
	Fort St	1.36	1.22	2	1.460	3.3	1.7	10.8	26.7	39.2	18.3	-1.289	.221
	O'Connell St	1.58	1.32	2	1.174	.0	.0	12.5	22.5	47.5	17.5	-1.090	.374

For the 'Placemaking and Pedestrian Focus' criteria, Fort Street outperformed the other two shared streets with the MPR of 1.27 and 1.42, respectively. Out of the three median difference comparisons, only the rating difference (0.24) between Elliott and Lorne Street ($MPR_{PLACE, E-L}$) was statistically significant ($Z = 2.039$, $p = .041$) based on the Wilcoxon signed-rank test at the 0.05 significant level. The MPR for the pedestrian objective (MPR_{PED}) that ranged between 1.35 and 1.42 were the highest out of all performance measures, indicating the streets were perceived to clearly enhance pedestrian priority and level of service for all the shared space sites. The Wilcoxon test revealed no statistical significance of the MPR_{PED} difference among the three sites, including the difference of 0.07 between Lorne and Fort Streets ($MPR_{PED, L-F}$).

The MPR for the 'Vehicle Behaviour Change' criterion (MPR_{VEH}) between 0.31 and 0.67, and the mean value of less than 1 across the three sites identified a need for improvement to better reduce the perceived vehicular dominance. The highest MPR difference between

Lorne and Fort Streets ($MPR_{VEH, L-F}$) of 0.36 was not statistically significant, which means the difference among the MPR_{VEH} values was due to sampling error or by chance. Additionally, the analysis results of the survey question (Item 7) also supported a concern of the driver behaviour within the shared street demonstrating it still requires the most improvement. The percentage of participants that perceived there were vehicle-related issues (to be most improved) were 31.7%, 23.3% and 44.2% for Elliott, Lorne and Fort Streets, respectively. Each of them represented the highest portion out of the total responses for each respective study area.

With respect to the ‘Economic Impetus’ criterion, Lorne Street underperformed relative to the other two sites. The median difference of 0.85 ($MPR_{ECON, E-L}$) and 0.87 ($MPR_{ECON, L-F}$) was statistically significant ($Z = -3.090$, $p = 0.002$ and $Z = 3.505$, $p = 0.000$, respectively). The low $MPR_{ECON, L}$ of 0.31 reflected the inactive land use frontage of the St James Theatre building that occupies one complete side of Lorne Street as discussed in Karndacharuk, Wilson, & Dunn (2013a). The results reinforce the importance of the mixture of street activities (e.g. outdoor tables) and active land uses (e.g. café and retail) abutting the street in meeting the economic improvement objective. For the ‘Safety for All Users’ criterion, both Elliott and Fort Streets had the MPR_{SAFETY} of 1.22. There was no statistical significance when computing the median difference among the three shared streets.

With the mode value of 2 for all study areas and performance measures, except the Economic aspect of the Lorne St area, the majority of pedestrian participants positively ‘agreed’ to the questionnaire statements.

The varying statistical values of each performance measure for the three shared spaces and the control site in Table 6.3 can also be illustrated via boxplots as shown in Figure 6.5. A boxplot displays the five statistics (minimum, first quartile, median, third quartile, and maximum), the distribution of the variable and outliers.

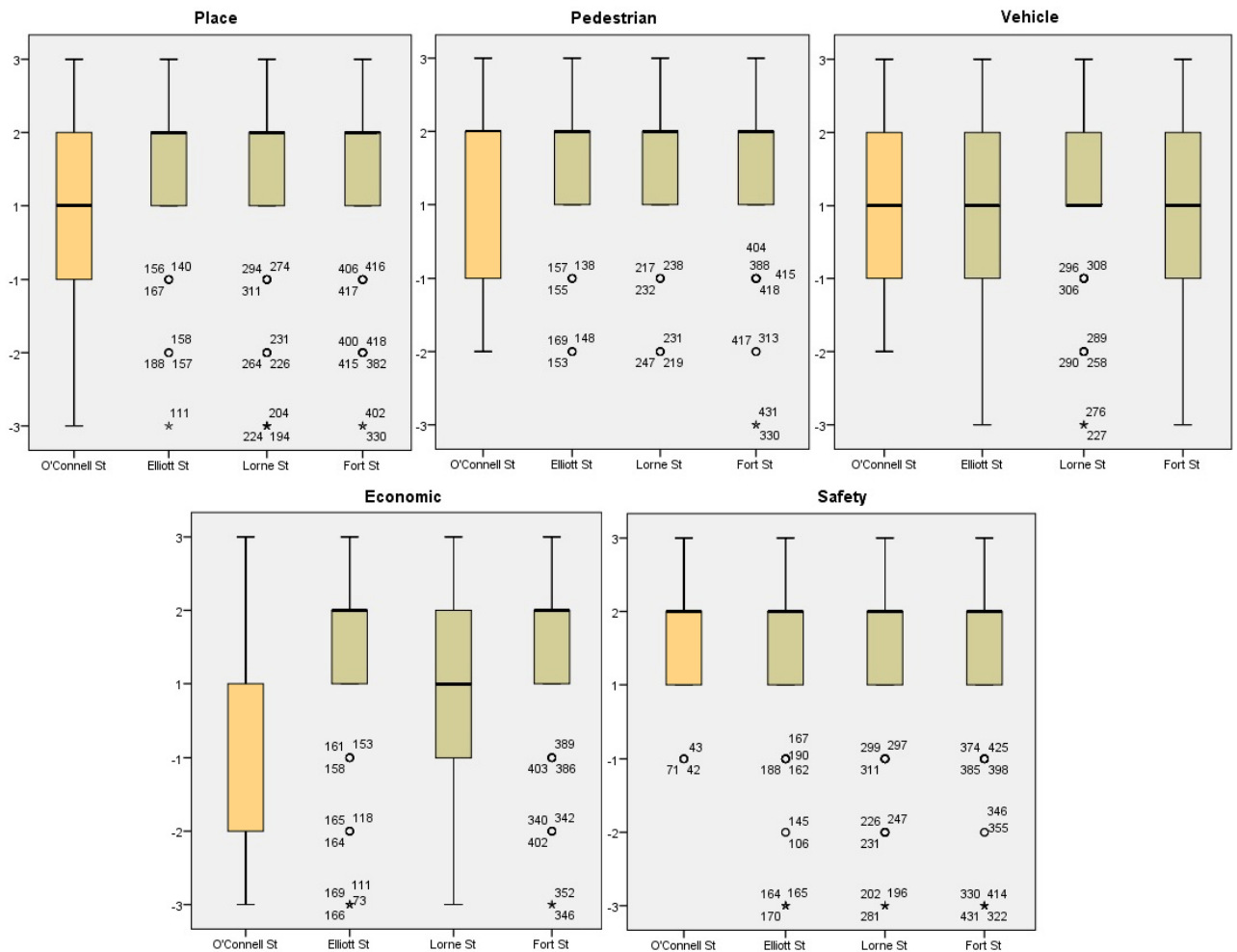


Figure 6.5 Boxplots of on-street survey results.

Correlation between performance measures

The Spearman's rank and Pearson correlation coefficients between the five performance measures for each study area are shown in Table 6.4. Correlation results with a statistical significance are displayed with asterisk(s), including the significant levels of 0.05(*) and 0.01(**).

Table 6.4 Spearman's rank correlation matrix of five performance measures.

	Place	Ped	Veh	Econ	Safety
Place	1				
Ped	.335**	1			
Veh	.085	.331**	1		
Econ	.213*	.258**	.126	1	
Safety	.302**	.482**	.458**	.395**	1

(a) Elliott Street (N=120)

	Place	Ped	Veh	Econ	Safety
Place	1				
Ped	.180*	1			
Veh	.152	.375**	1		
Econ	.388**	.406**	.244**	1	
Safety	.393**	.497**	.379**	.375**	1

(b) Lorne Street (N=120)

	Place	Ped	Veh	Econ	Safety
Place	1				
Ped	.492**	1			
Veh	.135	.420**	1		
Econ	.392**	.422**	.238**	1	
Safety	.343**	.548**	.477**	.402**	1

(c) Fort Street (N=120)

	Place	Ped	Veh	Econ	Safety
Place	1				
Ped	.130	1			
Veh	.007	.544**	1		
Econ	.549**	.485**	.260	1	
Safety	.259	.367*	.300	.510**	1

(d) O'Connell Street (Control Site, N=40)

The correlation matrix of the three study areas in Table 6.4 (a-c) confirms the complex interrelationship between the five shared space performance measures. Both the 'Pedestrian' and 'Safety' measures were related to the other performance measures all with statistical significance in every study area. The highest correlation coefficient among the shared spaces is 0.548 for the Fort Street site between the 'Pedestrian' and 'Safety' objectives at the 0.01 significance level. Quite the contrary, there was only one pair of the 'Place' and 'Vehicle' performance measures that was not statistically correlated across the three study areas with the nominal coefficient values of 0.085, 0.152 and 0.135 for Elliott, Lorne and Fort Streets, respectively.

The statistically significant correlation results from the Spearman's rank test were highly consistent with those from the Pearson's test. The only inconsistent outcome of statistical

significance was the correlation between ‘Place and ‘Vehicle’ measures of the Lorne Street dataset (Spearman’s $\rho = 0.152$ vs. Pearson’s $r = 0.228^*$).

The statistical analysis reaffirms the complex web of interconnectivity between the five performance measures from the user perception perspective. This in practice suggests that by considerably improving one particular performance measure, especially to achieve the ‘Pedestrian Focus’ and ‘Safety for All Users’ objectives, road users are likely to positively perceive the other aspects and the performance of a shared space as a whole. Conversely, if one aspect is negatively perceived, the overall performance is statistically likely to be compromised.

6.4.2 Comparison with Control Site and Other Contributing Factors

As displayed in Table 6.3, the control site of O’Connell Street was outperformed by the shared space sites with respect to the ‘Place, Pedestrian and Economic’ measures with statistical significance based on the Mann-Whitney U test. The most significant aspect was of the ‘Economic Impetus’ with a negative MPR value of -1.00. It is encouraging that the perception survey design was able to differentiate the operational outcome of a shared space and a normal street in meeting the established objectives.

Without a statistical significance, O’Connell Street was considered to function similar to the other streets from the ‘Vehicle Behaviour Change’ perspective, and operate better than the shared streets from the ‘Safety For All Users’ perspective. O’Connell Street had a relatively narrow corridor width (approximately 10m) with a one-way northbound circulation for vehicles and traffic calming measures (a speed table and humps). Therefore, vehicle speeds were restricted, which were perceived as being safe by the survey participants. With respect to the ‘Safety’ criterion, the survey outcome was therefore not a surprise given that a conventional street with clear delineation between pedestrian and vehicle space was generally perceived more positively than a shared street. It is hoped that the findings of this research that emphasises the importance of low-speed pedestrian and vehicle interaction in improving safety performance, as discussed in Chapter Five, will contribute to a better safety perception of shared space.

With respect to the degrees of statistical dependence among the performance measures as given in Table 6.3, it is observed that the control site of O’Connell Street exhibited

reasonably less statistical relationships between the variables when compared with the three shared spaces (i.e. only five out of ten measurements were statistically significant).

Other Contributing Factors

The on-street surveys also queried the pedestrians on the most and least important aspects of the street and which element would most require improvement (Items 6-7). Table 6.5 shows the value (mode) that appeared most often in a dataset for each study area. The ‘Safety’ objective was perceived to be the most important performance criterion in both shared and normal streets. Depending on the street and land-use environment, the ‘Placemaking’ and ‘Economic’ objectives were considered by the majority of the survey participants to be the least important aspect. While all of the shared spaces under investigation were perceived to require immediate attention to address the issue of ‘Vehicle’ dominance, the control site of O’Connell Street most needed improvement on the ‘Placemaking’ aspect.

Table 6.5 Perceived most and least important performance criteria.

Performance Criteria	Shared Street				Normal Street
	Elliott	Lorne	Fort	Overall	O'Connell
Most important	Safety	Safety	Safety	Safety	Safety
Least important	Place	Econ	Place	Econ	Place
Require improvement	Veh	Veh	Veh	Veh	Place

The statistical analysis of the demographic data such as gender, age, ethnicity, frequency and purpose of visit yielded little correlation with the performance variables. The only results of note were the Spearman’s rank correlation coefficients of the gender outputs. The correlations between gender (coded ‘1’ and ‘2’ for male and female, respectively) and the ‘Pedestrian’ and ‘Safety’ objectives were statistically significant for all shared space sites (but not the control site). The analysis yielded negative correlation coefficients $\rho(120)$ ranging between -0.206 and -0.301 ($p = 0.01$) and between -0.262 and -0.291 ($p = 0.05$) for the ‘Pedestrian’ and ‘Safety’, respectively. Although a weak relationship, these figures indicate that the female participants were more risk-averse and likely to rate the two performance criteria lower than the male participants.

6.4.3 Limitations of Perception Survey Design and Analysis

While the sample of 120 survey responses was an appropriate sample size to achieve statistically significant data at an error of 10% (Charlton, 2002; Israel, 1992) for the shared space sites, only 40 responses were obtained for the control site. This was due to limited resources and time available. Nevertheless, it is argued that sample sizes under 50 can still provide informative comparisons and useful results. Additionally, with the focus of developing the data collection and analysis methodology for quantitative measures (especially using the video surveys) in 2010, the ‘before’ qualitative data of the perception surveys could not be acquired. Therefore, these limitations should be kept in mind.

6.4.4 Discussion of Expert Interview Results

Given the confidentiality of responses and the semi-structured nature of the interviews where the questions were not restricted to a set order and the line of questioning was determined by the flow of responses, the interview results are discussed in accordance with the theme of the shared space objectives. The interview scripts are included in Appendix C.

In order to give a general understanding of the interactive, spontaneous communication in the interviews with the professionals, frequently occurring words in the interviews, extracted using the NVivo software, are shown diagrammatically in Figure 6.6. It is noted that similar words with the same stem are grouped together based on Nvivo’s Word Frequency query criteria (Nvivo, 2014) and the greater the size of the word the more frequently the word is used.



Figure 6.6 Frequently occurring words (tag cloud) in expert interviews.

Alternatively, the frequently occurring words are presented as underlining words in the following sentences. As anticipated, the conversations revolved around the discussion of the common design attributes and issues that contributed to a successful shared space, and how the changes made to the Elliott, Lorne and Fort streets in the CBD settings affected road users, (including pedestrians and vehicles), surrounding land use and businesses in the area. Placemaking and transport objectives were important in the development process. A collective understanding and ideas learnt from this evaluation process would adequately inform existing operating environments and future schemes so that the concept can be applied consistently across the region. The word ‘yes’ was a positive reply from the interviewees in response to the polar questions such as “do you believe that the shared spaces are attractive?” and “do the current shared spaces provide a safe environment for all users?”

Placemaking

Enabling the shared spaces to function as a place for people was considered a very important aspect by all interviewed professionals. The fundamental design of a level, paved surface with an aim to make the street simple, open and de-cluttered was well received by many experts, and deemed important for flexible, multiple uses (e.g. outdoor dining, events, markets and loading). The upgraded shared spaces were noticeably improved from the previous conventional streets that were “dirty, cluttered full of cars, and unattractive”, albeit Lorne Street still was perceived to perform poorer than the other two streets due to its “bleak and barren” look and the lack of land use activation on the St James theatre side.

Although the majority of the interviewees generally believed the current provision of street furniture (formal and informal seating, lighting, rubbish bins and artwork) were adequate, some looked to provide more streetscape elements and better management of movable street furniture to attract people to stay longer. Contrastingly, the others were conscious of “overstocking the spaces with street furniture”.

It is evident throughout the interview conversations that the experts in urban planning and design were able to naturally critique the key factors influencing the process of placemaking, including built form, building interface, aesthetics elements, microclimate effects (e.g. sunlight), street furniture design, colours and materials. In creating a great place for the city of Auckland, an urban design expert noted the role of the street paving and people as follows:

“The grey colour of the streets is like any of the beautiful streets around the world; the cobblestones of Rome, and the piazzas of the great cities. Auckland is built on Basalt, a grey volcanic rock; it is the story of Auckland. Grey provides a neutral colour which you can place anything on and it will stand out... let people provide the colour.”

Furthermore, the context-sensitive design and land use activation were highlighted. Concerns were raised about the design principles that created a somewhat “cookie-cutting” approach while retaining some basic elements for consistency, there is a need for a variation of street elements such as “the Wellington Cuba Street bucket waterfall” or street

furniture that “allows for more playful interaction, especially for children” and is “less static”. Future use of the St James site in the Lorne Street area was discussed at length with a transport engineering expert who was involved in the design development where there were many attempts to improve placemaking, including the use of poster boards or films projecting onto the building façade as part of special events.

Pedestrian Focus

The pedestrian focus objective is arguably the most agreeable topic among the professionals. All of the experts believed that the shared space design (including “very open and unencumbered space” and “the high quality paving and finish”) enabled the pedestrians to freely move around within the shared streets, especially when putting it in contrast with the previous road environment with kerb and channel. The provision of safe zones on either side of the street next to the boundary was supported by many participants, but one expert believed that the zone “compromised the shared space philosophy” where a true shared space should not restrict vehicles to travel in the middle of the street.

The link between pedestrian priority and that of vehicular traffic was often mentioned. The ambiguity (and confusion) “in the mind of the motorist” was believed to be a key to behavioural change. Most professionals felt that the legal regulations around shared spaces in New Zealand were sufficient as “vehicle (is required) to give way and at the same time pedestrian to not unduly impede the passage of (vehicular) traffic”. However, the majority emphatically noted that creating an environment that is “self-explaining” and clearly different from a conventional street is a much better way to influence user behaviour than that of a legal framework. Educational campaigns were also identified to raise public awareness of the use and priority within the shared zone.

Vehicle Behaviour Change

Unlike the dialogue about placemaking and pedestrian focus via street design and planning, the management and expectation of vehicle behaviour change are not straightforward. While the driver behaviour was mostly perceived by the experts as appropriate during peak hours, the increase of vehicle speeds at off-peak time was identified as a major issue by some practitioners, particularly those with the transport engineering and planning background. Some tended to recommend physical measures using streetscapes and street

furniture to restrict vehicular speeds. As discussed in Wilshire, Wilson, & Karndacharuk (2014), traffic calming measures of both vertical and horizontal deflections were suggested to ensure lower operating speeds. In contrast, many experts regardless of their educational background, including urban designers and traffic engineers alike, displayed a more relaxed, risk-neutral view of the off-peak vehicular management, and believed that the unique nature of the shared space design, coupled with education and monitoring, was primarily adequate to encourage the users to be thoughtful and behave appropriately. Besides, a few believed that physical traffic calming devices would be detrimental to the aesthetics of the space, and would lead to drivers focusing on avoiding them rather than interacting with other users of the space. Such self-regulating nature of shared space design is echoed in the following statements from a **transport practitioner**:

“Shared spaces should not control speeds through rigid traffic engineering measures. It goes against the shared space concept. If you have removed all other traffic engineering controls (kerbs, signage and road marking), why be tempted to start re-introducing them? Control the speed by people and activity in the space. Street furniture or trees to (meet) the required horizontal deflection would create artificial clusters of elements that (are) odd and contrived urban design. Clusters of street furniture would also reduce the flexibility of the space.”

In spite of the conflicting points of view on how to manage driver behaviour, a consensus of opinion among the professionals was gained on the need for vehicles to operate at as low speeds as possible. The recommended credible speeds range from a walking pace of 5 km/h to a 30 km/h design speed during the nighttime with minimum risk exposure. Also, a strong connection between the vehicle behaviour change and pedestrian focus objectives was mutually recognised in the interview process. Similar to the SmartRoads concept (VicRoads, 2011) where many competing demands for limited road space are managed depending on the time of day, the following statement from an interviewee reflects the acceptance that the use and priority between pedestrians and vehicles in a shared space vary according to the demand at different times of day:

“When the street is busy with people, people have more confidence to meander and traverse the entire space. When it is not so busy, the vehicles tend to take over, and pedestrians move to the side.”

When asked about parking provision and restriction, many believed the existing arrangements of no on-street parking, except loading activities only between 6 am-11 am were appropriate. While many acknowledged that parking would have a detrimental effect on the other shared space objectives, a few believed that “cars do provide some passive surveillance and activity to the space” and the parking provision should take account of “what local businesses want in conjunction with the vision of the local authority”. Moreover, some raised the issues of drivers parking within the safe zones that were located between the tactile delineator and the building line.

Economic Impetus

The interview discussion on the economic impetus subject reiterates the importance of the context-sensitive design of shared spaces in an activity centre. The key messages, consistently mentioned by the experts, involved a mix and wide range of land uses that would draw pedestrians into the space at all times of the day, high-quality retail and hospitality and the “significant amount of active frontage” to reduce vehicle dominance and improve pedestrian priority.

They all agreed that there should be as much active frontage along and throughout either side of the street as is possible. The great significance of the active land-use frontage can be summed up by an urban design practitioner as follows:

“The success of adjacent land uses and shared space are all about edge activation. It encourages pedestrians to travel through the street, stop and dwell. It provides for outdoor dining, brings vibrancy to street and helps to slow vehicles down. The ground floor use is important.”

For those who specified the minimum portion of the activation, the active edge requirements range from one-third to fifty and seventy-five percent of the total frontage. It was also recommended that a CBD shared space should be placed in a location where there are highly activated edges and plenty of existing businesses around.

Safety for All Users

Similar to the results of the on-street perception surveys and as discussed in Section 6.4.2 the safety for all users aspect was considered by the interview experts to be the most important issue. Given that the CBD shared spaces have been in operation since 2010, most experts believed the streets provided a safe environment for all users because of the low speed environment and the removal of street clutter. While one expert interestingly argued that:

“There will inevitably be an incident in a shared space, but (we) need to remember that such incidents happen in all streets. The (shared) spaces were not implemented for safety reasons, but were designed to be no less safe than a conventional street.”

Another expert touched upon a balancing act in designing a shared space from a road safety perspective as follows:

“Safety is most important but you cannot have a totally risk-averse mentality when designing these spaces - very important to differentiate the perception of a lack of safety with an actual lack of safety”.

To cater for the visually impaired, the shared space design team spent a lot of time with the Royal New Zealand Foundation of the Blind that was originally concerned about “loss of kerbs and straying onto the carriageway”. Extensive consultation on pavement materiality and design prototypes, especially the tactile delineators, eventually led to the satisfaction of the disability user groups. Furthermore, a few experts that were directly involved in the actual design and implementation of the shared streets felt the Auckland CBD design, incorporating the “accessibility zone” with a tactile delineator strip, led the world in the universal design for all shared spaces users.

Concluding Remarks

It is striking to learn from the expert interviews the great extent to which the established themes based on the shared space objectives are interrelated. For example, while exploring the placemaking objective, many practitioners discussed the need for vehicular speed reduction, mitigation measures required for enhancing the perception of safety and upgrade

works to improve pedestrian amenity and economic vitality. The following quotation from an urban design expert demonstrates the interconnectivity:

“An important part (of placemaking) is the adjacent land uses and how they activate the space. First, you may need to upgrade the public realm to provide the economic impetus, and to upgrade the land uses around the street which in turn help improve the attractiveness of the space. Risk of (vehicle) accelerations (would be) occurring when (there are) not many pedestrians around to provide friction.”

Such findings of the interconnected performance objectives from the interviews with the professionals are strongly consistent with the correlation outcome from the statistical analysis of the on-street surveys. Additionally, the interview results reaffirm the appropriateness of the five interlinked objectives for the evaluation of shared space schemes.

More importantly, the interview analysis revealed a less distinct demarcation between the perspective of urban design and traffic engineering professionals. Although they utilised their technical expertise in the respective fields and qualification to comment on and evaluate the various aspects of shared space attributes and performance, their overall opinion of shared spaces, in general, reflected the general understanding of multidisciplinary knowledge within and outside of the public road network as discussed in Chapter Two and illustrated in Figure 2.1. It is therefore fascinating to point out that the shared space concept helps to renew not only the multifunctional nature of a public street, but also the multidisciplinary collaboration between professionals that are involved in street design and management.

6.5 Conclusions

This chapter investigated the qualitative aspects of the shared space performance evaluation using the on-street perception and expert interview surveys. The Median Perception Rating (MPR) obtained from the 6-point scale questionnaire surveys was used as the performance outcome of a shared space towards each established measure (objective). The key conclusions of the qualitative study presented in this chapter can be outlined as follows:

- The quantitative results of no negative values from the on-street perception surveys by and large confirmed that the shared space schemes under investigation performed positively. The Elliott Street area generally operated better than the other two case studies with the highest MPR values in two criteria (i.e. Place and Pedestrian). The survey results of Lorne Street that lacked an important contextual aspect of land use activation on one side yielded the lowest MPR values for the three out of five criteria (i.e. Place, Economic and Safety criteria).
- The Spearman's rank correlation analysis highlighted the interconnection between the five performance measures in the overall perception of the success of a shared space. Not only correlated with all other objectives with statistical significance in every case study, the 'Pedestrian' and 'Safety' measures between themselves produce the highest correlation coefficient of 0.548 in the Fort Street area at the 0.01 significance level.
- Based on the Mann-Whitney U test, the shared spaces outperformed the control site of O'Connell Street with statistical significance with respect to the 'Place, Pedestrian and Economic' measures with the largest performance difference of 'Economic Impetus'. The MPR differences in the other two measures of 'Safety and Vehicle' were not statistically significant.
- The results of the interview surveys provided an insight into the specialist opinion of the key attributes of shared space design and operation as well as reaffirmed the interconnectivity and validity of the five shared space objectives within the New Zealand context. The importance of the context-sensitive design, taking into account adjacent land uses, and multidisciplinary collaboration cannot be overemphasised in the shared space design process.

The assessment results, coupled with the comparative analysis with the control site primarily substantiated the soundness of the design of both the on-street and expert interview surveys in measuring the success of shared space schemes based on the established objectives. Nonetheless, between the shared spaces and the control site, the on-street survey design was unable to differentiate between the 'Vehicle' and 'Safety' performance measures based on the statistical analysis alone. It is therefore suggested that more survey samples are required as there were only 40 responses for the control site of O'Connell Street. A wider group of space users (e.g. drivers, shop owners and workers) should be considered in the future on-street perception surveys to better understand users' subjective evaluation of the ability of a shared space to serve them.

CHAPTER SEVEN

ANALYTICAL HIERARCHY PROCESS

This chapter presents the implementation of the Analytical Hierarchy Process (AHP) that forms the final stage of the multi-faceted evaluation framework of shared spaces as outlined in Chapter Three. The data collection and analysis process of the quantitative performance measures, demonstrated in Chapters Four and Five, was applied to the 2013 quantitative data from the three shared space sites. The qualitative performance indicator of the Median Perception Ratings (MPR) from the 2013 on-street perception surveys, documented in Chapter Six, was analysed using the AHP technique. The qualitative results were then correlated and compared with the quantitative outcomes. A performance index for each study area was calculated and sensitivity tested to ensure the outcome was fit for purpose and a reliable indicator of its performance.

7.1 Introduction

The AHP is a widely-used multi-criteria decision analysis method. Developed by Thomas Saaty (1977; 1980) originally for the measurement of intangibles and to provide a mathematical foundation for social sciences, it is designed to select the best from a number of alternatives based on multiple criteria comparable at the same level of a decision hierarchy. The approach incorporates the concept of consistency, and allows for the inconsistency of judgements in a decision making process. Simple pairwise comparison judgements are employed to arrive at overall priorities for ranking the alternatives (Saaty & Vargas, 2012). An intensity scale of importance from 1 to 9 provides a basis of numerical measurement to evaluate any two homogeneous elements in the hierarchy.

The use of the analytical hierarchy process is well established in transport policy as well as transportation infrastructure planning, operation and maintenance. Tsita and Pilavachi (2012) utilise the AHP technique to evaluate alternative fuels for the Greek road transport sector in response to climate change and energy security concerns. Besides the alternative of the conventional combustion engine with gasoline or diesel, many different alternative fuel solutions were considered such as biofuels, hybrid and electric vehicles with a wide

variety of assessment criteria, including Implementation cost, Technology maturity cost, Cost of energy, CO₂ emission, Energy security, Employment and Social welfare. Employing similar alternative fuel systems and criteria, Poh and Ang (1999) undertook a multiple attribute analysis using the AHP to select the best fuel alternative for Singapore land transportation (namely, the use of electric vehicles). Moreover, sustainable transport options of carsharing has been investigated as a pilot study using various methods that included the AHP method, Dempster-Shafer theory and sensitivity analysis to demonstrate a sustainability evaluation process for environmental-friendly transport measures such as clean fuels and intelligent transport solutions (Awasthi & Chauhan, 2011).

The AHP is proven to be valuable in prioritising urban transport investments, and selecting from among alternative transport projects. Ferrari (2003) took congestion parameters, implementation costs, air pollution and land acquisition into account in a prioritisation process. Tudela et al. (2006) compared the evaluation outcome of Cost Benefit Analysis utilising an AHP process to conclude that non-economic attributes (such noise, air pollution, visual intrusion and environment benefits) as well as public opinion need to be incorporated in the decision making process in order to select the best transport project. De Brucker and Macharis (2011) performed a strategic evaluation of six road safety improvement scenarios that focused on making the road environment more forgiving and self-explanatory. The AHP is utilised to construct a hierarchical structure with the criteria of users, authorities and vehicle manufacturers, and to calculate relative weight (priorities) of each criteria. Furthermore, the AHP applications in evaluating and prioritising highway routine maintenance (Gonzales et al., 2013), transport facility management (Sinha et al., 2009) and traffic signal operations at signalised intersections (Hu, Tian, & Zang, 2012) are documented in the literature.

The key steps for the AHP evaluation of alternatives (for the three shared space schemes for this research) can be outlined as follows:

1. Establish the **hierarchical structure**. It requires the decomposition of a problem into interrelated elements. The hierarchy is structured into three levels with the overall goal positioned at the top (first level), followed by a set of criteria and subcriteria (midlevel) and a set of alternatives at the bottom (last level). As stated by Caliskan (2006), the main purpose of the hierarchical structure is to measure the

effect of the relative importance of the elements at each level to the goal (highest level) from a decision-maker's viewpoint.

2. Determine a **relative weight** (priority or priority vector) for each criterion and subcriterion. A pairwise comparison matrix is established at each hierarchical level. With preference judgements assigned to each pair of homogeneous elements, the matrices are translated via Saaty's eigenvector method into priority vectors of criteria and subcriteria (Farhan & Fwa, 2011). The calculation of the priority vectors of the five shared space performance criteria are documented in Section 3.3.3 of Chapter Three. Table 7.1 displays the fundamental scale and rating definitions along with a random consistency matrix that is used for assessing judgement consistency.

Table 7.1 The pairwise comparison scale and average random consistency
(Source: Saaty & Vargas, 2012).

Intensity of Importance	Definition	Explanation
1	Equally Important	Two factors contribute equally to the objective.
3	Somewhat more important	Experience and judgement slightly favor one over another.
5	Much more important	Experience and judgement strongly favor one over another.
7	Vey much more important	Experience and judgement very strongly favor one over another.
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity.
2, 4, 6, 8	Intermediate values	When compromise is needed
Reciprocals	When activity i compared to j is assigned one of the above numbers, then activity j compared to i is assigned its reciprocal	

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

3. Check **consistency ratio** (CR). The CR value is to be less than 0.1, which represents allowable 10% inconsistency in human judgements. If the value is not less than 0.1, Saaty and Vargas (2012) recommend revisiting the problem and revising the judgements. With respect to the formula used to determine the CR, Section 3.3.3 includes the CR calculation of the matrix of the shared space performance criteria.

4. Calculate an **overall weight** of an alternative. In absolute measurement AHP, the overall weight is termed by Saaty (1987) a ‘total ratio scale score’, which is derived from the sum of the scores of the criteria (and corresponding subcriteria). A score of each criterion is the product of its weight and the ideal intensity (rating) of the alternative. An ideal intensity is a weight of each rating divided by the largest rated intensity where the largest ideal intensity value is equal to one.

The process of obtaining the total AHP score is demonstrated via the calculation of the performance index of the shared space schemes under the multi-faceted evaluation framework in the following sections.

7.2 Previous Work

As discussed in Chapter Three, an overall multi-faceted evaluation framework of shared spaces integrates the AHP method of absolute measurement with a goal of determining performance indices. The evaluation framework consists of two AHP hierarchical structures or models; the first is the quantitative evaluation structure and the other the qualitative one. Both models share the elements and attribute weights of the first two hierarchical levels. These include the goal of arriving at a performance index at the top and the five performance criteria at the second tier as earlier shown in Figure 3.4 in Chapter Three for the quantitative performance hierarchy.

7.2.1 Shared Space Data Collection and Processing Methods

As demonstrated throughout Chapters Four to Six, the data collection and processing were designed to derive key performance indicators (KPIs) that represent how well the case studies meet the established shared space objectives from both quantitative and qualitative measurements. Table 7.2 summarises the data collection methods and processing techniques of the CBD shared spaces and the reference chapters in which they are discussed and elaborated.

Table 7.2 Quantitative and qualitative data collection and processing techniques.

	Data Collection	Data Processing	Output		Reference
			KPI	Unit	
Quantitative	Video survey	24-hour profile review	Pedestrian occupancy ratio	%	Chapter Four
			Pedestrian density	p/m ²	
			No. of RUICS interactions	count	Chapter Five
			No. of RUICS conflicts	count	
		15-min peak zone review	Mean dwell time	minute	Chapter Four
			Ratio of pedestrians walking along vehicle path	p/m	
			Ratio of pedestrians accessing land use	p/m	
	Traffic count	Descriptive statistics	Mean vehicle speed	km/h	
			Vehicle volume	vpd	
	Measurement		Active frontage ratio	%	Chapter Three
	Crash Analysis System (CAS)		No. of reported crashes	count	Chapter Five
Qualitative	On-street perception survey		Mean Perception Rating (MPR)	-	Chapter Six

As can be observed in Table 7.2, the main quantitative data collection was the video survey with the data analysis methods of the 24-hour profile and peak 15-min peak zone review for macroscopic and microscopic time-period processing, respectively. By examining the video footage over the 24-hour period at 15-min intervals, the KPI of pedestrian occupancy ratio, pedestrian density and the number of pedestrians accessing the adjacent land uses can be computed. With respect to the Road User Interaction and Conflict Study (RUICS) as discussed in Chapter Five, the video footage was reviewed for the whole 24-hour period in order to identify both pedestrian-vehicle conflicts and interactions within the vehicle travelling area. Once the daily profile was established, the detailed processing of the 15-min peak period within an approximately 40m-long zone was undertaken to determine the average user dwell time as well as the number of pedestrians walking along the vehicle travelling path and pedestrians accessing adjacent properties (per linear metre of vehicular lane width and active land-use frontage, respectively).

Other quantitative data collection methods were the automatic traffic tube counter for vehicle speed and volume information, physical measurement of active land-use frontage and NZTA's Crash Analysis System for injury and non-injury reported crash data. For the

qualitative data collection and processing, Chapter Six documents the process of obtaining the Median Perception Ratings (MPR) for the three study areas via the on-street perception surveys.

7.3 Implementation of the Analytic Hierarchy Process

The quantitative and qualitative performance data collected in 2013 were used for the AHP analysis implementation to evaluate the three shared spaces in the Auckland CBD. The geographical extent of the three study areas are depicted in Figure 1.2 in Section 1.1.1 of Chapter One. The following dates of the video footage on a Thursday at the three sites with predominantly good weather conditions were used for the quantitative data processing, including the RUICS analysis:

- Elliott Street: 26 September 2013
- Lorne Street: 3 October 2013
- Fort Street (Jean Batten Place): 19 September 2013

The vehicle speeds and volumes were collected continuously for a week at each site during a similar period as for the video surveys. Similarly, the percentage of edge activation was measured in 2013, taking into account the change to adjacent land use, particularly in the Fort Street area. The CAS analysis was undertaken for the ‘after’ shared space implementation period between July 2010 and the time of writing in April 2014. As mentioned before, the MPR values from Chapter Six constitute the qualitative performance data of the three study areas. The input data of Key Performance Indicators (KPIs) can be summarised in Table 7.3 for both the quantitative and qualitative 2013 data.

Table 7.3 Quantitative and qualitative key performance data of the CBD shared spaces.

Key Performance Indicator		Study Area		
		Elliott St	Lorne St	Fort St
QANTITATIVE DATA				
Place:	Pedestrian occupancy ratio (%)	20	46	15
	Mean dwell time (min:sec)	5:20	12:24	7:30
Pedestrian:	Pedestrian density (p/m ²)	0.010	0.009	0.011
	Ratio of pedestrians walking along vehicle path (p/m)	4.50	1.33	2.86
Vehicle:	Mean vehicle speed (km/h)	17.3	20.0	17.3
	Mean vehicle volume (vpd)	985	480	1,950
Economic:	Active frontage ratio (%)	90	50	70
	Ratio of pedestrians accessing adjacent land use (p/m)	0.57	1.10	0.02
Safety:	Reported crashes (#)	1*	0	1**
	RUICS conflicts (#)	14	2	13
	RUICS interactions (#)	987	249	586
QUALITATIVE DATA				
Place:	MPR _{PLACE}	1.26	1.02	1.27
Pedestrian:	MPR _{PED}	1.40	1.35	1.42
Vehicle:	MPR _{VEH}	0.42	0.67	0.31
Economic:	MPR _{ECON}	1.16	0.31	1.18
Safety:	MPR _{SAFETY}	1.22	1.20	1.22

Notes: * Non-injury crash with 'stolen vehicle' and 'speed misjudgement' noted in the Police report

** Non-injury crash with 'intoxicated pedestrian' noted in the Police report

7.3.1 Discussion of Key Performance Indicators

Table 7.3 presents the KPIs of the five shared space objectives in both quantitative and qualitative performance measurements. Quantitatively, the outputs of the pedestrian occupancy ratio from the 24-hour profile review of the 2013 video footages were largely consistent with the earlier analysis of the 2011 'after' implementation data (Karndacharuk, Wilson, & Dunn, 2013a), described in Chapter Four. The Lorne Street area had the highest occupancy ratio of 46%, followed by Elliott and Fort Streets at 20% and 15%, respectively.

This was largely due to a number of formal and informal seating areas provided for people who visited the central library. This Pedestrian Occupancy (PO) group in the Lorne Street area also spent the longest time in the road space with an average dwell time of 12 minutes 24 seconds.

The pedestrian density KPI was the total number of pedestrians, both Pedestrian Movement (PM) and Pedestrian Occupancy (PO), averaged over the 24 hour-profile snapshots per square meter of the study area. Within the whole day, it resulted in a small variation of the values that ranged from 0.009 to 0.011 p/m². It is noted that the area of each case study varied due to the road reserve width. The KPI of the number of pedestrians walking along the vehicle path was designed to quantify pedestrian confidence and assertiveness to freely move around in the street. As indicated in Table 7.2, the values were calculated using the 15-min peak zone technique whereby the pedestrians that walked in the 40m long zone were observed and tracked at the 0, 5th, 10th and 15th minutes of the peak period. The peak period of investigation was identified from the 24-hour profile, which was between 12.45-13.00 pm, 12.30-12.45 pm and 13.00-13.15 pm for the Elliott, Lorne and Fort street areas, respectively. Subsequently, out of the three study areas, Elliott Street had the highest ratio of pedestrians walking in the vehicle travelling zone of 4.50 p/m (i.e. 18 pedestrians over 4.5m allowable lane width for vehicles).

Consistent with the analysis approach used for the safety performance study (Karndacharuk, Wilson, & Dunn, 2014b) as discussed in Chapter Five, the vehicular speed KPI was averaged over a one-week period. While the mean operating speeds of the Lorne and Fort Street areas in 2013 were virtually the same as the earlier speed results in 2011 and 2012 the mean speed value on Elliott Street increased from 15.8 km/h immediately after the shared space completion in 2011 to 17.3 km/h in 2013 (and 17.4 km/h in 2012). Although the mean vehicle speeds of all the ‘after’ shared space implementation on Elliott Street were lower than that of the ‘before’ scenario (which was 19.7 km/h in 2010), it becomes clear that the vehicular speed reduction of approximately 20% due to the high quality streetscape improvement scheme on Elliott Street was momentary only within the first year of implementation. Given the same urban street design and streetscape materials were used for the three CBD study areas, a plausible explanation unique to the Elliott Street environment lies with the adjacent land use activation. In 2011, when the first shared spaces were open to the public, the majority of fine-grained land uses (of shops, cafes and

restaurants) fronted Elliott Street whereas only half of the Lorne and Fort Street edges were activated and dominated by a single land use activity (i.e. central library and office buildings with ground-floor commercial space in the Lorne and Fort Street areas, respectively). The drivers when they first experienced the new street design (e.g. Elliott Street) with a level, paved surface would react and drive more carefully on this section that potentially posed numerous roadside conflicts and hazards. Once the users became familiar with the street environment that was linear with unobstructed lines of sight as discussed in Section 5.4.1, the higher speeds were adopted. Nevertheless, the three-year speed data, including the 2013 data, confirmed the mean operating speeds at the appropriate range of 17-20 km/h of the CBD shared space design.

The vehicle volumes were stable over the three-year 'after' shared space implementation periods across the three study areas where the Fort Street area on Jean Batten Place serviced the highest mean volume of 1,950 vpd in 2013 (refer to Table 4.2 in Section 4.4.4 for comparison with the vehicular data in 2011, albeit only for a one-day analysis period). The relatively low volumes of less than 1,000vpd on Elliott and Lorne Streets indicate that the predominant users and drivers were localised and utilised the streets for the Access function more than the Movement purposes. Given that all of the road sections under study were one-way streets, it is noted that the flow data presented excluded the vehicles travelling in the wrong direction. As discussed in Section 5.4.6 of Chapter Five for Elliott Street based on the video footage review in 2010, 2011 and 2012, the wrong-way incidents in shared spaces were of a safety concern because of their relatively higher operating speeds. Nonetheless, the proportion of the wrong-way vehicles was somewhat low at less than 2%, which was comparable to normal streets, except the Lorne Street area. There were 40vpd on average, travelling in the wrong direction on Lorne Street in 2013, which accounted for 7.7% of the total vehicle traffic. The open, wide vehicular zone with the linear street design in the Lorne Street area would encourage familiar users to risk disobeying the law for the sake of convenient access to the nearby areas, thereby contributing to the increase of opposing flow incidents.

For the economic KPIs, the Elliott Street section had in 2013 the highest active frontage ratio of 90%, followed by the Fort and Lorne Street areas at 70% and 50%, respectively. With the shared space investment, Jean Batten Place in the Fort Street area saw an activation of a blank façade on the eastern side where the activity in a new food retail store

was visible from the public street. The KPI of the number of pedestrians accessing the adjacent land use per linear metre (of active frontage) was designed to quantify exposure to the commercial establishment. As anticipated, the Lorne Street area had the highest foot-traffic ratio of 1.1 p/m (44 people over 40m active frontage) due to its function and nature in servicing the community.

From the safety performance perspective, the reported crashes from the CAS database and pedestrian-vehicle conflicts and interactions based on the RUICS analysis are presented in Table 7.3. There was one non-injury crash reported for each of the Elliott and Fort Street areas. The detailed analysis of the Police report revealed the influencing factors of ‘stolen vehicle’ and ‘intoxicated pedestrian’ that were not necessarily attributed to the shared space implementation. Lorne Street had the lowest number of user interactions (249) and conflicts (2) largely due to the elevation difference between the pedestrian desire path to and from the library and the vehicle travelling zone located lower to the west.

7.3.2 Evaluation Hierarchy and Priority

With a multitude of criteria and subcriteria, the process of determining a performance index as an ultimate goal of the shared space evaluation framework involved trade-offs in making complex decisions of prioritisation. The AHP hierarchical structure in the absolute measurement mode as illustrated in Figure 7.1 is therefore an important step in objectively defining and prioritising an individual value of each performance measure.

The top of the hierarchy is the goal of determining a performance index. The second level represents the five objectives of shared spaces or main performance criteria. The assignment of their priorities (weights) via the pairwise comparisons is presented earlier in Chapter Three. The priorities are 0.111, 0.185, 0.265, 0.073 and 0.367 for the Placemaking, Pedestrian Focus, Vehicle Behaviour Change, Economic Impetus and Safety for All Users criteria, respectively. The first two tiers are applicable to both the quantitative and qualitative performance evaluations.

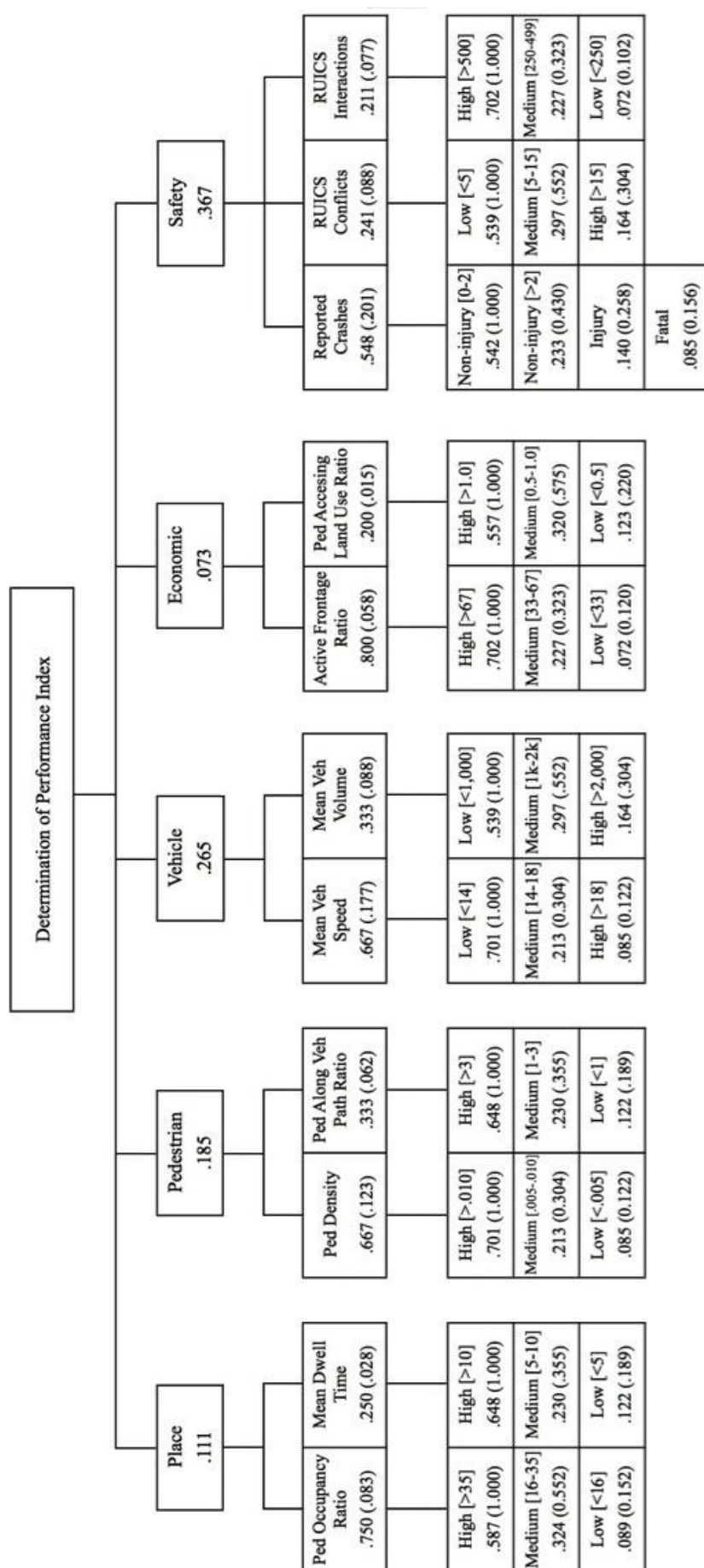


Figure 7.1 AHP evaluation hierarchy with local (global) priorities

As identified in Table 7.3, the subcriteria of the KPIs for quantitatively evaluating the shared space schemes are located in the third level. Each subcriterion is subsequently divided into a few intensity ranges in level four. The majority consists of three intensities of High, Medium and Low with an exception of the Reported Crashes KPI, which is divided into Non-Injury (Low), Non-Injury (High), Injury and Fatal groups. The values in square brackets correspond to the KPI values in level three. The local priority (relative weight) for the third and fourth levels is shown under the subcriteria and intensity with the global priority in parentheses. According to Saaty, Peniwati, & Shang (2007), the global or idealised priorities of the intensities are obtained by dividing each by the largest in order that the largest becomes one and the others proportionately less. The AHP pairwise comparison matrices of level 3 subcriteria and level 4 intensities along with their consistency ratios are included in Appendix D.

7.4 Evaluation Results

Outlined in Table 7.4, the performance indices (total score or overall weights) of the three CBD shared spaces were obtained from both the quantitative and qualitative analysis procedures. Consistently in both the quantitative and qualitative measures, Elliott Street ranks first on the performance index, followed by the Fort and Lorne Street areas.

Table 7.4 Quantitative and qualitative performance index of CBD shared spaces.

Evaluation Process	Performance Index		
	Elliott St	Lorne St	Fort St
Quantitative	0.691	0.611	0.659
Qualitative	1.041	1.003	1.019

The calculation of the qualitative performance scores was straightforward, involving only the weights at the criteria level. The index was the total of the product of the Median Perception Rating that ranges from -3 to +3 and the corresponding weight of the criteria (shared space objective). For example, the qualitative performance index of 1.003 for Lorne Street was the sum of (0.111×1.02) , (0.185×1.35) , (0.265×0.67) , (0.073×0.31) and (0.367×1.20) .

With a range between 0 and 1, the quantitative index of 0.691, 0.611 and 0.659 for Elliott, Lorne and Fort Streets respectively was the total of the weights of the corresponding intensities assigned to each subcriterion (or KPI). In other words, the idealised priority of each intensity on level four was multiplied by the global priority of its corresponding subcriterion on level three before summing up the individual scores (weights) for each KPI to arrive at a total composite score of the performance index. This can be summarised in the following equation:

$$PI_i = \sum_{j=1}^k W_j X_{ij}$$

where,

- PI_i is the performance index of shared space scheme i
- W_j is the global priority assigned to subcriterion j
- X_{ij} is the idealised priority of the intensity of scheme i given subcriterion j
- k is the total number of subcriteria or key performance indicators

To elaborate this, the performance index of 0.611 for the Lorne Street scheme can be calculated as follows:

$$\begin{aligned} PI_{ELLIOTT} = & 0.083(1.000) + 0.028(1.000) + 0.123(0.304) + 0.062(0.355) + 0.177(0.122) + \\ & 0.088(1.000) + 0.058(0.323) + 0.015(1.000) + 0.201(1.000) + 0.088(1.000) + \\ & 0.077(0.102) = 0.611 \end{aligned}$$

The findings of the performance ranking of the three CBD shared spaces are generally in agreement with the outcomes of the previous analysis. As discussed in Chapter Four, the comparative analysis of the pedestrian density and the mean vehicle speed indicated the highest correlation value for the Elliott Street scheme, followed by Fort Street (Jean Batten Place section) and Lorne Street. In the perception surveys and expert interviews, documented in Chapter Six, the Elliott Street area was often praised by many participants for its land-use activation and associated street activities (e.g. café seating and informal gathering of people) whereas a number of concerns were raised with respect to the Lorne Street performance, including the lack of active frontage on the St James Theatre side opposite the central library and the perceived safety risk of vehicle speeding in the shared zone located in the middle of the street.

7.4.1 Performance Index Correlation

The two sets of the quantitative and qualitative performance indices were plotted in order to observe the strength of association between the two variables. Figure 7.2 shows a plot of the three performance values of Elliott, Lorne and Fort Streets. The positive relationship between the two indices can be observed. Although with only three data points, the regression model can only at best indicate that a qualitative performance value could be predictive of a quantitative one and vice versa.

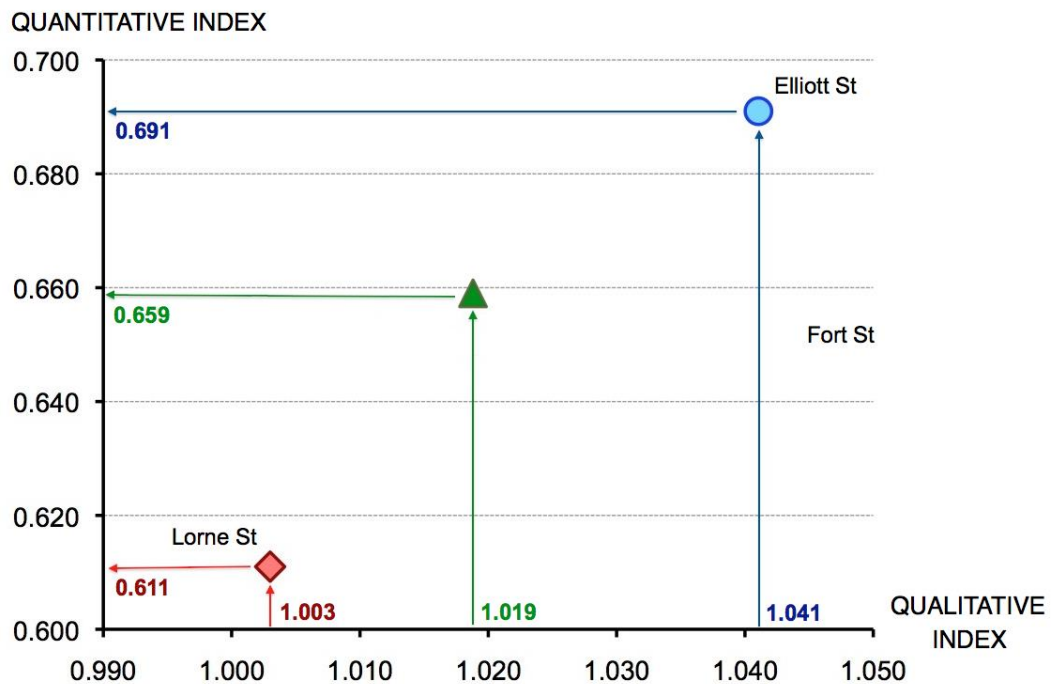


Figure 7.2 Correlation between quantitative and qualitative performance index.

With more data set, the quantitative performance index of a shared space that incorporates complex performance indicators based on a number of data sources (e.g. video survey, traffic count and crash database) can therefore be predicted from the qualitative index that is obtained from a single data source of the on-street questionnaire surveys

The development of a predictive model for estimating a performance index of shared spaces based upon the qualitative user perception data, which is far less time consuming and labour intensive in data processing and analysis (especially with the video survey analysis), requires further investigation and testing to improve reliability and repeatability. The further research will require several repeats of both the quantitative and qualitative data collection of the same sites at different times of the year. The focus would be to observe

any change of user characteristics in the street environment and surrounding land use while strictly controlling the on-street perception survey procedures in order to ensure reliable subjective outputs. The relative and global priorities in the AHP hierarchical structure would remain largely unchanged in the model calibration process to minimise input variables.

Nevertheless, with the advancement in survey technologies, the determination of the shared-space performance index can be suitably derived from the multitude of quantitative data sources via automatic data processing methods. Such automated detection and tracking technology to gain statistical robustness that cannot be practicably achieved by manual techniques has been used in a number of applications in road safety and transportation research projects such as pedestrian behaviour and safety analysis (Li et al., 2012; Zaki et al., 2013), pedestrian-vehicle conflict and collision study (Autey, Sayed, & Zaki, 2012; Ismail et al., 2009; Saunier, Sayed, & Ismail, 2010) and traffic violation detection (Ismail, 2010).

7.4.2 Sensitivity Analysis

The findings of the performance indices were drawn from the AHP process that integrated the methodical use of comparison judgements. With the multiple variables (criteria and subcriteria), the priority assumptions and estimates in the decision making process undoubtedly affect the certainty and stability of the analysis and the resulting conclusions. It is therefore important to test whether a certain variable change will result in a reasonable change in the final outcomes. This will not only assist in improving the decision makers' judgement by revealing the relative importance of the variable in influencing the outcome, but also identify associated risk in making certain comparison judgements.

A sensitivity analysis was carried out by varying the relative weight of each criterion and subcriterion either plus or minus 20% one at a time. The performance index of both the quantitative and qualitative measures for the three case studies was then recalculated, taking into account the redistribution of the weights across the variables (so as to make the total weight equal to 1.0). The ranking of the final scores was observed. Table 7.5 gives an example of the ranking results from the sensitivity test of the 'Vehicle Behaviour Change' criteria for both qualitative and quantitative AHP scores. With respect to the performance index of the quantitative AHP data, there was no change in the rankings in all sensitivity

scenarios of both criteria and subcriteria tests. This indicates the reliability of the multifaceted quantitative AHP hierarchy structure in determining the success of shared spaces. The sensitivity test gives confidence to the pairwise comparison judgements made to acquire the relative and global weights of the variables in the hierarchy.

Table 7.5 Performance index results of Vehicle criterion from sensitivity analysis.

Weight of Vehicle Criterion	Performance Index		
	Elliott St	Lorne St	Fort St
QUANTITATIVE DATA			
Base Case	0.691	0.611	0.659
+ 20%	0.680	0.597	0.640
- 20%	0.702	0.626	0.679
QUALITATIVE DATA			
Base Case	1.041	1.003	1.019
+ 20%	0.996	0.979	0.968
- 20%	1.086	1.027	1.070

However, when considering the sensitivity test of the qualitative performance scores, there was one test scenario where the ranking priority changed with the Lorne Street performance index becoming higher than that of Fort Street. This was the scenarios with a 20% increase in the relative weight of the Vehicle criterion. The change of the qualitative index ranking for the Vehicle criterion can be observed in Table 7.5.

As indicated in the statistical analysis in Section 6.4.1 of Chapter Six, the MPR difference of the Vehicle criterion between Lorne and Fort Streets ($MPR_{VEH, L-F}$) was not statistically significant. With a sufficient change to the weight and corresponding weight redistribution across other criteria, it is not unexpected to see an alteration in ranking of the Lorne Street performance index given that only in the Vehicle criterion, Lorne Street had the highest MPR value.

In practice, it is unlikely that there is anything wrong with the priority (weight) assignments in accordance with the AHP technique. The discrepancies of the end outcome were likely due to the subjectivity of the perception survey process and the interconnectivity among various shared space objectives (AHP criteria). The findings of the sensitivity tests,

however, reaffirm the robustness of the quantitative multi-criteria model and its ability to appropriately evaluate the effectiveness of shared spaces.

An additional sensitivity test has been undertaken in order to estimate the impact of frontage activation in the Lorne Street area by assuming that the anticipated development of the St James Theatre has taken place. The hypothetical scenario involved adjusting the KPI and MPR values for the quantitative and qualitative measures, respectively. By applying the same AHP priorities (weights) of the performance criteria, the results were promising. Drawing upon the understanding from assessing the Elliott and Fort Street areas, the potential quantitative and qualitative performance indices range between 0.71-0.76 and 1.12-1.26, respectively. Both values were higher than those of the best performing site of Elliott Street. This indicates the significance of active land-use frontage on both sides of the street against the backdrop of the major pedestrian generator of the Central City Library in enabling successful shared space operation.

7.5 Conclusions

In this chapter, the absolute method of the Analytical Hierarchy Process (AHP) was implemented, which was the final step of the multi-faceted evaluation framework, in order to determine a performance index by bringing together the performance outputs from the various data collection and processing techniques. The quantitative data for the AHP analysis study was methodologically collected in 2013 from the three CBD shared spaces, and processed in accordance with the established methods discussed in Chapters Three to Five. The qualitative data of the Median Perception Ratings (MPR) for the five shared space objectives were obtained from the on-street perception surveys, described in Chapter Six. The multitude of the key performance indicators (KPIs) and their values for the three case studies of the Elliott, Lorne and Fort Street areas are summarised in Table 7.3.

The evaluation hierarchical structure has been established and illustrated in Figure 7.1 with the first two levels (goal and criteria) applicable to both the quantitative and qualitative AHP models. The third and fourth levels of the hierarchy were applied to the quantitative evaluation process with the KPIs constituting the subcriteria in level three. Level four of the structure included the intensity range that corresponded to each KPI value.

The weights (priorities) of the criteria, subcriteria and intensities were derived by the author from pairwise comparisons between the homogenous elements. The relative (local) and global priorities are also included in Figure 7.1. The weights of the performance criteria have been validated through the qualitative study as discussed in Chapter Six whereas those of the subcriteria and intensities were hypothetical, which can be modified to suit different performance indicators. The quantitative overall weight or performance index was the total of the product of the global priority assigned to each subcriterion and the idealised priority of the intensity of a shared space scheme.

The results of the AHP process were the two sets of the performance indices for the three case studies from the quantitative and qualitative evaluation processes. A good degree of association between the two indices can be observed albeit with only three data points, indicating an ability to predict an index value from the other. Elliott Street was considered the most successful shared space based on the quantitative and qualitative values of 0.691 and 1.041, respectively, and followed by the Fort and Lorne Street areas. The most favourable outcome of Elliott Street was consistent with the conclusions of the earlier analysis methods (including the pedestrian performance study, perception surveys and expert interviews) that emphasised the importance of land-use frontage activation, pedestrian activities and the reduction of vehicular dominance.

The robustness of the quantitative AHP model and the suitability of the priorities (weights) of the criteria and subcriteria were confirmed via sensitivity analysis. By varying the relative weight of the criteria and subcriteria plus or minus 20% one at a time, the results showed no change in ranking of the quantitative performance indices. It is therefore concluded that the quantitative AHP model within the overall multi-faceted framework is appropriate to evaluate the performance of shared spaces based on the five assessment criteria of Placemaking, Pedestrian focus, Vehicle behaviour change, Economic impetus and Safety for all road users. Future research should incorporate into the evaluation framework automated user identification and detection techniques to improve accuracy in data processing and analysis.

CHAPTER EIGHT

CONCLUSIONS AND FUTURE WORK

The findings of the shared space research, together with its contributions to the body of knowledge and the relevance of the research are summarised in this chapter. Recommendations on future research studies are also provided to further advance the understanding and best practice of the design and evaluation of shared spaces.

8.1 Summary of the Research

This PhD research project set out in 2010 to investigate a way to thoroughly measure the performance of the shared street spaces in Auckland. The research was supported by the regional transport and road controlling authority, Auckland Transport, and has advanced knowledge of shared space concepts, particularly related to the performance measurement and assessment. Motivated by the practical need for a better understanding of key contributing factors to the successful operation in New Zealand and by the research gaps of shared spaces schemes identified in Section 1.3 of Chapter One, a multi-faceted evaluation framework was developed using both quantitative and qualitative performance data from the three case studies of the Elliott, Lorne and Fort Street areas. The ‘before’ qualitative data was collected at the three sites in 2010 prior to the international event of the Rugby World Cup in 2011 in Auckland, which was considered the catalyst for many transformation projects in Auckland’s city centre, including the CBD shared space schemes. The ‘after’ data collection of the video surveys and traffic counts were conducted from 2011 to 2013.

An extensive review of the literature in relation to the road user integration concepts was carried out to inform the development of the evaluation framework. As illustrated in an evaluation flowchart in Figure 8.1, the literature review findings, discussed in Chapter Two, contributed to the establishment of the five shared space objectives of Placemaking, Pedestrian focus, Vehicle behaviour change, Economic impetus and Safety for all road users and the corresponding Key Performance Indicators (KPIs).

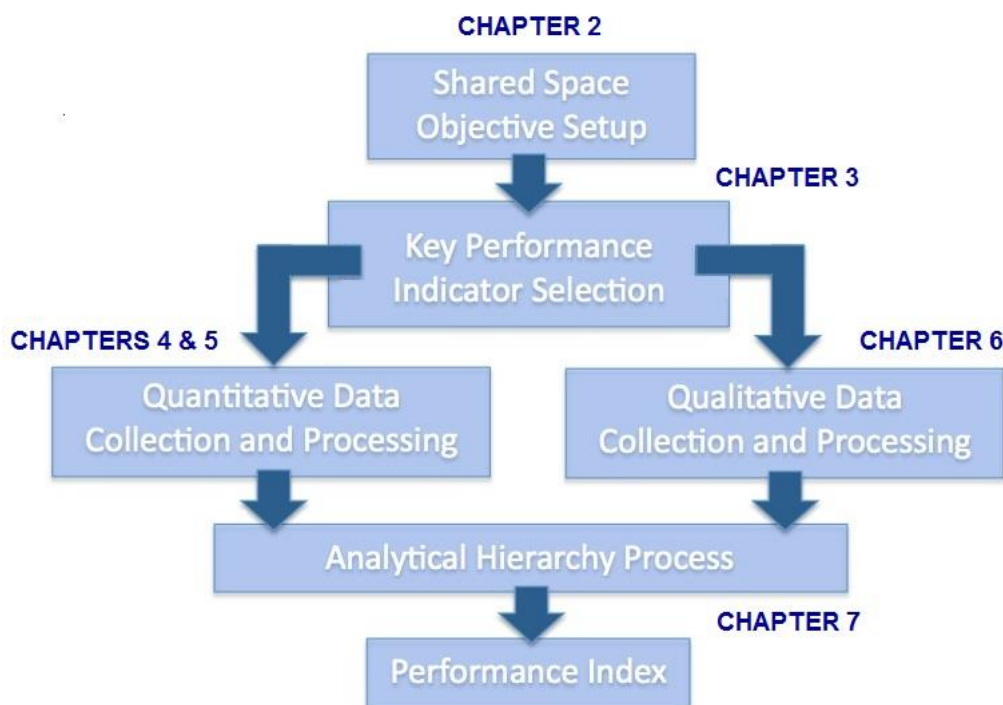


Figure 8.1 Summary of research work on shared space evaluation.

The multi-criteria evaluation framework, incorporating the quantitative and qualitative data collection and processing as well as the Analytical Hierarchy Process (AHP) methodology, was proposed in Chapter Three, and explored in detail from Chapters Four to Seven. The ‘place’ function of an urban street was combined with the mobility and access functions in order to guide the selection of the KPIs and the methods of collecting the performance data. This resulted in the KPI of pedestrian occupancy and dwell time along with a novel method of analysing pedestrian demand and activity in the shared space environment. Explained in detail in Chapter Four, the pedestrian analysis of the video data involved a footage review for a 24-hour period and a detailed 15-minute peak zone examination. While the 24-hour profile provided a holistic view of the demand of the two distinct pedestrian groups: the Pedestrian Movement (PM) and Pedestrian Occupancy (PO), the 15-minute analysis enabled a close-up inspection of the pedestrian behaviour and interaction (e.g. pedestrian trajectory and dwell time) within a peak activity zone. Chapter Five investigated in depth the safety aspects of a shared space. Acknowledging that reported crash data alone are inadequate to represent the safety performance of a low-speed shared street, the research examined the pedestrian-vehicle conflicts and interactions in Elliott Street in the ‘before and after’ shared space implementation.

Within the evaluation framework, the research has also developed the qualitative data collection and analysis techniques as described in Chapter Six. The main process of the on-street perception surveys was undertaken at the three shared spaces and the control site with an aim to derive the Median Perception Ratings (MPR) as the qualitative KPIs for the five shared space objectives. The descriptive evaluation of the interviews with professionals proved an appropriate complement to the evaluation framework as the expert opinion provided the context and breadth of the performance assessment that could not be captured otherwise. Their views confirmed the interconnections among the various objectives of shared spaces. Chapter Seven involved the undertaking of the AHP method to produce the performance index. The magnitude of the quantitative and qualitative performance data, collected from the three sites in 2013, was distilled into the numerical values in the criteria and subcriteria levels of the AHP evaluation structures, equipped with the relative weights (priorities) for each hierarchical element. The performance indices of the three shared spaces were obtained for both the quantitative and qualitative evaluation structures, and subsequently correlated to create a predictive model. Finally, a sensitivity analysis was performed to ascertain the robustness of the multi-criteria performance evaluation process.

In the process of developing and implementing the multi-faceted evaluation framework, the key conclusions regarding the shared space performance can be outlined as follows:

1. A shared space can be distinguished from a calmed street based on the design and intended use of the physical separation between vehicles and pedestrians. According to the comparative analysis of design and performance between New Zealand and international schemes, as discussed in Chapter Two, a successful shared street can be achieved by key design elements, namely road space reallocation for people, level and paved surface, safe zone provision and street furniture strategically positioned for placemaking and ‘staying’ activity, in order for the public street space to adequately perform multi-functions, particularly the place function, at consistently low operating speeds.
2. The shared space implementation based on the Auckland CBD design generally achieved the established objectives. Firstly, with an improvement in pedestrian activity and dwell time in the ‘before and after’ analysis, the shared spaces enabled the road reserve to better perform the place function. The pedestrian priority was

improved as a result of a level, paved surface with streetscape elements that created a street environment for people. In reducing vehicular dominance, the shared space design effectively resulted in a street environment with lower vehicle operating speeds and volumes albeit highly sensitive to the context of the adjacent land use. Although without assessing the economic data of the surrounding businesses in the area, the economic performance was primarily evaluated by considering the active land-use frontage. Its significance has been evident throughout the research study (e.g. its role in contributing to lower vehicle speeds as per the pedestrian analysis in Chapter Four and the consensus among the professionals about the importance of the edge activation as discussed in Chapter Six). Lastly, based on the ‘before and after’ study of Elliott Street safety performance, the shared space design improved safety of road users by generating more pedestrian-vehicle interactions and lowering vehicle speeds, coupled with the fact that since the completion of the shared spaces in mid-2011, there has been no injury reported crash. Additionally, the success of the shared spaces was reflected in the consistently positive MPR values based on the on-street perception surveys, presented in Chapter Six.

3. The quantity of pedestrians, walking, dwelling or interacting with other road users or the surrounding environment, is critical to the success of a shared street, especially in negating the dominance of vehicles. The ‘before and after’ pedestrian analysis, documented in Chapter Four, utilised the normalised density of both the PM and PO groups in the correlation with the mean vehicle speed that resulted in an inverse relationship consistently for all the three case studies. In other words, the greater number of pedestrians in a shared space, the lower the vehicle operating speeds. In Chapter Five, the ‘before and after’ study of the vehicle speed and volume data over the three-year period confirmed that pedestrian-vehicle interaction and the mean vehicle speed in the shared zone had an inverse correlation at a very high degree of association ($R^2 = 0.81$). This means the design and surrounding land use activity attract more people into the space. Furthermore, the same study showed the road use interaction profile over a 24-hour period in 2012 (in Figure 5.6) with a peak interaction period between 1 pm and 3 pm coinciding with the lowest mean vehicle speeds averaged over a one week period (in Figure 5.4). Besides the direct influence of pedestrian densities and interactions on the reduced vehicle speeds, the shared space implementation with the placemaking objective suppressed the vehicle

volumes and created a street environment similar to that of well-designed Local Area Traffic Management schemes where ‘rat-running’ is restrained, and appropriate driver behaviour is encouraged.

4. The understanding of the interconnectivity of the five shared space objectives is important in the design and development process of shared spaces. This interrelationship was qualitatively substantiated in the findings from the expert interviews whereby the professionals often discussed one design attribute in the context of other factors, and expressed how the objectives influenced one another. The qualitative results of the statistical correlation analysis, discussed in Section 6.4.1 of Chapter Six, revealed that the performance criteria of ‘Pedestrian’ and ‘Safety’ have a commanding influence over the other performance measures and eventually the perceived success of an urban shared space. Additionally, the ‘Safety’ objective was consistently perceived to be the most important performance criterion across the three shared spaces and the control site based on the questionnaire surveys of the 400 on-street participants as well as the results from the expert interviews. Given the quantitative research also demonstrated the strong association between the ‘Safety’ objective and the ‘Pedestrian’ and ‘Vehicle’ performance criteria, it is therefore reasonable to conclude that these three themes of performance attributes are required to be integrated into the street design, operation and maintenance process for successful shared space implementation.
5. A practice-ready AHP model using the quantitative KPIs is proposed in this thesis to evaluate shared space schemes and to determine a performance index. In accordance with the AHP procedures, the judgements made in the pairwise comparison matrices have been checked for consistency. The established weights (priorities) of the five performance criteria for the three case studies were tested via a sensitivity analysis. The Safety criterion had the highest priority of 0.367, followed by the Vehicle and Pedestrians criteria with a priority of 0.265 and 0.185, respectively, which are generally consistent with the aforementioned findings of the objective prioritisation. Through the quantitative AHP model, Elliott Street scored the highest performance index value of 0.691. This, on the whole, demonstrated the key contributing factors of active land-use frontage, reduced vehicular dominance and pedestrian priority and activity in the urban street environment for an effective shared space.

A final summary of the research work can be best described via its contributions to the existing knowledge and research relevance.

8.2 Contributions to Knowledge

Consistent with the order of the research objectives set out in Section 1.4, the research contributions to the body of knowledge and industry can be described in detail under the following headings.

8.2.1 Contribution One: Origin and Evolution of Shared Spaces

As documented in Chapter Two, the origin and evolution of the shared space concept has been analytically examined, especially how a shared street approach fits within the road design spectrum for road user integration. Figure 2.2 in Section 2.3.1 traces the philosophical origin of shared spaces to an environment area concept in the *Traffic in Towns* (MoT, 1963) as well as acknowledges the *Woonerf* idea (Hass-Klau, 1990) as one of the first street design countermeasures to the automobile's pervasiveness in residential areas. The distinction between shared and calmed streets critiqued in this research based upon the theoretical aspects of the concepts and their practical applications reveals the underlying importance of the design approach to whether to segregate vehicular traffic from pedestrians and other road users. While Table 2.1 in Section 2.3.2 further demonstrates the interrelationship between various concepts and techniques in the shared and calmed street continuum, the discussion in Section 2.4.1 explains the context-sensitive and self-explanatory nature of a shared space when taking into account the multi-functions of a public urban street.

The findings of the review of the literature challenges the view observed by many shared space advocates and commentators that a certain profession of traffic engineering could single-handedly create a pervasively automobile-centric street environment. The review inquiry is also extended to the development timeline of the shared space concepts. While many are of an opinion that the idea of particular public streets designed to be shared by motorists, pedestrians and cyclists has been put into practice around the turn of the twenty-first century, the *Woonerf* shared streets, as documented in this thesis, were first

implemented in the Netherlands, and formalised by the government in the 1970s with legal status and regulatory requirements. As the contents of Chapter Two have been published in *Transport Reviews*, this alternative perspective of the origin and evolution of shared spaces is accessible to a wide ranging readership.

8.2.2 Contribution Two: Shared Space Design and Definition

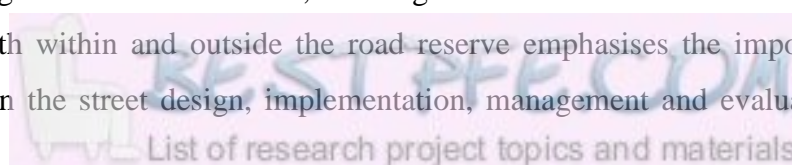
As discussed in Chapter Two and complimentary to Contribution One, key design characteristics of a shared street space in an urban environment include a level, paved surface, space allocation for pedestrians, street furniture for staying activities, a safe zone for the visually impaired and vulnerable road users, a minimum use of traffic control devices and an appropriate signage and treatment at the entry and exit points. The important design features are established primarily based on the critique and findings of the comparative performance analysis of New Zealand and international shared space schemes, documented in Section 2.4.2 and Table 2.2. These, coupled with an unambiguous delineation between shared and calmed streets, have contributed to the refinement of a new definition of an urban, mixed-use shared space. The definition, which can be applicable universally, is as follows:

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.

A shared space in this context is situated exclusively within the (public) road reserve. It predominantly serves a local catchment of vehicular traffic, and functions as a destination for all users. The inclusion of a consistently low-speed environment in the definition is critical to minimise the safety risk and serious traffic conflicts, especially to pedestrians and cyclists, while promoting the social and behavioural interactions and the placemaking objective.

8.2.3 Contribution Three: Place Function in Street Design and Evaluation

As shown in Figure 3.2 in Section 3.2, the diagram of multi-functions in an urban street environment both within and outside the road reserve emphasises the importance of the place function in the street design, implementation, management and evaluation process.



First published in the *Road and Transport Research* journal, the diagram in Chapter Three provides a basis of establishing the five shared space objectives as well as contributes to the development of the subsequent Key Performance Indicators (KPIs) and data collection and analysis methodologies in evaluating the shared streets.

The incorporation of the ‘Place’ related measures in the evaluation process is categorically important. As demonstrated in Section 2.4 under the review and assessment of the urban shared spaces in theory and practice, the consideration of the placemaking objective has a direct impact on the street design and performance. Many shared spaces schemes that have achieved a low-speed street environment and improved priority and levels of service for pedestrians and cyclists, particularly when with interacting vehicles (such as the Sonnenfelsplatz scheme in Austria), would not necessarily meet the placemaking goal, simply because of little or no provision for staying activities in the space design and allocation.

While the place or placemaking function has been conventionally embraced in the fields of creative arts and industries such as urban design and planning, architecture and landscaping, this research has successfully extended via publications and presentations the place(making) values into the areas of transportation engineering and planning as well as road network operation and management. Lists of the publications and presentations undertaken over the course of this research study are included in Appendix A.

8.2.4 Contribution Four: Shared Space Objectives and Data Collection

The data collection strategy, as generally described in Chapter Three, has been developed to measure the extent to which a shared space implementation meets its objectives, relating to Place, Pedestrian, Vehicle, Economic and Safety. While the motivations and purposes of implementing shared spaces vary from jurisdiction to jurisdiction, the five shared space objectives, established in this thesis, can be universally applied to any shared space scheme in an activity centre, especially in respect of its performance monitoring.

The methods of collecting data were categorised into the quantitative and qualitative groups with an aim to capture both objective and subjective performance measures that can be used for comparison and benchmarking of different schemes and between before and after implementation. This resulted in a combination of various data sources, as shown in Table

3.1, including video surveys, automatic (vehicular) traffic counts, crash database and user perception surveys. Appendix B includes photographs of video surveys and traffic count implementation. It is noted that the total length of video data observations from the continuous video recording over the time periods as identified in Table 3.2 is approximately 3,000 hours.

By systematically collecting the video survey data from the three shared space sites in the Auckland CBD between 2010 and 2013, this research work has created an extensive video library of user movement and behavioural activity, coupled with the SCATS and traffic count data (volume, speed and composition) that can be used for future analysis and comparative study, especially to observe the fluctuation of user demand and the interaction based on various time periods of the day, week and weather conditions.

8.2.5 Contribution Five: Quantitative Pedestrian Performance Analysis Methodology

With the establishment of the quantitative KPIs and data collection strategy, this thesis proposed a new methodological analysis process to assess the complexity of user behavioural performance and characteristics, particularly those of pedestrians, in a shared space environment. Presented at the *TRB 92nd Annual Meeting* in 2013, and published in *Transportation Research Record*, the analysis of the ‘before and after’ quantitative data incorporates a two-step data processing methodology. Described in Section 4.3.5 of Chapter Four, the first step of a 24-hour profile analysis using a 15-minute snapshot interval gives a sound representation of pedestrian demand for those who travel and stay within the space – which are termed Pedestrian Movement (PM) and Pedestrian Occupancy (PO), respectively. The second step involves a more detailed analysis of a 15-minute peak zone, including PM trajectory, PO activity types and PO dwell times.

The analysis methodology enabled not only a performance assessment based on the ‘before and after’ data of a shared space project, but also a comparative analysis of different case studies by employing a standardised unit such as pedestrian density and occupancy ratio.

8.2.6 Contribution Six: New Safety Analysis Method for Shared Spaces

A novel safety analysis method of the Road User Interaction and Conflict Study (RUICS) was developed to address the need for a safety evaluation specifically for public streets that

encourage mixing of vehicles with vulnerable road users such as pedestrians and cyclists. In addition to considering crash figures and detailed police reports available from the national crash database, the research analysis measured both traffic conflicts and interactions as illustrated in Figure 5.3. A road user interaction is defined as follows:

An event in the vehicle travelling zone where at least one road user (i.e. pedestrian or vehicle driver) modifies their travel path and/or speed due to the existence of the other user(s) and if an evasive action was not taken, the event would have led to a collision.

The RUICS method, first presented at the *TRB 93rd Annual Meeting* in 2014, and officially accepted for publication in *Transportation Research Record*, incorporated the Pedestrian-Vehicle Conflict Analysis (PVCA). Developed by Kaparias et al. (2013), the PVCA employs four quantitative factors to classify a conflict, including time to collision, severity of evasive action, complexity of evasive action and distance to collision.

The findings of the RUICS analysis, discussed in Chapter Five, indicated that the increase of user interactions and low-speed conflicts played a major role in reducing the operating speeds of motor vehicles. Accordingly, the safety analysis work documented in this thesis challenged whether the concept of traffic events in pyramid form can or should be applied to a shared space environment. With decreased kinetic energy and likelihood of crash severity in the event of a crash due to lower vehicle speeds, more road user interactions in a shared space do not necessarily result in more injury or fatal crashes as suggested in the conventional continuum of traffic events.

8.2.7 Contribution Seven: Qualitative Perception Survey Methodology

Within the multi-faceted framework, the design and implementation of the user and expert perception surveys, as discussed in Chapter Six, can be seen as a contribution to knowledge by extending the objective evaluation methodology into the realm of subjectivity. As such, the core aspects of the questionnaire design were subject to a great deal of thought and scrutiny to ensure consistency in repeatability. These included the design of questions and statements with an aim for clarity and unambiguity in definitions, a rating scale that consists of a response point defined with a clear and accurate label and a rigorous procedure to ensure the confidentiality and anonymity of the responses. Appendix C contains the

qualitative evaluation documentation, including the ethic approvals and the on-street perception survey questionnaire.

8.2.8 Contribution Eight: Analytical Hierarchy Process and Performance Index

The novel AHP evaluation model of shared spaces developed in this research is significant because of its practicality and robustness. The quantitative hierarchical structure using the absolute AHP method was created based on the methodological framework that integrated the shared space objectives and KPIs. While the consistency in comparison judgements was assured through the AHP process, the data collection and processing methodologies were designed to appropriately capture the performance measures that logically correspond to the established objectives. In addition, the sensitivity tests of the relative weights assigned to the criteria (objectives) and subcriteria (KPIs) has confirmed the soundness of the AHP prioritisation with consistency in the index ranking. Moreover, the high degree of association between the quantitative and qualitative AHP models suggests an ability of the objective performance index to be predictive of the subjective one and vice versa, giving more flexibility in implementing this final stage of the new framework for assessing the performance of shared spaces in an urban environment.

8.2.9 Contribution Nine: Shared Space Design Guidelines

The most significant contribution to industry was the development of Auckland Transport's operational design principles for shared spaces and shared zones (Karndacharuk, 2013; Karndacharuk, Peake, & Wilson, 2014) based primarily on the findings from this research. For instance, Design Principle 4, deduced from the analysis in Chapter Four, emphasises the importance of active land use frontage, and defines active frontage as “the distance along a property boundary that provides the opportunity for people movement into and out of buildings, along and across the street or for street activity (such as street dining)”. Additionally, Design Principle 10 that requires street furniture to act as traffic calming measures is formulated based primarily on the recommendation from the safety performance analysis in Chapter Five due to a safety concern of the linearity of the streetscape elements of the Auckland CBD case study.

The principles, documented in a memo in Appendix A, have been incorporated into the Auckland Transport Code of Practice (ATCOP). The ATCOP provides quality standards

for new and upgraded transport assets and systems across the Auckland region, taking into account whole-of-life design, value for money and robust engineering details and construction (Auckland Transport, 2014). In other words, the outcome of this research-led collaboration has bridged the gap between the conceptual shared space understanding drawn from the international experience and the need for design guidelines that are appropriate and fit for the New Zealand context.

Moreover, the process of developing the design guidelines enabled the author to be involved in reviewing and commenting on a number of shared street proposals within the Auckland region, thereby applying the key findings of this research work to practical schemes besides the three case studies investigated in this thesis.

8.3 Relevance of the Research

It is evident through the presentation and publication of the research findings of this doctoral research that this particular topic of shared street design and implementation has been of a significant interest to transportation researchers, practitioners and road controlling authorities. This is especially so in the area of road user behaviour and performance measurement of shared space design. The relevance of the research to industry can be grouped into the following three categories based on their roles and perspectives with respect to the involvement in shared space policy, management, design and operation.

Territorial and Road Controlling Authorities

The multi-criteria evaluation framework, including the data collection and process methods, developed in this research, to a large degree, is ready to be adopted and integrated into any monitoring scheme, administered by a road controlling authority, for both existing and proposed shared space projects. Such monitoring or evaluation scheme would mandate mitigation measures if and when necessary, and keep shared space design guidelines and principles up-to-date with any lessons learnt. Given the flexibility inherent to the AHP process, new criteria or subcriteria can be added and the current ones removed in order that the assessment hierarchy appropriately reflects the visions and motivations for shared space transformation investment.

The key contributing factors for successful shared space implementation, particularly to create a safe street environment, should be taken into account by the territorial authority in the process of policy-making, site selection, scheme and detailed design, day-to-day operation and maintenance programming. The place function that is sensitive to the context of each public space within the road reserve should continue to be the focal interest in supporting the transport infrastructure investment in an activity centre.

Urban Designers and Land Use Planners

The research findings supported the concept of multi-functions of public urban space – such concepts that have been embedded in urban design and planning. While the role of urban designers for an area within the road reserve is critical in placemaking and pedestrian priority improvement, land-use planners are required to play a key role in balancing the competing requirements of, inter alia, cultural and heritage values, building and environmental controls and land-use regulations in order to ensure street frontage activation as high as possible for successful operation of shared spaces.

The linear design of the CBD shared streets in Auckland has been critiqued in this research because of its contribution to higher vehicular speeds during off-peak periods with much lower pedestrian and land-use activities. A shared space designer is encouraged to rebalance the space design and allocation between the need for a linear built form with a spacious and flexible space for social activity and special events and the importance of self-explanatory street design that influence driver behavioural change and lower vehicle speeds.

Transport Planners and Traffic Engineers

The addition of the place function within the road reserve will require transport planners and traffic engineers to focus more on a provision for active modes of transport and how to appropriately allocate the public space for those who choose to ‘stay’ rather than ‘move’ along the street. Even though it was observed in the expert interviews that many traffic and transportation practitioners who had direct involvement in the shared space development have embraced the placemaking and pedestrian focus objectives for the urban street network, more attention is required by transportation professionals in general to maximise the limited road space for multi-functions other than traditional traffic functions of movement and access, especially in metropolitan, city and town centres.

8.4 Recommendations for Future Research

The following sections offer recommendations for future research opportunities that have been identified over the course of this shared space evaluation research.

8.4.1 Extension of the Evaluation Framework

Future research can apply the framework to a public street surrounded by different land use environments. These include residential and industrial zones in suburban, rural or coastal settings. Although home zones or residential shared spaces have been commonly implemented in the European context, they still pose unique design and operational challenges, particularly requirements for parking, provisions for residents and ability for the streets to operate autonomously with much less active management when compared with the urban, mixed-use shared street. The variation of certain design features can be examined for a shared street in a town or local centre, particularly the use of stone paving and high-quality street furniture. The framework can also be extended to the following areas:

- A comparative study of street design and operation between a shared space and a pedestrian mall would be worthwhile in future research. Even with a carfree development (vehicle free zone), some vehicular movements such as those of delivery and service vehicles are still to be allowed within the public space, thereby resulting in user interactions and conflicts.
- As this research has studied the shared space performance in mid-block areas, a research opportunity arises for an in-depth analysis and examination of user behaviour and activity at intersections and to determine possible performance improvement measures, taking into account the movement, access and place functions.
- A research study into the opportunities and challenges of a one-way street operation is recommended. While the normal two-way operation eliminates the identified safety and operational issue of vehicles travelling in a wrong direction for the CBD shared spaces, a one-way shared street minimises road space allocated for vehicles and in turn makes the space for other users, especially for placemaking functions.

- As mentioned before in Chapter Seven, automated road user detection and tracking technology will significantly improve the accuracy and reliability for shared space data processing and analysis. Further research is recommended to incorporate such automated techniques into the quantitative evaluation framework.
- The impact of special events and how the shared space can accommodate unusual peak demand of additional street users and activities warrants future research. With a 'before and after' analysis, the framework can be adapted to quantify the success of the events in a shared space environment.

It is anticipated that by applying the framework to a wider application of the shared space concept, guidelines on more specific design approaches can be developed with respect to the different threshold of vehicular traffic speeds and volumes that best suit the various land-use environments. It is important to note that a shared space similar to a road network should be designed to suit the capacity of the (environmental) area not vice versa. In other words, the current and future land-use zoning and designations are employed to guide the street design approach and operational principles.

8.4.2 Further Behavioural and Performance Study of Shared Space Users

A future study on shared spaces can investigate the performance of a wider range of road space users such as cyclists, motorcyclists and the disabled. Further research recommendations can be outlined as follows:

- Unlike situations in Europe (particularly in the UK) where there was opposition and criticism on the shared space concept due to the potential adverse impacts on the vulnerable and the visually impaired (Imrie, 2012; Imrie & Kumar, 2011; Thomas, 2008; 2011), the implementation in Auckland has not had such a thorough debate and discussion about the challenges for disabled people in a shared space. This was primarily due to the provision of the safe zone on either side of the street and comprehensive consultation and due to engagement with end user groups. Nonetheless, the research into the perception of vulnerable street users within the framework developed in this research is recommended.

- With global movements to encourage active modes of transport, the impact of shared space implementation on cyclists can be further examined, together with design opportunities and challenges for cyclists.
- Certain behavioural interactions such as eye contact and visual interaction were claimed to be an important part of successful shared spaces operation (Shared Space, 2005; 2008). Future research can quantify this and determine its effect on shared space performance. Also, the research work investigated only pedestrian-vehicle conflicts and interactions. Other types of user interactions (e.g. cyclist-vehicle and cyclist-pedestrian) can be further examined.

8.4.3 Other Factors Influencing Shared Space Operation

There are a number of other contributing factors, independent variables or performance indicators that can be further investigated to advance the understanding of the performance evaluation and the benefits of shared space implementation, including:

- Economic growth and productivity. Economic data of, inter alia, tenancy rates, business turnover and change to land and capital values.
- Carbon footprint and CO₂ emissions comparison between a typical local street and a shared space. Social, cultural and health impacts of shared spaces in a society. An investigation into modal shift to sustainable transport due to shared space implementation.
- Vehicular traffic impact on the capacity of the surrounding street network due to the traffic redistribution. The operational effects on shared space performance and operation between equal or pedestrian priority requirements.
- Maintenance costs, especially for on-going repairs of street furniture. Considerations of appropriate vehicle and pedestrian space allocation. Changing performance index based on time of day and weather conditions.
- Regulatory and process requirements for shared space declaration. Impact of policy change (e.g. new speed limit and signage) to cater for shared space operation.

8.4.4 Further Study on Qualitative Evaluation and AHP Process

The qualitative study utilised the two data collection methods of the on-street questionnaire surveys and expert interviews. There are of course a number of other perception studies of road space users. These include repeated cross-sectional and longitudinal panel surveys (Tourangeau, Zimowski & Ghadialy, 1997) and stated preference surveys that incorporate randomised attribute order and alternatives (Ortuzar & Willumsen, 2011). Additionally, besides using the median (MPR) values as a key performance indicator, an alternative approach is to first convert the qualitative data from the on-street survey to imputed interval scales using Multidimensional Scaling techniques (Green & Rao, 1972; Shepard et al., 1972). This would then allow parametric statistical tests to be employed.

As indicated previously, there are other characteristics of a shared street environment that can be measured objectively and when properly weighted and combined can predict a user's subjective evaluation of the ability of the street to serve the community. There are therefore limitless opportunities to utilise AHP models in evaluating shared spaces as well as informing policies and practices. In this research, the range and intensities of the key performance indicators were based on the information available from the data collection and analysis of the CBD shared spaces. They are certainly subject to adjustments and further considerations if the models are to be used for other types of shared spaces or in other land-use environments as discussed in Section 8.4.1. Nevertheless, the AHP frameworks developed in this thesis can provide solid foundations for any further research work into the AHP evaluation process of shared spaces.

8.5 Final Remarks

This research study has achieved the development of a conceptual evaluation framework of shared spaces that includes the detailed procedures on data collection and analysis, particularly of those related to pedestrians and vehicles (drivers) within the road reserve in a mixed use, urban metropolitan setting. As demonstrated in Chapter Two, a shared space philosophy links to, and overlaps with a number of road user integration concepts such as context-sensitive solutions and self-explaining roads. This, coupled with the professional and political movements to rebalance the infrastructure provision for people and sustainable transport choices, gives rise to an opportunity to apply the multi-faceted evaluation

framework to other types of transport infrastructure schemes such as walking, cycling and safety improvement projects and urban transport corridor upgrades.

The vehicular speed reduction to a level that road users are comfortable and willing to share the space with one another is of great importance in achieving all the shared space objectives mentioned in this thesis. Lower speed thresholds (e.g. 10 km/h speed limits) may be difficult to reach in practice by many users, but such speed control devices are necessary from the outset of the concept introduction to communicate an underlying message of a slow-speed environment in addition to the street design, particularly in a city that has long been separating pedestrians from the vehicular traffic. By emphasising a reduced speed close to walking or cycling speeds, the establishment of a higher speed pattern can be largely avoided. From a longer term perspective, credible design speeds can be established by taking into account the surrounding land use, frontage activation, road space allocation between vehicles and pedestrians and on-street parking provision with a clear recognition and expectation between peak and off-peak activity periods.

With limited resources and funding for transport infrastructure, the focus of shared space implementation should continue to be in urban areas, especially to revitalise an activity centre. With the paradigm shift away from providing for single-occupant vehicles, the population growth in the urban area will naturally suppress the vehicular dominance, and enable an urban shared space to better perform the multi-functions, especially the place function. The space design and allocation for space users and the vulnerable are therefore at the forefront of the shared space operational criteria and principles, and increasingly important in optimising the use of public road space. With technological changes, the dominant road users and their behaviour will continue to evolve. An on-going monitoring and evaluation process that builds on this research work is important to the adaptation and resilience of the use of a shared street space to ensure the road user integration concept is flexible enough to cater for the immediate and future demand for the multi-functions of a transport network and for a changing world.

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APPENDICES

Appendix A: Research Publications and Presentations

- A1 List of Publications
- A2 Journal Article Abstracts and Responses to Peer Reviewer's Comments
- A3 Conference Paper Abstracts
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Appendix B: Quantitative Data Collection

- B1 Elliott Street Video Surveys and Traffic Counts
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- C1 University of Auckland Ethic Approvals
- C2 On-Street Perception Survey Documentation
- C3 Expert Interview Documentation

Appendix D: Analytical Hierarchy Process

- D1 Pairwise Comparison Matrices and Consistency Ratios

Appendix A: Research Publications and Presentations

A1 List of Publications

Journal Articles

1. **Karndacharuk, A.,** Wilson. D., & Dunn, R. (2013). An analysis of pedestrian performance in shared-space environments. *Transportation Research Record: Journal of the Transportation Research Board*, 2393, 1-11, DOI:10.3141/2393-01
2. **Karndacharuk, A.,** Wilson. D., & Dunn, R. (2013). Evaluating shared spaces: Methodological framework and performance index. *Road and Transport Research*, 22(2), 52-61.
3. **Karndacharuk, A.,** Wilson. D., & Dunn, R. (2014). A review of the evolution of shared (street) space concepts in urban environments. *Transport Reviews*, 34(2), 190-220, DOI:10.1080/01441647.2014.893038
4. **Karndacharuk, A.,** Wilson. D., & Dunn, R. (2014). Safety performance study of a shared pedestrian and vehicle space in New Zealand. *Transportation Research Record: Journal of the Transportation Research Board* (In Press)

Conference Papers

5. **Karndacharuk, A.,** Peake, M., & Wilson, D. (2014). *Operational guidelines and principles for shared zones in New Zealand*. Paper presented at the IPENZ Transportation Group Conference, Wellington.
6. **Karndacharuk, A.,** & Wilson, D. (2010). *Development of performance evaluation framework for shared space schemes in New Zealand*. Paper presented at the NZTA & NZIHT Annual Conference, Christchurch.
7. **Karndacharuk, A.,** Wilson, D., & Tse, M. (2011). *Shared space performance evaluation: Quantitative analysis of pre-implementation data*. Paper presented at the IPENZ Transportation Group Conference, Auckland.
8. **Karndacharuk, A.,** Wilson. D., & Dunn, R. (2013). *An analysis of pedestrian performance in shared space environments*. Paper presented at TRB 92nd Annual Meeting, Washington, D.C.

9. **Karndacharuk, A.**, Wilson, D., & Dunn, R. (2014). *Safety performance study of a shared pedestrian and vehicle space in New Zealand*. Paper presented at TRB 93rd Annual Meeting, Washington, D.C.
10. Wilshire, B., Wilson, D., & **Karndacharuk, A.** (2014). *A qualitative analysis of CBD shared street spaces using perception surveys*. Paper presented at the IPENZ Transportation Group Conference, Wellington.

Auckland Transport Memorandum

11. **Karndacharuk, A.** (2013). *Operational guiding principles for shared space design*. Auckland: Auckland Transport.

A2 Journal Article Abstracts and Responses to Peer Reviewer's Comments

A2.i) Karndacharuk, A., Wilson, D., & Dunn, R. (2013). An analysis of pedestrian performance in shared-space environments. *Transportation Research Record*, 2393, 1-11.

Analysis of Pedestrian Performance in Shared-Space Environments

Auttapone (Aut) Karndacharuk, Douglas J. Wilson, and Roger C. M. Dunn

The concept of shared space as applied in an urban road environment aims to reduce the dominance of motor vehicles by promoting pedestrian and cyclist activity and utilizing road space as a place. Unlike a conventional road, a shared space encourages all road users to legally occupy the same road space with little physical separation. The paper presents pedestrian-related performance measures that were developed under a multifaceted methodological framework to evaluate the success of shared-space schemes on the basis of study areas in the city center of Auckland, New Zealand. Analysis of the data before and after implementation revealed a positive result for pedestrian performance across all sites on the basis of a 24-h pedestrian profile, pedestrian trajectory, dwell time, and stationary activity. A comparative analysis of the data after implementation highlights the importance of the active frontage in enabling a lower (vehicular) speed environment in relation to the number of pedestrians within the shared space. The reported research analysis forms part of a doctoral research study at the University of Auckland with support from Auckland Transport, a regional transport agency in New Zealand.

A shared space is a road space in which all road users (including pedestrians, cyclists, vehicles, and the disabled) are encouraged to legally occupy and share the same public space with little physical segregation, particularly between pedestrians and vehicles. Unlike a conventional road with carriageway and footpath, distinct design features of a relatively level surface with minimum use of traffic control devices (signage and marking) are employed to reduce the dominance of the automobile. Similar to a pedestrian mall, a design approach for shared spaces aims to create a lively street environment. It encourages a wider range of pedestrian and community activities occurring within the space (a public right-of-way), which functions as a destination in addition to serving as a transport corridor.

The shared-space concept is one of many approaches developed in response to the dominance of the automobile and the realization of the adverse environmental and social impacts from decades of planning and design primarily focused on the priority of motor vehicles. Like traffic-calming principles, the concept of shared space evolved from the *Woonerf*. The *Woonerf* concept was first introduced in 1965 by De Boer, a professor of urban planning in the Netherlands, who

advocated the street as a living area for neighborhood residents. The initial experimental application of the *Woonerf* was in the form of residential shared streets (*Woonerven*) and was undertaken to integrate vehicular traffic into social residential space (1). The idea was also contemporary with and arguably influenced by the notion of environmental areas in the 1963 report *Traffic in Towns*, commonly known as the Buchanan Report (2). An environmental area, being a good environment where people can live, work, shop, and move around on foot in a reasonably safe and comfortable manner, incorporates a network of local distributors and access roads where, up to a point, a mixture of pedestrians and vehicles is not seriously harmful (3).

The idea of road user integration was subsequently embraced in many countries such as Denmark, Germany, the United Kingdom, Switzerland, Japan, and Israel (4) along with the United States (5), Australia, and New Zealand (6) and generated a number of similar terms to describe a shared (road) space, including shared street, living street, festival street, encounter zone, shared zone, and home zone. In the United Kingdom, a residential shared space is called a home zone; one of the initial schemes was implemented in 1969 (7). Although the applications of the *Woonerf* concept were extended to town centers and shopping areas in the 1980s in Western Europe (8), in the past few decades there has been a rise of the applications of the shared street concept in inner-city areas. Prominent in the recent development of the concept, Monderman pioneered the idea as a means to influence traffic speeds and driver behavior and address transport safety issues (9, 10). In 2011, the UK Department for Transport published a guideline document on shared space (11). Although Moody and Melia discussed some shortcomings of the published guideline, the document provides useful information on design considerations and the process of developing shared-space schemes (12).

STUDY BACKGROUND

In this section, the place function of an urban street is briefly discussed. Place making is one of the main objectives in transforming a street into a shared space along with an aim to reduce vehicular dominance in the road environment. Since the operation and behavior of various road users influence one another, a methodology for evaluating pedestrian performance is integrated into the shared-space performance evaluation. This evaluation consists of the identification of the shared-space objectives, performance indicators, and quantitative data collection and analysis.

The data used for the analysis here are part of a doctoral research project at the University of Auckland in New Zealand with support from Auckland Transport. The goal of the research is to develop a multifaceted performance evaluation framework for shared spaces

A. Karndacharuk, Road Corridor Operations, Auckland Transport, Private Bag 92250, Auckland 1142, New Zealand. D. J. Wilson and R. C. M. Dunn, Department of Civil and Environmental Engineering, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand. Corresponding author: A. Karndacharuk, auttapone.karndacharuk@aucklandtransport.govt.nz.

Transportation Research Record: Journal of the Transportation Research Board, No. 2393, Transportation Research Board of the National Academies, Washington, D.C., 2013, pp. 1-11.
DOI: 10.3141/2393-01

A2.ii) *Transportation Research Board and Transportation Research Record* response letter dated 15 November 2012



15 November 2012

Dr. David Levinger
Mobility Education Foundation
Chair / Paper Review Coordinator, ANF10

6 Henderson Valley Rd
Henderson, Waitakere 0612
Private Bag 92 265
Auckland 1142
New Zealand
aucklandtransport.govt.nz
Ph 09 355 3553
Fax 09 355 3550

Dear Dr. David,

RE: Letter of response to review comments (TRB Paper 13-0081)

Thank you for your email and the reviewer comments. This letter aims to systematically respond to the peer review comments on the original manuscript, submitted for presentation at the TRB Annual Meeting and for publication in the 2013 TRR series (Journal of the Transportation Research Board). The review comments are itemised in italics, and paraphrased where appropriate, with our response on each point raised.

A reference paper, presented at the Institute of Professional Engineers New Zealand (IPENZ) Transportation Group Conference in 2011, is included in the attachment to provide further clarification when addressing some of the reviewers' concerns.

REVIEWER 1

Comment 1.1 – This is an important topic that deserves more intensive and detailed research than this preliminary description reveals.

Response – The authors agree with the reviewer that the topic about road design and theory that allows the mixing of road users is important. As mentioned in the abstract and study background, the quantitative analysis of pedestrian performance, discussed in this paper, forms part of a comprehensive (doctoral) research study at the University of Auckland. The study is undertaken to understand multi-faceted performance indicators that contribute to the successfulness of shared spaces.

Comment 1.2 – More reading in current research will help, including reference and diagram in the Project for Public Spaces (www.pps.org), the writings and films of William H. Whyte and the space syntax research from Technical University Delft, Department of Architecture.

Response – As part of the literature review process, the importance of urban streets as the basic structure of urban forms and public open space from urban design perspectives has been studied, including, for example, the works of William Whyte, Jane Jacobs, Jan Gehl and David Engwicht. While the definition of a public space or public realm, commonly used in urban design and planning includes activity centres, road spaces and parks, a shared space in the transportation context is an area situated exclusively within the road reserve. The Project for Public Spaces undoubtedly shares

common objectives similar those of shared space (e.g. placemaking, reducing vehicle dominance, improving public road spaces). However, the focus of this shared space study aims to provide research-based evidence to road controlling authorities and transport practitioners rather than urban designers and town / city planners.

The Space Syntax concept that provides a framework to analyse urban public space in terms of connectivity and accessibility, taking into account land use and spatial layout, is certainly relevant to shared space research. Although we appreciate the reviewer's advice on further research reading, the specific reference to the Project for Public Spaces and Space Syntax has not been added to the introduction that give a brief statement of the shared space literature.

Comment 1.3 – The very active anti-shared-space initiatives of the Dutch and UK organisations for the blind, in spite of the commitment to spaces all can use. Curbing is the key outdoor wayfinding cue for pedestrians who are blind.

Response – The design of the three shared spaces under study incorporates an Accessible Route, which is the (min) 1.8m wide area adjacent to the road boundary on either side. The road design also includes a 600mm wide tactile delineator band, placed between the Accessible Route and the Shared Zone (i.e. area in the middle provided for all types of users and activities) to warn the visually impaired about the possibility of moving vehicles outside the Accessible Route. The Royal New Zealand Foundation of the Blind has been consulted throughout the design development process. The use of the roughened stone tactile delineator is endorsed by the Foundation.

Revision – This provision for the blind and the visually impaired has been included in the discussion on Page 7, Lines 8-13.

Comment 1.4 – A recent UK survey of current research (written by Moody and Melia) questioning many shared space claims should be in the bibliography and should inform the work.

Response – The reference to Moody and Melia's work has been added to the paper.

Revision – Page 3, Lines 14-17.

Comment 1.5 – Many conditions (e.g. presence of benches, the nature of adjacent tenancies, the presence of key destinations) affect the pedestrian life of a street. I hope your further research can have a more scientific basis.

Response – The next steps as part of the doctoral shared space research include surveys and interviews with road users (both pedestrians and drivers), business owners and tenants and the project team that have involved in the shared space development and monitoring. The goal is to map out relevant factors that contribute to the economic, safety and functional operation of a shared space. Moreover, a Multi-Criteria Decision Analysis method will be utilised to quantify selected Key Performance Indicators, (both quantitative and qualitative) with an aim of developing a universal performance index and accepted evaluation framework.

REVIEWER 2

Comment 2.1 – This paper is interesting and has some potential. It needs quite a bit of work to be acceptable for publication. There is too much extraneous information and not enough focus on the specifics of the underlying research questions. Needs more focus and coherence.

Response – The authors believe that the information provided in the Introduction and Study Background sections is essential to inform the reader about the context and the basis of the pedestrian analysis. Nonetheless, the paper is revised to eliminate any unnecessary information or description throughout the paper. For example, the texts relating to the Planning Department of Delft, Ben Hamilton-Baillie and MetroCounter Roadside Unit have been removed. Furthermore, the Study Methodology section is now separated from the Study Background section.

Revision – For example, texts about the Delft Planning Department and Ben Hamilton-Baillie were in the Introduction section (Original manuscript, Page 2-3). MetroCount Roadside Unit text (Original, Page 8, Lines 5-6) and its reference (Original, Page 18, Lines 39-40) are also removed.

Comment 2.2 – It's not clear to me what the definition of shared space is. There is big difference between the woonerf and the use of these shared spaces in urbanized, retail areas.

Response – In New Zealand, a shared space is declared a Shared Zone according to the Land Transport (Road User) Rule. It means a length of roadway intended to be used by pedestrians and vehicles. The interaction between pedestrians and vehicles in an equitable manner is outlined as follows:

- A driver of a vehicle entering or proceeding along or through a shared zone must give way to a pedestrian who is in the shared zone.
- A pedestrian in a shared zone must not unduly impede the passage of any vehicle in the shared zone.

The shared space street in New Zealand has design characteristics similar to the original residential shared street in Netherlands e.g. continuous surface for the entire road width with special paving, access points are clearly marked, slow speed environment with streetscape elements to promote people to stay within the space.

Revision – A new section (Street Design as Shared Space) is added to provide more description on the shared-space design (Page 7, Lines 1-13) although there have been referenced to earlier author publications.

Comment 2.3 – The work on festival streets in Portland, Or Third Street Promenade in Santa Monica and many other efforts to deal with these issues hasn't been sufficiently described. It is, however, refreshing to learn about the efforts in New Zealand.

Response – A reference to the festival streets in Portland is added to the Introduction and References sections.

Revision – Page 3, Lines 4 and Page 19, Lines 1-2.

Comment 2.4 – Between placemaking, mobility and access there are very different objectives. So much of this, ultimately, depends on design. I did not get a clear sense of the

design interventions and how these different elements affecting mobility, access, and placemaking shape pedestrian and vehicular movements and performance. While I think some of the graphics and visual displays of data are informative, I'd like to see a more explicit relationship between these measures and the specific design interventions that were introduced.

Response – It is agreed that design features are very important in achieving placemaking, mobility and access objectives. Since this paper concentrates on performance aspects given the design that was implemented and due to the length of the paper, all design aspects could not be adequately addressed. However, some design aspects have been added in the ‘Street Design as Shared Space’ section of the paper. The shared-space design interventions include a level surface with stone paving and the use of a 600mm wide tactile delineator band to warn the visually impaired pedestrians. Additionally, Page 4 of the attached IPENZ TG conference paper (Reference 12 in the TRB manuscript) illustrates other design interventions.

Revision – Page 7, Lines 1-13 for ‘Street Design as Shared Space’ section.

Comment 2.5 – There is need for more discussion of conflicts. And the safety dimension. How does this relationship bear out in the cases: increasing pedestrian volumes, decreasing vehicular access, decreasing vehicular speeds, amidst peak and off-peak differences. There is quite a bit of missing literature not just on Pedestrian LOS but also in terms of pedestrian-vehicular interactions.

Response – The authors agree with the reviewer that there is a need to consider the safety aspects of the overall shared space performance in order to be able to conclude whether such design intervention is appropriate for certain transport and land use contexts. The ‘after’ period is however not yet long enough for this to be adequately considered at this point. It is proposed that future research tasks will study these safety aspects (including pedestrian and vehicle conflicts) of the three shared spaces in the Auckland CBD.

With respect to the literature on Pedestrian Level of Service (LOS), the authors believe the established pedestrian LOS methodology is not adequate to assess the pedestrian performance in shared spaces. This is predominantly due to current LOS concepts are based on segregation between pedestrians and vehicles (except at the crossing points) and that they do not take into account stationary pedestrians. Also, as noted on Page 5 (Lines 15-25), in many cases, the stationary activity in LOS analysis is considered as an impediment to the pedestrian movement, resulting in a lower pedestrian LOS. Whereas from a ‘Shared Space’ objective the longer a pedestrian remains in the zone is considered an increasing success.

Revision – Further study on a more detailed safety analysis, including user conflict is added in the ‘Conclusion and Future Research’ section (Page 18, Lines 28-29).

Comment 2.6 – The conclusions in the paper are rather limited and not well supported by the data or the analysis.

Response – The conclusion has been rewritten to highlight the main conclusions of the research and the novelty and importance of the methodological analysis process (i.e. the 24-hour profile and the 15-minute peak zone analysis), employed to

objectively measure pedestrian performance in a shared space. The outcome of the additional analysis of the pedestrian and vehicular data is, to a certain degree, consistent with the previous ‘before’ data analysis (refer to the IPENZ TG paper in the attachment) in terms of the effect of active frontage on the number of pedestrians, and, as demonstrated in this paper, on the operating speeds of vehicles within the shared space environments.

Revision – The ‘Conclusion and Future Research’ section has been updated as described above (Page 18, Lines 1-32).

Comment 2.7 – This seems to be more of an initial work in progress rather than a more finished, defensible analysis. While this is good start, it's not all that convincing, as yet, in terms of the findings, conclusions, lessons, and applicability to other settings.

Response – The authors acknowledge that the paper may be limited in terms of road safety analysis, but we believe like Reviewers 3 and 4 that the research analysis methodology is rigorously structured to objectively measure pedestrian performance within the shared space environments. This is especially so for the measuring of placemaking objective where many evaluation studies of (urban) design interventions are site-specific and difficult to compare with similar schemes. The classification of the Pedestrian Movement (PM) for moving pedestrians and the Pedestrian Occupancy (PO) for stationary pedestrians based on a 15-minute snapshot of a 24-hour video footage provides a well-defined framework for the ‘before and after’ analysis. More importantly, with the conversion to the pedestrian density, the three sites can be quantitatively compared to assess how successful the shared space design intervention in different land use settings (albeit all sites are within the CBD context).

REVIEWER 3

Comment 3.1 – This paper reports on the effectiveness of shared space approaches to street design and use. The research design is clear and the methods used are carefully structured and applied, assessing pedestrians and vehicles before and after the intervention. However, the authors need to provide more specific information on what the before and after conditions were.

Response – The authors very much appreciate the positive feedback on the paper with respect to the research design and methodology. A new section (Street Design as Shared Space) is added to provide more description on the ‘after’ conditions of the shared space street, including a level surface with stone paving and the use of a 600mm wide tactile delineator band to warn the visually impaired pedestrians.

Revision– Page 7, Lines 1-13 for ‘Street Design as Shared Space’ section.

Comment 3.2 – More information on how the video observations were translated into spatial and quantitative data will be needed for the methods to be used and replicated by other researchers.

Response – The ‘Analysis Methods’ section describes how the video data and observations can be translated into the spatial and quantitative data, including the determination of Pedestrian Movement (PM) and Pedestrian Occupancy (PO) over a 24-hour period. In the first stage, a review of a 10-second period immediately before and after the snapshot differentiate pedestrians who use the space to move along and

across (PM) from those who are stationary (PO). The overall PO percentage (PO_{24h}) represents the number of stationary pedestrians out of the 24-hour total.

The 15-minute peak zone analysis in the second stage considers each group in further detail, including pedestrian trajectory for the PM group and pedestrian activity and dwell time for the PO group. The scope of the peak analysis is limited to the 40m long zone at the zero, fifth, tenth and fifteenth minutes of the 15-minute peak period.

Revision– Page 9, Lines 18-19 for a description of the overall PO percentage (PO_{24h}). Figures 4(a), 5(a) and 6(a) on pages 11, 13 and 15 are also updated accordingly.

Comment 3.3 – If the limitations mentioned above were addressed, then the paper could be more useful to both practitioners and researchers.

Response – The authors trust the above responses and revisions satisfactorily address the review's concerns.

REVIEWER 4

Comment 4.1 – p. 2 and elsewhere, suggest adding parenthetical translations of terms (e.g., "Right-of-way" for "reserve")

Response – This has been undertaken once in the introduction, but not repeated multiple times.

Revision– Page 2, Line 27.

Comment 4.2 – p. 7 line 14, asf should be capitalized

Response – The reference to 'asf' has been removed due to the revision.

Comment 4.3 – p. 10, don't abbreviate PM & PO in this chart and add quantified comparisons to the chart (from p. 9)

Response – PO and PM are written in full for figure texts (b), (c) and (d).

Revision– Figures 4, 5 and 6 on Page 11, 13 and 15, are updated accordingly.

Comment 4.4 – In the beginning of the paper, the conceptual model includes a measure for safety including conflicts and crashes. This is not referenced in the data or discussion section. It seems that the major oppositions to shared space (where deemed at all appropriate) include concerns for people with disabilities and concerns about safety in general. Does this paper really address those concerns? I'm not sure. But it nevertheless seems like a rigorous study that contributes to the understanding of the topic, and before-after studies are valuable.

Response – The reviewer is right to point out the lack of safety analysis in the paper. As indicated in the study background, road user safety is one of the key shared space objectives. However, with limited recorded crash data for the 'after' scenario, the pedestrian safety analysis is unable to be thoroughly investigated at this point in time. As part of the future research, it is proposed to investigate not only recorded crashes but also user conflict and safety risks in the three shared space sites.

Revision – Safety discussion is added in the following sections; ‘Data Acquisition’ (Page 8, Lines 10-17), ‘Results and Discussion’ (Page 10, Lines 8-11) and ‘Conclusion and Future Research’ (Page 18, Lines 13-14 and 28-29).

Comment 4.5 – The level of contextual commentary and explanation by the authors is commendable. The data presentation for the three cases is exemplary and inspirational.

Response – Thank you very much. This is very much appreciated.

We believe the revised paper with the above responses satisfactorily addresses the reviewer’s concerns. We look forward to hearing from you with regards to the TRR journal publication recommendation following the Annual Meeting.

Yours sincerely,

Auttapone Karndacharuk
Principal Consent Specialist
(Corresponding author on behalf of all authors)

A2.iii) Karndacharuk, A., Wilson, D., & Dunn, R. (2013). Evaluating shared spaces: Methodological framework and performance index. *Road and Transport Research*, 22(2), 52-61.

Evaluating shared spaces: methodological framework and performance index

Auttapone (Aut) Karndacharuk,
Douglas J. Wilson and Roger C. M. Dunn

Abstract

This paper presents a framework to thoroughly evaluate the performance of a public urban road in a shared space environment. Utilising road space as a place for activity is considered a key driver to transform a conventional street to a shared space in a city centre. This, coupled with an aim to improve the economic vitality of the abutting land use, forms the key objectives of implementing shared spaces. Conventional road design relies primarily on the two functions of 'Mobility & Access', which are principally related to motor vehicles. This is reflected in the conventional approach on how local authorities currently assess the performance of roadways along with the associated data collection and monitoring schemes. With the concept of shared space, this paper holistically captures the necessary data, both quantitative and qualitative, to properly evaluate shared space schemes. A framework incorporating an Analytical Hierarchy Process is proposed to analyse the processed data in order to obtain a performance index that is universally applicable to evaluating shared spaces in different street environments. The framework will be tested using before and after data collected from the shared space implementation projects in Elliott, Lorne and Fort Street areas in Auckland, New Zealand.

INTRODUCTION

The shared space concept is one of various approaches in response to the realisation of the adverse environmental and social impacts due to decades of planning and design primarily focused on the priority for motor vehicles. Even though there has been a recent surge in the use of the term 'Shared Space' and its applications in the past decade largely influenced by the work of a European project (Shared Space 2005; 2008a; 2008b) and the UK's Department for Transport (DfT 2009; 2011), the concept of various street users sharing the same public space is not new. The road user integration concept can be traced back to the philosophical

Peer reviewed paper

This paper has been critically reviewed by at least two recognised experts in the relevant field.

Received: July 2012.

A2.iv) Road and Transport Research response letter dated 1 July 2013



6 Henderson Valley Road, Henderson, Auckland 0612
Private Bag 92250, Auckland 1142, New Zealand
Ph 09 355 3553 **Fax** 09 355 3550

1 July 2013

Dr Ray Brindle

Editor of Road and Transport Research Journal

Dear Dr Ray

RE: Letter of response to review comments and request for revisions (RTR 415)

Thank you for your email and the reviewer comments. This letter aims to systematically respond to major comments from the reviewers on the original manuscript, submitted for publication in the Road and Transport Research (RTR) Journal. The review comments are itemised in italics with our response on each point raised.

Any changes and additions made in the revised manuscript are highlighted.

REFeree 1

Comment 1.1 – In fact the local distributors were usually ‘small roads’, rather than ‘shared spaces’

Response – The authors agree with the reviewer. The sentence is revised to indicate that shared spaces are considered to be part of Local Distributors.

Comment 1.2 – (the place function as part of the shared space concept) adds to current approaches in a minority of situations

Response – While the point raised is acknowledged, the authors do believe that the place function incorporated in the shared space concept can be applied to a wide range of situations, including main streets, CBD streets and low-speed, low-volume residential streets.

Comment 1.3 – This diagram (figure 2) needs to be more dynamic, to show how there are interactions between the three aspects within the road and the activities adjacent to the road reserve.

Response – The objective of the diagram is to demonstrate various functions of land use with respect to the area ‘within and outside’ the road reserve, and identify the place function ‘within’ the road reserve. All of the elements currently in the diagram serve such purposes. Instead of modifying the diagram, the sentences describing the diagram are revised to better explain the dynamic interactions as requested.

Comment 1.4 – (a relatively level surface) not always, spell out whether this refer to gradient, of flatness eg no kerbs. ..this positive attraction is probably more important than removing the negatives.

Response – This paragraph discussing the design principles of shared space has been revised to spell out the key elements to support placemaking within the road reserve as well as to reduce vehicular dominance.

Comment 1.5 – (subjective values in urban design).. too stereotyped and trite: urban design is as much to do with hard-nosed functionality and objective factors e.g. also safety and risk i.e. pretty much the same as for drivers, but from a different point of view.

Response – The intention of this statement is not to criticise the appropriateness of the urban design performance evaluation methods, but rather to highlight the need for a systematic evaluation framework, taking into account both objective and subjective values. The sentence, nonetheless, is revised to remove words that may convey a negative connotation.

Comment 1.6 – there is an interesting comparison here: a driver makes a decision to travel a certain route, or down a particular street, in a certain manner some time before actually doing it. The pedestrian likewise – decides to use the shared space or not.

Response – The comment is acknowledged and the planned on-street perception surveys in continuing research is based upon a qualitative methodology and will investigate the purpose of the pedestrian trips, primarily whether they are in the PM or PO groups.

Comment 1.7 – (shared space objectives) need to consider bicycles, motorised wheelchairs, etc as well. Need to also build in assessment of user satisfaction, including economic effects through discussion with traders, etc, not just active frontage. See Rolf Monheim references.

Response – The comments are appreciated. However, the references to Rolf Monheim on extensive research and pedestrian analysis (e.g. Monheim 1992; 1998) are not included in the revised paper as they are outside the scope of this paper. Since the original manuscript submission in July 2012, the authors have decided to amend the qualitative performance methods from primarily using an online survey to an on-street perception survey in order to better capture the opinions and perceptions of actual space users as well as the adjacent businesses. The section of qualitative data collection and processing has been revised accordingly.

Comment 1.8 – Be careful of min peaks and mega peaks (for pedestrian activity data collection).

Response – The comment is noted. By investigating the pedestrian demand over the 24 hour period based on the 15min interval, the peak demand at different time periods can be appropriately revealed (Karndacharuk, Wilson & Dunn 2013).

A detailed pedestrian analysis based on the quantitative methodology has been undertaken. The results were presented at the Transportation Research Board (TRB)'s Annual Meeting in January 2013, and accepted for publication in the Transportation

Research Record journal. The TRB manuscript (Karndacharuk, Wilson & Dunn 2013) is attached to demonstrate the use of the 24-hour pedestrian profile along with a 15-minute peak zone analysis to assess the complexity of pedestrian performance and characteristics.

Comment 1.9 – As with all modelling: don't forget the commonsense or intuitive test. There is a growing recognition of the links between choices, perception, etc and neuroscience, but that is a step too soon for this piece.

Response – The comment is acknowledged.

Comment 1.10 – (In the conclusion).. this runs the risk of most traffic analysis - “if you can't measure it, it doesn't exist”.

Response – The conclusion section is updated to reflect the research progresses.

Comment 1.11 – Other references which I expect would include Jan Gehl, Rolf Monheim and Bendingo shared space

Response – While the references to Rolf Monheim and the Bendingo shared space are not included in the revised paper as they are not entirely within the paper scope, the authors have included Jan Gehl's reference in the Place function section along with those of Jane Jacobs and William Whyte.

REFeree 2

Comment 2.1 – The abstract is pretty clear, paper objective is not stated in body of paper

Response – The objective of the paper has been added at the end of the Introduction section.

Comment 2.2 – The spider diagram needs explanation; Table 1 appears to be missing some KPI.

Response – An explanation is added to highlight the Safety as the most importance criterion. Table 1 has been updated to reflect the current KPIs used for overall analysis.

Comment 2.3 – On the whole, the proposed evaluation framework seems okay, although the authors have not addressed some of the obvious issues regarding data collection and effects measurement, time frame for evaluation. My main criticism has to do with proposing the framework, objectives, measures, indicators and so on without reference to criteria for selection. Also they need to be clear and that it will be tested (and perhaps modified) and reported later.

Response – It is noted that the data collection and analysis, especially for the quantitative methods, are described in more detail elsewhere i.e. in Karndacharuk, Wilson and Tse (2011) and the TRB paper (attached). With the objective to present an overall framework, this paper provides in the Key Performance and Data Acquisition section a general description of the data collection and analysis process.

The reviewer is correct that as indicated in the Conclusion and New Steps section, the framework will be tested and perhaps modified to ensure that the end product of the performance index is meaningful, and reflects the success of a shared space in accordance with the established objectives.

The references suggested by the reviewers along with some others have also been added to the revised manuscript. We believe the revised paper with the above responses satisfactorily addresses the reviewers' concerns. We look forward to hearing from you with regards to the RTR journal publication.

Yours sincerely

Auttapone (Aut) Karndacharuk
Principal Consent Specialist
(Corresponding author on behalf of all authors)

CC: Dr Doug Wilson and AP Roger Dunn

A2.v) Karndacharuk, A., Wilson, D., & Dunn, R. (2014). A review of the evolution of shared (street) space concepts in urban environments. *Transport Reviews*, 34(2), 190-220.

Transport Reviews, 2014

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A Review of the Evolution of Shared (Street) Space Concepts in Urban Environments

AUTTAPONE KARNDACHARUK*[§], DOUGLAS J. WILSON** AND ROGER DUNN**

*Road Corridor Operations, Auckland Transport, Private Bag 92250, Auckland 1142, New Zealand;

**Department of Civil and Environmental Engineering, The University of Auckland, Private Bag 92019, Auckland 1142, New Zealand

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ABSTRACT This paper aims to clearly establish the origin and evolution of the shared space concept from a New Zealand perspective by reviewing the literature in the disciplines of both urban design and transportation engineering. The review process involves investigating the use and function of a public road space in the context of the changing of public expectations and how this can relate to a number of interconnected street design approaches (e.g. traffic calming and self-explaining roads (SERs)). These approaches have been used to minimise the influence of motor vehicles since the beginning of the automobile era. The shared space concept, when applied in public road environments in activity centres, has increasingly been embraced by urban planners, transportation engineers and regulatory agencies. A shared space diverges from a conventional road where all road users are encouraged to legitimately occupy the same road space with little physical separation. To achieve this in a safe and efficient manner, the design aims to reduce the dominance of the motor vehicle by promoting pedestrian and cycling activity and utilising the road space as a 'place' in addition to its 'transport' mobility and access purposes. Given the fundamental conceptual differentiation between a traffic-calmed street and a shared space, the paper argues that there are certain design elements, constituting a shared space, and without them, it would be difficult for a public street to function as a genuine shared space for all road users.

1. Introduction

The notion of different street users sharing the same public road space is not new. However, the idea of encouraging the mixing of slower speed, smaller mass pedestrians or cyclists with a higher speed, larger mass vehicles is novel, particularly after the pinnacle of widespread automobile domination in the automobile era of the twentieth century and previous objectives of separating vulnerable road users from vehicles. The road user integration idea can be traced to Buchanan's environmental area philosophy and further developed in the Netherlands in the form of the residential shared space (*woonerf*) concept (Karndacharuk, Wilson, & Dunn, 2013). The renewed interest in the shared space concept, one of many integrated

[§]Corresponding author. Email: auttapone.karndacharuk@aucklandtransport.govt.nz

A2.vi) Transport Reviews response letter dated 1 December 2013



6 Henderson Valley Road, Henderson, Auckland 0612
Private Bag 92250, Auckland 1142, New Zealand
Ph 09 355 3553 **Fax** 09 355 3550

1 December 2013

Dr Moshe Givoni

Associate Editor of Transport Reviews: A Transnational Transdisciplinary Journal

Dear Dr Moshe

**RE: Letter of response to reviewer comments and request for major revisions
(Manuscript ID TTRV-2013-0061)**

Thank you for your email and the reviewer comments. This letter aims to systematically respond to all comments from the reviewers on the original manuscript, submitted for publication in the Transport Reviews: A Transnational Transdisciplinary Journal. The review comments are itemised in italics with our response on each point raised.

The paper structure and review content have been revised to take into account feedback from the peer review process. With the focus now on the critical review form *a New Zealand perspective*, the title and content have been updated accordingly. Any changes and additions made to the texts in the revised manuscript are highlighted.

REVIEWER 1

Overview: This paper provides a review of shared space streets, and associated concepts (woonerven, etc.) with some historical background. This provides coverage of relevant material, linking the concept of shared space streets to environmental areas in Traffic in Towns, and some more recent developments in the last decade. The paper is written clearly in good English, and has some appropriate illustration. Unfortunately, the paper falls short of what would be expected for a review paper, on a number of fronts (detailed below). The material could ultimately be the basis for a successful paper, but in its present state is not nearly ready for publication, and would need major reincarnation (including clear scope, structure, and substantial additional critical review and synthesis) before it could be considered for publication.

Major points First, the paper does not seem to be nearly comprehensive enough in its coverage. Even from a UK perspective, there are several authors and references that seem to be missing – for example, the work of Steve Melia; Barrell & Whitehouse (home zones), etc. This does not give confidence that the rest of the paper gives a good geographical coverage elsewhere (a quick check on Google Scholar immediately shows up potential further references that might have been helpful – Bliek in USA; Sorensen in Tokyo, etc...). In any case the paper should be clear from the start about which parts of the world it is attempting to cover.

Response – Thank your for your detailed review of the paper. The paper scope, structure and content have been revised with an emphasis on the New Zealand context. The scope is revised to provide a better critical review of the literature, covering the whole spectrum of street treatments. The structure and synthesis will be revised accordingly.

There are a number of ‘shared street’ related papers that have been reviewed, but deliberately excluded from this paper. The reasons for the exclusion vary from inadequate literature review and irrelevance to the paper objective to papers with scope that is too specific or too generalised. Some of the literature were considered to be deficient in structure, context and analysis, especially those freely available on the internet. Others do not provide added value to the review paper, or simply superfluous to be included.

Nonetheless, we have revisited the coverage of the papers reviewed, and adjusted them to align with the revised paper objective and scope.

Second, the paper does not give sufficient critical, substantial, cross-cutting analysis. There is a ruck of concepts to understand and untangle – shared surfaces, shared spaces, woonerven, home zones, etc. but there is not really a systematic scrutiny of what these are and how they relate to each other. Figure 4 would be a useful starting point. However what would be really useful would be a more systematic scrutiny – such as tabulation of (i) the different concepts, (ii) where they have been applied (iii) and when, and (iv) any outcomes (in terms of use, etc.); (v) with further notes and sources. (In such a table, Figure 4 would be simply the structural subdivision of the first column); with such a table or tables accompanied by critical discussion on the similarities and differences between approaches, etc.

Response – Table 1 has been created to specifically address the issues raised. The paper indeed seems unfocused, as to whether it is just about shared streets (ie. without segregation) or including the other kinds of calmed street (Figure 4). There would seem to be a choice here, as to whether to simply focus on shared streets proper, and deepen the analysis; or to keep the current breadth (while also adding in more depth and detail) – or even extend it to include car-free streets and pedestrianisation, if this would give a better perspective on how shared surface streets fit in to the whole spectrum of street treatments. If going for a broader approach, it could be a useful service to readers, to critically distinguish between all these perhaps half-familiar terms (e.g. complete street) and really ‘pin them down once and for all’.

Response – Section 3 now discusses the road design spectrum for user integration as suggested. Various shared and calmed streets are tabulated in Table 1 with the authors’ comments and references for each term discussed.

The historical dimension is not accomplished well. Section 2 has some background but is not a history of shared space, and most of the material could be cut. Elsewhere, the historical grasp seems shaky; the paper does not seem really attuned to chronology or historical order (e.g. in several places citing sources from decades ago without further comment as if the date they were written were of no import). It is possible that the paper could be redeveloped as either a proper historical account of shared space, or be a state of

the art (contemporary) critical review – it is recommended the latter would be more useful for this journal.

Response – the revised paper offers a contemporary critical review as recommended although key historical points of thinking in the development of shared spaces are still reported for completeness.

There seems to be little discussion of shared streets in practice – how they have been implemented and used. Given the relative attention to the UK context, for example, one might expect to have seen more detailed critical discussion of DfT literature; and the RNIB concern for the impacts on blind people. (Discussion of alternative/equivalent examples from other countries would be equally welcome.) It would seem useful to round up studies of performance of shared space streets? E.g. Bliek's Impacts of Shared Space Design on Pedestrian and Motorist Behaviour.

Response – In Section 4.2, a New Zealand CBD shared space is employed as a reference scheme in an activity centre, and compared with six international schemes in the UK, Austria, Australia and the Netherlands. Because Bliek's paper offers an analysis of shared spaces in a residential context, it is referred to in Section 3 as one of the references for the term 'Shared Street'.

Finally, it is difficult to detect key findings, novel insights, added value, or how the paper advances the field of knowledge of shared spaces. A proper conclusions section would usefully deliver this.

Response – The conclusion has been rewritten.

Detailed points.P2 – You could give clearer sense of geographical coverage; and a clearer indication of the overall (ultimate) structure of the paper (i.e. once the overall scope, direction and structure of the paper is settled).

Response – Section 1 (Introduction) has been revised accordingly.

Pp 3–4 Section 2 seems superfluous. It is not really the history of shared space. It contains rather general well-worn material that could be cut.

Response – Section 2 (Urban street value and changing public expectation) is retained to give a brief background on changing public expectations over the use and function of public road space. This also aims to demonstrate that transport policy, planning and infrastructure provision for the automobile for the most part of the 20th century were supported by the society as a whole as opposed to being influenced exclusively by the traffic engineering profession.

P4-5 If a historical introduction is being offered, it would seem useful to at least mention the historical trend of increasing segregation (including the footway/carriageway distinction of surfaces in the first place), against which the 'shared surface' concept can be seen as an innovation.

Response – The revised paper does not now focus on a historical review of the concept.

P5 The claim that shared surface roads ‘would be’ classified as local distributor roads seems suspect or at least is unjustified without further explanation and evidence.

Response – The sentence is revised to indicate that shared spaces are considered to be part of local distributors or access roads.

P6 While it is reasonable to claim that Buchanan’s environmental area concept helped pave way for shared surfaces (in fact you make a better justification of this later by citing Dutch and German interpretation of Buchanan), it seems potentially misleading to back this up by a reference to ‘mixture of pedestrians and vehicles’. It is not clear here whether Buchanan is really meaning a conventional street (i.e. as opposed to pedestrian-only or vehicle-only) or – with reference to the American example – a kind of suburban road in which there may be no footway but where vehicles might still have priority over pedestrians rather than sharing the space on an equal footing.

Response – The comments are appreciated. The reference to Buchanan’s statement is to substantiate that the environmental area allows for road user integration and that the complete separation between pedestrians and vehicles is not a necessity in the area.

P6 The discussion here – and elsewhere on historical aspects of streets and Buchanan etc. – might benefit from reference to Hebbert’s papers on streets (2005).

Response – Hebbert’s paper has now been referred to in Section 2.

P7 Text implies the woonerf idea swept through England in the mid 1970s. This seems a rather too loose interpretation in this context (where the exact distinction between a home zone and what preceded it in UK, and a woonerf, ought to be unambiguous).

Response – This particular statement has been removed as part of the paper structural revision.

P7 Around here, the benefit of having some sort of table with a systematic analysis of attributes of the different kind of street would seem increasingly advantageous.

Response – Table 1 is created accordingly.

P7 The text refers to ‘is primarily adopted’ when referring to sources from 1992, 1993. This does not seem appropriate for a historically sensitive account.

Response – This has been removed from the text.

P8 Not clear why now going on to talk about traffic calmed streets

Response – As aforementioned, the paper is revised to provide a spectrum of shared and calmed streets.

P10 ‘There are a number of well known techniques’ – again, a table would seem to help here.

Response – The various concepts for calmed streets are included in Table 1.

P10 'New Urbanism' does not seem an appropriate label for a specific street treatment

Response – The reference to 'New Urbanism' is removed.

P10 'do not specifically aim' – so why include? – but on the other hand, if reorienting the whole paper to include these, that could be helpful, if they are scrutinised in a critical substantive way.

Response – The paper scope has been revised properly to include these.

P11 Discussion – it does not seem clear why this is labelled as such – the paper has been already been a discussion up till now.

Response – The paper scope has been restructured as suggested.

P12 To say that 'the two functions are fundamental' needs clarification. A critique of this 'inverse relationship' is given in Streets and Patterns (Marshall, 2005). Road classification is also dealt with in detail in Streets and Patterns.

Response – The discussion on street functions have been revised and documented in Section 4.1 (Shared space in theory)

*P12 Again, the reference to Brindle is as if it is current, when in fact it's over 15 years ago.
P13 'cannot be applied to all streets' – why not?*

Response – The reference to Brindle's has been removed as part of the paper structural revision.

P13 'cannot be applied to all streets' – why not?

Response – The sentence is revised to indicate that the three street functions of Place, Access and Mobility can be applied to all urban streets subject to the context, especially active land-use frontage for the Place function.

P13 'It is debateable... with the shared space concept in this paper'. Understood. But what a review paper might ideally do is to compile a reasonably wide (if not literally comprehensive) review of the difference concepts of shared space, and classify these into different categories, into which any and all examples could be slotted. This would certainly add value and be useful to the reader. As it is, it is not really clear what 'the shared space concept in this paper' actually is (e.g. if it includes collector and distributor roads as well as access roads...).

Response – This particular critique of the Laweiplein example in the Netherlands is now offered in Section 4.2 (Shared space in practice) where the design features and performance outcomes of six international schemes are reviewed and compared with those of the Elliott Street shared space in New Zealand.

P14 'should emphasise' – according to whom?

Response – This sentence is revised to read ‘...shared spaces are expected to incorporate a continuous paved surface...’

P14 The Leonardo case is a nice example – or would be, if the paper were about pedestrian/vehicle segregation; or the history of streets in general. It does not seem directly relevant for a paper on shared streets.

Response – The reference to the Leonardo case is removed.

P14 Here, Buchanan’s influence on segregation is made, appropriately enough (one might add Tripp too); might this be linked to your earlier point that Buchanan was open to mixing?

Response – Various points about Buchanan’s influence are now contained in one section, Section 3.1.

P14 ‘are still promoted’ (MoT, 1996) This does not make sense. Either it means 1966 in which case ‘is still’ seems wrong; while MoT 1996 does not sound right.

Response – This has been removed.

P15 The ‘concluding remark’ is inadequate. There should be a proper conclusions section drawing attention to the key findings – e.g. new insights or novel syntheses – and added value and significance. As it is, the present text is so general, it could have been in the introduction – unfortunately, a hallmark of a paper that is not sure of its own added value.

Response – Section 5 (Conclusion) has been rewritten to summarise the paper’s key findings and contributions to the literature.

REVIEWER 2

This is a very extensive and well written review. I should start by noting that this is not one of my areas of research but walking and cycling more generally are subjects I work on. My main question after reading the paper is what does it adds? What is the added value of the extensive review apart from mapping the various terminologies and their meaning (over time)? This is a major shortcoming of the paper. The paper ends with no real conclusions or valuable insights that those dealing with shared space concepts (in academia and practice) can learn from. Section 5 is a short summary of the paper and represents this point. I also have some comments on the structure. The first parts of the paper are well structured but towards the end the structure seems to fall. Especially section 4 seems to be a continuation of section 3 with presentation of different categories. I'm not sure why is this section termed discussion. Related to the first comment, as far as I know there is a heated debate on the usefulness and effectiveness of the shared space concept. This debate is missing from the paper and can greatly enhance it. What is the empirical evidence after many years of using shared space in different forms and different locations? I understand this is not the purpose of this paper but maybe this is needed to provide the added value. I find it hard to reach a conclusion on the paper. It will help a lot if the author(s) could identify and clearly state the added value of their review.

Response – The authors appreciate the points made by the reviewer, including equivocality of the added value to the existing knowledge of shared street concepts, the structure and conclusion of the paper and the effectiveness of the concept. As aforementioned, the original paper has undergone major revisions. The introduction and conclusion sections outline the paper's contributions to the understanding of shared space streets. A shared space concept is placed into the street design spectrum for road user integration in Section 3 while Section 4 specifically discusses key design features and performance results of urban shared spaces in activity centres (as opposed to residential shared spaces).

REVIEWER 3

This overview of the background, literature and practice of shared space has the potential to provide a very valuable addition to the knowledge base in this rapidly expanding and relevant field. There is much useful material in the draft, and it could form the basis for a very helpful explanatory reference to the subject. However I would urge you to give a little more time to exploring some key sources in more detail, and to redrafting the paper to both overcome some critical omissions, errors and misunderstandings, as well as to provide a more clear focus on shared space itself as a key concept. The widespread influence that the principles and techniques represented by shared space now evident suggest that it should be considered as more than merely one of a number of approaches, as suggested in your Figure 4 (for example). The most important starting point is to get your definitions right. The definition you give in the abstract, "A shared space diverges from a conventional road where all road users are encouraged to legitimately occupy the same road space with little physical separation", falls well short of an adequate summary. Contrary to your assertion, the contemporary meaning of the term "shared space" has been clearly defined (and registered in The Netherlands. It was coined by Ben Hamilton-Baillie and Hans Monderman in 2002 in preparation for the submission for research funding from the European InterReg project. Although there are references to "shared streets" and sharing in the writings of people such as Hass-Klau and Pharaoh, these refer to much earlier and less comprehensive concepts. The definition stated that "Shared Space describes streets and public spaces where interactions are governed by informal negotiations and social protocols, rather than through regulation and control" (Hamilton-Baillie, 2002). You will note that this definition does not attempt to describe any physical manifestations of shared space, but merely the way in which people use it. I would avoid the term "Shared Spaces", as opposed to "Shared Space". The term has often been misinterpreted by some groups, such as the use of the term "shared surfaces" or "shared streets" (a tortology), but the original definition remains intact.

Response – This paper traces the shared space concept to the *Traffic in Towns* and acknowledges that the integration idea discussed in this book paved the way for the road user integration concept, the *Woonerf* concept, traffic calming and so on. On the contrary, Ben Hamilton-Baillie claims that the same publication, the Buchanan Report, renewed and advocated the road user segregation concept (Hamilton-Baillie, 2008) without a proper acknowledgement that Buchanan has been considered the father of traffic calming in the Netherlands and Germany. Given the conflicting point of view, it is difficult for the authors to fully agree with Ben's perspective of a narrative on the evolution of the shared space concept.

According to the literature, Ben Hamilton-Baillie's understanding of the shared space idea was influenced by the *Woonerf* concept, especially after his study tour in Northern Europe in 2000 to study *Woonerf* streets i.e. residential shared spaces or home zones in England (Biddulph, 2010). He along with Hans Monderman could have acknowledged that a non-residential shared space is in fact another type of *erf* streets that have been operating in the Netherlands long before the European Shared Space project.

Additionally, the authors believe that the broad definition mentioned above falls far short of providing any meaningful description and behavioural expectations from a perspective of local or regional bodies that manage and maintain public spaces, including road spaces. Based on such a definition, not many public streets can be classified as 'Shared Space' because of standards and regulations required to manage them. For example, the much celebrated Laweiplein 'Shared Space' incorporates not only roundabout signage, but also pavement marking at both formal and informal crossing points.

I would strongly recommend looking into the historical roots of shared space in a little more detail, particularly the work of Joost Váhl "Traffic Calming through Integrated Urban Design" (Armacande), and the French 1980's initiative "Villes plus Sûre" (Safer Towns). Francine Loisseau in Paris, former editor of Armacande, has an extensive archive of the early work that laid much of the groundwork. It might be also worth touching on the work of Professor John Adams and particularly his work on "Risk" (1995). Risk compensation effect is a core foundation for the sometimes counterintuitive outcomes of shared space. I would also recommend looking at the work of Allan B Jacob ("Great Streets" and "The Boulevard Book" - MIT Press). Worth touching on the earlier work of pioneers such as William Phelps Eno, and the assumptions made about speed and capacity during the early development of traffic engineering. Váhl's work is of particular importance. I would also give more space to the portfolio of work and experimentation completed by Hans Monderman. I think you could trim or delete much of the sections on related issues such as LATM (Page 9). Worth a mention, but they do not add much to our emerging understanding of shared space.

Response – In general accordance of the advice from Reviewer 1, the authors decided not to follow the route of a full review of the historical account of shared space, but rather a contemporary review of road user integration concepts and urban shared spaces from a New Zealand perspective.

The risk compensation concept is briefly discussed in Section 4.1. With a refined definition of a shared space provided in Section 4.3, the risk of traffic conflicts and crashes can be minimised via the design requirements of a consistently low-speed environment as opposed to uncertainty or eye contact.

You should try to avoid simplistic, unsupported statements that have no clear reference or supported arguments. For example, "Consequently, it can be seen the primary purpose of a street has always been the movement of people and goods" (page 3, line 28) leaves the reader struggling to follow this conclusion. There are very many streets where the primary purposes were ones of exchange, interaction, display, information and encounters.

Response – These comments are acknowledged and the paper updated to reflect this.

A few other corrections - the early woonerf definitions referred to "schritstaapen" as the design speed ("trotting speed") - not walking speed (page 6, line 5). There is no definition of an "encounter zone" (page 7, line 34). This is a fairly poor translation of the term used in Switzerland, France and Belgium of "Begegnungszonen" or "Zones des Rencontres".

Response – These comments are appreciated. The reference to *Begegnungszonen* is included in Table 1.

Hans Monderman's work was only very peripherally concerned with retail streets (page 8, line 9). His work started in rural villages, and then developed in busier urban locations such as Haren near Groningen, and later the "Laweiplein" in Drachten. Hans would be offended from his grave if you suggest that the latter was not shared space - the way in which interactions work on an informal, social basis in the reconstructed Laweiplein is quintessential shared space!

Response – The reference to ‘retails streets’ has been amended to ‘activity centres’. As discussed in Section 4.2 and Table 2, the authors question the ability of this ‘Shared Space’ intersection space to cater for the place function and associated staying activities given that the majority of space is allocated for the movements of various road users (e.g. drivers, cyclists and pedestrians).

"As aforementioned, a shared space in commercial or shopping areas in Australia and New Zealand is generally equal to, and should be declared as Shared Zones." (Page 7, L. 27). I am not clear what this sentence means, and whether it contributes anything useful to the paper... I would be very careful of using the term "legally occupy" in relation to definitions of shared space. (Page 7, L 44). There is no change in the law necessarily appropriate to shared space, and there are many, many noted examples of shared space (Ashford, Poyntonetc) where you would not wish to see pedestrians "occupying" the carriageway. Shared space can occur in all sorts of contexts and traffic volumes, and may include kerbs and even physical barriers in some locations. The core issue is underpinning shared space is the attempt to foster CIVILITY through the definition of public space, something that was frequently referred to by Hans Monderman, JoostVáhl and Ben Hamilton-Baillie.

Response – As aforementioned, the review is from a New Zealand perspective, including a legal definition of a Shared Zone in New Zealand.

The Elwick Square in Ashford is included in the comparative analysis in Section 4.2 of the paper. It is found that with the relatively high vehicular traffic volumes and speeds, the movement separation between pedestrians and vehicles can be observed with the majority of pedestrians at defined, informal crossing points; even though the design incorporates a level, paved surface and the minimisation of traffic control devices in order to foster ‘civilised’ interactions. This scheme could as well be included in the ‘Calmed Street’ category in the paper given the pedestrian-vehicle segregation identified.

I would urge you to explore (and refer to) some key publications and peer-reviewed articles on shared space which are missing from your references. These include Ben Hamilton-Baillie's "Shared Space: reconciling people, places and traffic" (Built Environment 2008) - <http://www.hamilton-baillie.co.uk/index.php?do=publications&action=details&pid=25as>

well as "Towards Shared Space" (Urban Design International) - <http://www.hamilton-baillie.co.uk/index.php?do=publications&action=details&pid=30>. It might also be helpful to browse some other similar publications and polemics, such as "Challenging Assumptions" (Urban Design Quarterly) - <http://www.hamilton-baillie.co.uk/index.php?do=publications&action=details&pid=31>.

Response – These publications have already been included in the original manuscript and continued to be included in the revised paper.

Finally, I think the paper would benefit from a quick reference to some of the notable recent examples of shared space schemes. These might include the work of Fritz Kobi in Bern (<http://www.hamilton-baillie.co.uk/index.php?do=projects&sub=details&pid=113>), the key shared space schemes in Sweden (such as Skvallertorget, Noorkøping), and the work of Bjarne Winterberg in Denmark. You should certainly bring the conclusion up to date with reference to the notable scheme in the centre of the Cheshire town of Poynton in England, and its implications for extending the boundaries and application of shared space. I hope this is helpful, and that the revised paper will provide a useful reference and summary in this critical subject area.

Response – Given the word limit of 8,500, the suggested schemes are not included in the revised paper; nonetheless, the relatively recent schemes in New Zealand, the UK and Austria are included in Section 4.2.

We believe the revised paper with the above responses adequately addresses the reviewers' concerns. We look forward to hearing from you with regards to the Transport Reviews journal publication.

Yours sincerely

Auttapone (Aut) Karndacharuk
Principal Consent Specialist
(Corresponding author on behalf of all authors)
CC: Dr Doug Wilson and AP Roger Dunn

A2.vii) Karndacharuk, A., Wilson, D., & Dunn, R. (2014). Safety performance study of a shared pedestrian and vehicle space in New Zealand. *Transportation Research Record* (In Press)

Karndacharuk, Wilson and Dunn

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Safety Performance Study of a Shared Pedestrian and Vehicle Space in New Zealand

Auttapone (Aut) Karndacharuk, ME(Civil) MIPENZ CPEng *

Principal Consent Specialist

Road Corridor Operations, Auckland Transport

Private Bag 92250

Auckland 1142, New Zealand

Telephone: +64 27 675 2959

Fax: +64 9 355 3550

Email: auttapone.karndacharuk@aucklandtransport.govt.nz

Douglas J. Wilson, PhD MIPENZ

Senior Lecturer in Transportation Engineering

Department of Civil and Environmental Engineering, The University of Auckland

Private Bag 92019

Auckland 1142, New Zealand

Telephone: +64 9 923 7948

Fax: +64 9 373 7462

Email: dj.wilson@auckland.ac.nz

Roger C. M. Dunn, MEngSc FIPENZ FITE

Associate Professor and Director of Transportation Engineering

Department of Civil and Environmental Engineering, The University of Auckland

Private Bag 92019

Auckland 1142, New Zealand

Telephone: +64 9 923 7714

Fax: +64 9 373 7462

Email: rcm.dunn@auckland.ac.nz

*Corresponding author: Aut Karndacharuk

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A2.viii) *Transportation Research Board and Transportation Research Record* response letter dated 1 November 2013



6 Henderson Valley Road, Henderson, Auckland 0612
Private Bag 92250, Auckland 1142, New Zealand
Ph 09 355 3553 **Fax** 09 355 3550

1 November 2013

Dr Robert Schneider

University of Wisconsin, Milwaukee

Chair / Paper Review Coordinator, ANF10

Dear Robert,

RE: Letter of Response to Review Comments (TRB Paper 14-0244)

Thank you for your email and the reviewer comments. This letter aims to systematically respond to all comments from the reviewers on the original manuscript, submitted for presentation at the TRB Annual Meeting and for publication in the Journal of the Transportation Research Board (TRB). The review comments are itemised in italics with our response on each point raised.

REVIEWER 1

Interesting and well-written paper on Shared Space. Paper only had one study site. Paper would be better if it included more than one study site.

Response – The reviewer is right to point out that more case studies would better the paper, especially from a comparative analysis. Nonetheless, the authors believe the paper scope and the detailed examination of one study area are adequate to achieve the paper objective of evaluating the safety performance of a shared space, demonstrating a new safety analysis using the Road User Interaction Analysis and Conflict Study (RUICS) method, and challenging the conventional pyramid of traffic events in the context of a shared street environment. As stated in the conclusion of the paper, the data from other shared space sites in New Zealand will be available using the RUICS method and results in ongoing research.

The authors suggested improvements, such as traffic calming, for issues identified in the data (e.g., higher speeds at night). Would like to see results from those suggestions. While the addition of street furniture could address some of the speed concerns, it could cause sight distance restrictions resulting in more negative interactions between vehicles and pedestrians.

Response – The potential concerns from the suggested mitigation measures (e.g. traffic calming) are acknowledged. The authors have put forward improvement

List of research project topics and materials

recommendations to a team in Auckland Transport that is responsible for the operation and management of the road network, including the Elliot Street area. The detailed design and implementation are currently subject to funding prioritisation and allocation.

One page 11, line 12, the authors noted that increased pedestrian volume was associated with reducing the vehicle speed and then cited an earlier paper. You have 500 words available before reaching TRB's 7500 word limit. Please spend some of those words on giving a brief overview on the number of pedestrians in the before / after conditions in association with the change in operating speed.

Response – It is important to note that in accordance with the updated Information for Author (dated May 10, 2013), a word limit of 7,000 is applied when excluding up to 35 references from the word count. If the references are included, a limit of 7,500 is, instead, applied. The word count of the original paper would have exceeded the 7,500 word limit if the 34 references were included in the count.

Nevertheless, upon revisiting this paragraph, the reference to the increasing pedestrian use and occupancy in relation to the shared space implementation based on the previous study has been removed because the texts are not directly relevant to the section of ‘vehicle speed variation’.

Revision – Page 11, Lines 12. The phrase ‘together with increasing pedestrian use and occupancy as discussed in the previous study (13)’ has been removed.

Was the distribution of vehicular speeds (shown in Figure 5) significantly different (using an appropriate statistical test)? The 2011 curve (after treatment) looks more similar to the 2010 curve (before treatment) than the 2012 curve (after treatment). The authors comment that a speed limit sign added in early 2012 contributed to the difference between the 2011 and 2012 curves. Do you have other ideas of why the speed distribution is so different (if, in fact it is different - just because it looks different in the graph a statistical test, which would consider sample size, etc., may tell a different story)? Were enforcement or education campaigns different in 2011 and 2012? Perhaps the additional year of experience was a contributing factor (in other words, the drivers and pedestrians had a better understanding of how they should use the space).

Response – As stated in the paper, the distribution profile of vehicle speeds was best fitted based on the data from the traffic tube counters. The indicative profiles are to illustrate the shift towards lower operating speeds from 2010 to 2012.

The points about education campaigns and the better understanding of the road users over appropriate speeds within the shared zone are appreciated. It is noted that Auckland Transport’s enforcement team deals predominantly with on-street parking whereas speed enforcement is the responsibility of the New Zealand Police (a different organisation and so outside of the control of current research).

Revision – Page 12, Lines 23-24. Further information is added to include Auckland Transport’s ongoing education campaigns.

REVIEWER 2

How many total pedestrians and vehicles were observed? How many pedestrians and vehicles were involved in interactive events?

Response – As described in the RUICS sub-section in the ‘Safety Analysis Methods’ section, an interaction involves one vehicle interacting with one or more pedestrians exclusively within the vehicle travelling area (as illustrated in Figure 2).

Therefore, the total number of vehicles being observed and considered as part of the RUICS analysis is 8,194 (2,727 + 2,608 + 2,859). The exact number of pedestrians involved and observed in the RUICS analysis is not the focus of the study, but can be estimated at a range of some 12,000 and 20,000 over the three-day period.

What did your data show about interaction type (pedestrian priority, vehicle priority, equal priority) vs. number of pedestrians in a group? I would think that pedestrian priority becomes more likely as group size increases.

Response – The authors acknowledge that there is a benefit of correlating the interaction type with the number of pedestrians in a group. This task would justify its own research study to better understand the Safety in Number theory in a context of a shared space.

Since the focus of the paper is on the number of interactions and the interaction type, it is recommended that the Safety in Numbers effects are to be further investigated for future shared space research.

Revision – Page 16, Lines 45-47 added recommending future research on this aspect. Also, Reference 35 is added on Page 19.

Page 6, lines 18-23: What were the specific dates that the cameras were recording?

Response – Page 8 under the RUICS sub-section specifies the recording dates.

Page 8, lines 36-42: Why did you choose Tuesday, Thursday, and Saturday, and not other days of the week? Why didn't you perform the analysis for the entire period of video recording?

Response – It is our standard practice in New Zealand for traffic study investigation to study Tuesday and Thursday, which represent typical weekdays while a weekend survey is undertaken on Saturday. The processing and analysis of the video data is very time consuming and at this point not automated (these methods were investigated but at the time were not yet available to the quality required) therefore manual processing methods were utilised. This meant the entire recording period could not be analysed, however future studies could still utilise this collected data.

Page 9, line 11: What do you mean by "force of situation"?

Response – The term is used to contrast a situation when a road user willingly or by choice takes an evasive action. If there is no force of situation, road users travel in the street undisturbed.

REVIEWER 3

This paper is well-written, logical, interesting, and focused on a topic that is very timely. I was particularly glad to see note of the blind pedestrian considerations, which is typically a key barrier to shared street implementation. The methodology is comprehensive and well-documented, but I was expecting to see statistical tests on the before/after data to determine if the reduction in speeds was statistically significant. I think a control case would have been helpful too.

Response – Thank you very much for your feedback. This is very much appreciated. With respect to the statistical analysis to assess the reduction in speeds, the authors believe the use of mean speeds, which are shown in Figures 5 and 7, is adequate to show the speed variation over a 24-hour period.

REVIEWER 4

The study is interesting and lends some credence to the "safety in numbers" theory that those who encourage design for pedestrians and cyclists like to discuss. I am not recommending this as a published paper, however, due to the study limitations. Having more study locations evaluated would have provided more credence to the thesis posed by the authors. Accordingly, I would recommend the authors take that as the next step. It is not entirely clear if table 1 Safety Performance Indicators is counting all pedestrians and vehicles on the street, or just the ones that had a conflict. If the latter, it would have been both interesting and informative to do a pre and post implementation count of exactly how many total vehicles and pedestrians that were present, and not just the ones that did or may have had a conflict.

Response – The authors are of a strong opinion that the outcome of this paper advances the understanding of how a shared space performs, which will benefit the audience of the TRR journal. With the proposed RUICS method, transportation practitioners are better equipped with a new analysis tool that can be used to appropriately evaluate a shared street environment.

As aforementioned, the in-depth analysis of one shared pedestrian and vehicle street is considered by the authors to be sufficient to demonstrate the safety analysis method, and, at the same time, challenge the conventional thinking about traffic conflicts in the context of shared spaces. Furthermore, the detailed RUICS investigation of the Elliott Street area presented in this paper is comparable with the UK study that analysed pedestrian-vehicle traffic conflicts in one single site of Exhibition Road.²

Regarding the counting of road users, the RUICS analysis considered the users that involved in the interactions (and conflicts), exclusively within the area that is defined

² Kaparias, I., M.G.H. Bell, W. Dong, A. Sastrawinata, A. Singh, X. Wang and B. Mount. Analysis of Pedestrian-Vehicle Traffic Conflicts in Street Designs with Elements of Shared Space. In *Transportation Research Record: Journal of Transportation Research Board*, Transportation Research Board of the National Academies, Washington, D.C., 2013. (In Print)

in Figure 2. As described in the RUICS sub-section in the ‘Safety Analysis Methods’ section, an interaction involves a vehicle interacting with one or more pedestrians exclusively within the vehicle travelling area (as illustrated in Figure 2). It is acknowledged that indicating the total numbers of vehicles and pedestrians that were observed may add value to the understanding of the study. However, given the word limit of 7,000 (excluding references), the reference and discussion of the total user numbers observed have not been included.

We believe the revised paper with the above responses satisfactorily addresses the reviewers’ concerns. We look forward to hearing from you with regards to the TRR journal publication recommendation.

Yours sincerely

Auttapone (Aut) Karndacharuk
Principal Consent Specialist
(Corresponding author on behalf of all authors)

CC: Dr Doug Wilson and AP Roger Dunn

A3 Conference Paper Abstracts

A3.i) IPENZ conference abstract dated March 2014

CONFERENCE PAPER

OPERATIONAL GUIDELINES AND PRINCIPLES FOR SHARED ZONES IN NEW ZEALAND

AUTHORS

Auttapone (Aut) Karndacharuk BE(Civil), ME(Civil, Hons), MIPENZ, CPEng
Principal Consent Specialist, Auckland Transport
Email: auttapone.karndacharuk@aucklandtransport.govt.nz

Martin Peake MEng(Civil with management, Hons), CEng, MICE, MCIHT (Presenter)
Traffic Operations Team Leader, Auckland Transport
Email: martin.peake@aucklandtransport.govt.nz

Dr Douglas James Wilson NZCE, BE(Civil, Hons), PhD, MIPENZ, PIARC, REAAA
Senior Lecturer in Transportation Engineering, The University of Auckland
Email: dj.wilson@auckland.ac.nz

ABSTRACT

Expectations are increasing for public road space to integrate pedestrian and social activity into the underlying transport functions. This has led to several shared space schemes within Auckland that re-designed the road reserve to provide a sense of place, enhance priority for pedestrians and encourage greater use of the road space rather than solely as a transport infrastructure asset.

While the terms 'Shared Space' and 'Home Zone' are applied to a shared pedestrian and vehicle street in mixed-use and residential areas, respectively, both concepts are declared a Shared Zone in the Land Transport (Road User) Rule.

Auckland Transport (AT) has identified the need to provide guidance to designers of shared spaces to ensure consistent public expectations. AT has reviewed existing and proposed shared zones in both activity centres and residential areas.

The paper will discuss outcomes from a University of Auckland research study into the operation of shared spaces. The paper will detail key design principles for the effective operation of shared spaces and home zones developed by AT for the Auckland Transport Code of Practice (ATCOP). The principles from this code of practice for shared zones can be applied to other New Zealand regions.

A3.ii) NZTA & NZIHT conference abstract dated November 2010

**DEVELOPMENT OF PERFORMANCE EVALUATION
FRAMEWORK FOR SHARED SPACE SCHEMES IN
NEW ZEALAND**

Authors

Auttapone (Aut) Karndacharuk BE(Civil), ME(Hons), MIPENZ, CPEng
Traffic Engineer, Auckland City Council
Email: aut.karndacharuk@aucklandcity.govt.nz

Dr Douglas James Wilson NZCE, BE(Civil, Hons), PhD, MIPENZ, PIARC, REAAA
Senior Lecturer, the University of Auckland
Email: dj.wilson@auckland.ac.nz

Presenter: Aut Karndacharuk

ABSTRACT

A number of streets are being transformed by Auckland City Council to Shared Spaces with a level surface in preparation for the Rugby World Cup 2011. The schemes are largely driven by the CBD Projects and Urban Design teams in order to create high quality urban public spaces for people and improve local economic development. Transport planning and traffic engineering measures and principles are key factors in the process e.g. the improvement of pedestrian service levels and reduced vehicle speeds whilst maintaining accessibility.

A shared space in effect is a road corridor in an urban environment with the minimisation, or frequently the absence of, the use of traffic regulations and control devices such as signage, road marking and physical demarcation. This allows pedestrians and drivers in vehicles to occupy the same public space in an equitable and integrated manner. Shared space schemes in other countries have been subjectively observed to enhance cooperative behaviour of all space users, improve the environmental quality of space, reduce vehicular speed and dominance, and introduce a wider range of pedestrian and community activities.

This paper discusses the concept of Shared Space within the New Zealand context and presents a literature review, including the consideration of the distinct 'Place' function of the urban transport corridor. The concept also aims to significantly enhance pedestrian priority and amenity while reducing the dominance of motor vehicles within the road space.

The research includes 'before and after' case studies in Auckland City, of the shared space projects for Elliott, Lorne and Fort street areas. A data collection process has been developed to capture the existing and future road environments, including pedestrian and vehicle activity within the road corridor and their effects to the wider network. It is proposed to identify and assess a range of key performance indicators using both qualitative and quantitative methods.

This study between Auckland City Council and the University of Auckland seeks to provide research-based evidence of how a shared space performs, and is expected to form the basis of design guidelines and a methodological framework to assess and evaluate the performance and perception of shared space schemes both internationally and in New Zealand.

NZTA & NZIHT 11th Annual Conference, Christchurch – November, 2010

A3.iii) IPENZ conference abstract dated March 2011

TECHNICAL PAPER

**SHARED SPACE PERFORMANCE EVALUATION:
QUANTITATIVE ANALYSIS OF PRE-IMPLEMENTATION DATA**

AUTHORS

Auttapone (Aut) Karndacharuk BE(Civil), ME(Hons), MIPENZ, CPEng (Presenter)
Principal Consent Specialist, Auckland Transport
Email: auttapone.karndacharuk@aucklandtransport.govt.nz

Dr Douglas James Wilson NZCE, BE(Civil, Hons), PhD, MIPENZ, PIARC, REAAA
Senior Lecturer, The University of Auckland
Email: dj.wilson@auckland.ac.nz

Mitch Tse NZCE, CTPMC(NSW), REA
Principal Traffic Signal Engineer, Auckland Transport
Email: mitchell.tse@aucklandtransport.govt.nz

ABSTRACT

This paper discusses Shared Spaces within the New Zealand context and presents a literature review, including the consideration of the distinct 'Place' function of the urban transport corridor. The concept also aims to significantly enhance pedestrian priority and amenity while reducing the dominance of motor vehicles within the road space in appropriate locations.

The scope of research includes 'before and after' case studies of the shared space projects in Elliott, Lorne and Fort Street areas in the Auckland Central Business District (CBD). A data collection process has been developed to quantitatively capture the existing and future road environments, including pedestrian and vehicle activity within the road corridor. This paper will discuss the key performance indicators that have been developed, and presents early outcomes of the data analysis based on the 'before' quantitative data.

This study collaboration between the University of Auckland and Auckland Transport (which is an Auckland Council controlled organisation) seeks to provide research-based evidence of how a shared space performs, and is expected to form the basis of design guidelines and a methodological framework to assess and evaluate the performance and perception of shared space schemes both internationally and in New Zealand.

A3.iv) IPENZ conference abstract dated March 2014

CONFERENCE PAPER

**A QUALITATIVE ANALYSIS OF CBD SHARED STREET SPACES
USING PERCEPTION SURVEYS**

Benjamin Wilshire
Graduate Engineer – Fulton Hogan
Email: Benjamin.Wilshire@gmail.com
Presenter and Primary Author

Dr Douglas James Wilson NZCE, BE(Civil, Hons), PhD, MIPENZ, PIARC, REAAA
Senior Lecturer in Transportation Engineering, The University of Auckland
Email: dj.wilson@auckland.ac.nz
Second Author

Auttapone (Aut) Karndacharuk BE(Civil), ME(Civil, Hons), MIPENZ, CPEng
Principal Consent Specialist, Auckland Transport
Email: auttapone.karndacharuk@aucklandtransport.govt.nz
Third Author

ABSTRACT

The shared space concept is one response to the realisation of the adverse environmental and social impacts of designing streets primarily for vehicle priority. While the concept has been used internationally for some time, it has only been recently introduced to New Zealand, and there does not yet exist a framework to monitor and evaluate the effectiveness of shared spaces in a New Zealand context. This paper reports upon a Bachelor of Engineering (Civil) final year research project that formed part of a doctoral research programme at the University of Auckland and included collecting and analysing the qualitative data required to develop the shared space evaluation framework.

Interviews were conducted with industry professionals from the fields of Planning, Urban Design, and Transportation Engineering, and user perception surveys were conducted on-site with pedestrians at Elliott Street, Lorne Street, Fort Street (three Auckland CBD shared spaces), and O'Connell Street (a conventional control street) in the Auckland CBD area. The research demonstrated that the shared spaces are performing well, but the Lorne Street space has some potential for improvement. It was also found that different professional experience influenced designers' perspective on some key elements of shared space design and operation.

The research concluded that the main factors influencing the shared spaces in Auckland are land usage, street design, traffic volumes, and operational policies.

IPENZ Transportation Group Conference, Shed 6, Wellington – 23 – 26 March, 2014

A4 Auckland Transport Memorandum on Shared Space Design Principles

Memorandum



To: Shared Space Steering Group
 From: Aut Karndacharuk, Road Corridor Operations
 Date: 1 May 2013
 Subject: Operational Guiding Principles for Shared Space Design

1. Purpose

This document provides a set of operational principles for the creation of a shared space scheme. The aim of these principles is to ensure that a level of consistency is delivered throughout all of the shared space schemes in Auckland. The principles have been developed in consultation with stakeholders including Road Corridor Operations, Parking and Enforcement, Investigation and Design and Infrastructure Development (CBD Streetscapes) departments.

It is intended that designers and policy makers should utilise these principles in developing schemes to understand Auckland Transport's requirements for the operation of a shared space. It is also expected that shared space designs will be reviewed against the principles to ensure they incorporate the key elements outlined so that there is consistency in operation between spaces and that the operational aims are achieved through effective and appropriate design. Designs through all stages of a project from concept to detail design should be developed with close consultation and input from key Auckland Transport stakeholders, particularly Road Corridor Operations.

Although this document is developed for projects within the legal road reserve, adoption of the principles to other spaces would be advantageous so that the public is provided with consistency and clear legibility of shared space across the region.

2. Shared Space Overview

Even though the recent surge of the use of the term 'Shared Space' and its applications in New Zealand is largely influenced by the work of a European Shared Space project (2004-2008) and the UK's Department for Transport (2009-2011), the concept of various street users sharing the same public road space is not new. The first Shared Spaces were developed after the pinnacle of the automobile era in the 1960s. Their creation can be traced back to the philosophical concept of an 'environment area' in the Traffic in Towns (1963); commonly known as 'the Buchanan Report'. The theoretical construct for road user integration, especially between vehicle and pedestrian, was first embodied in the form of a residential shared street in the Netherlands ('Woonerf'). The concept was recognised by the Netherlands government with legal status and formal traffic guidelines and regulations. The typical design and operational characteristics for a residential shared space (or 'Home Zone') can be summarised as follows:

- Pedestrians have priority to use the full width of the road. Drivers are urged not to drive faster than walking speeds.

- There is little demarcation between carriageway and footpath, including the minimisation of signage and road marking. The entire width is often constructed in a continuous surface with special pavers.
- Through vehicular traffic is discouraged. Vehicle dominance (speed and volume) is restricted by street design (e.g. horizontal curves, bollards and parking layout).
- Streetscape elements are designed to promote people to stay within the space.
- The access points to the shared street are clearly marked.

With these vehicular restraining features to enhance liveability in residential neighbourhood environments, the Woonerf idea swept through Europe in the 1970s. Its design guidelines for shared spaces were adopted in many countries, and extended to town centres and shopping areas. The same concept also evolved into traffic calming principles and Local Area Traffic Management. Although there are different, but comparable design approaches (e.g. liveable streets, self-explaining roads, civilised streets, road diet and context-sensitive designs) used to emphasise the place function and the need to reduce the vehicular dominance within the road reserve, a shared space is distinguished from these by its aim to remove the segregation between vehicles and pedestrians (e.g. omitting vertical kerbs or distinct surface materials and eliminating/reducing road markings and signage).

The concept of different street users sharing the same public road space is not new, but the idea of encouraging the mixing of slower-speed, smaller-mass pedestrians with higher-speed, larger-mass vehicles is no doubt novel, particularly after the widespread automobile domination in public road space. The renewed interests of the Shared Space concept reaffirm the multi-faceted functions of a public street, including the place function as well as the shifting public demand and expectations away from the automobiles towards sustainable and safe transport.

A shared space in New Zealand is declared a 'Shared Zone' in accordance with the Land Transport (Road User) Rule. The interaction between different users in a shared zone in an equitable manner is reflected in the following road rule:

The Land Transport (Road User) Rule 2004 defines a shared zone as:

10.2 Shared zone

- (1) A driver of a vehicle entering or proceeding along or through a shared zone must give way to a pedestrian who is in the shared zone.*
- (2) A pedestrian in a shared zone must not unduly impede the passage of any vehicle in the shared zone.*

This is further reflected in the Auckland Transport Bylaws which states that in Shared zones:

13 Shared Zones

- (1) Auckland Transport may by resolution specify any road to be a shared zone*
- (2) Except where Auckland Transport has by resolution specified otherwise, no person may stand or park a vehicle in a road specified as a shared zone.*
- (3) A person must not use a shared zone in a manner contrary to any restriction made by Auckland Transport.*

Shared space is just one urban design outcome amongst many other tools that can be used in a space. It may not always be the best solution and is not necessarily appropriate to be implemented in all locations or situations. The objectives of the project should be carefully identified prior to selecting shared space as the solution, with clear consideration given to the context of the street being upgraded, the requirements for place-making and

the need to accommodate the movement of people (pedestrians, cycles, motor vehicles, loading etc.).

3. Design Principles

The operational design principles have been developed to:

- Provide details of fundamental aspects that should exist in the environment of the shared space to maximise the chances of the space operating successfully.
- Ensure commonality and legibility for the end user so that they easily understand that the area is a shared space and what is expected of them irrespective of the location.

It is not intended that common materials or design be used in each shared space, simply that the principles are applied for the ease of each particular user to assist them in understanding the environment.

Given the aforementioned overview, it is important to recognise that this document is intended for shared spaces within the public road space (as opposed to open space or private area) where all road users (including pedestrians, cyclists, vehicles and the disabled) are encouraged by design to legally occupy, interact and share the same public space. If shared space is used outside of the legal road reserve, it would be beneficial to adopt these principles to assist in providing a coordinated and consistent approach throughout the region.

The following provides the key design principles that shall be considered for new or modified shared space schemes:

1. The distinct street design must be context-sensitive, taking into account the surrounding land use and the complementary street functions of economic, social, cultural, historical and environmental amenity.
2. Designers should identify the range of movement and activities that the space is expected to provide for at different times of the day, and give due regard to changes of use between day time and night time operation. Layout and streetscape features should be provided to meet these intentions and to enable appropriate use of the street space, such as outdoor dining.
3. The scheme should generally attempt to limit vehicular volumes, dominance and speed. Traffic calming measures, such as lateral shifting of horizontal alignments, and street closures, can be employed to restrict vehicular movements and speeds. Based on the walking speed criteria, the recommended design speed should be 10km/h; designers need to demonstrate how such speed is achieved. It is desirable to have a posted speed limit of 10km/h to reinforce to motorists the requirement for slow speeds.
4. Based on the AT research publication for town centre areas, the influence of pedestrian density on reducing vehicular speeds is most effective in the zone with the highest active land use frontage. Active frontage can be defined as the distance along a property boundary that provides the opportunity for people movement into and out of buildings, along and across the street or for street activity (such as street dining). Schemes should generally only be considered where there is a significant proportion of active street frontage along the street or where there are significant pedestrian movements within the street, both laterally and transversely. These characteristics help to lower vehicle speeds and limit the dominance of motor vehicles in the space. Where active frontage is limited, designers need to consider if the street is appropriate for shared space.

5. The design should clearly indicate where motorists should not drive and (where permitted) should not park. The layout should ensure drivers are not given the impression of priority over other road users when using the vehicle zone. The design should consider not only the preferred movement and occupying spaces for vehicles and pedestrians, but also the likely behaviour of the full range of users. The requirement for vehicles to make reverse manoeuvres within the space should be avoided where possible for safety and to reduce the risk of vehicles damaging street furniture.
6. Parking should generally be avoided within a shared zone. Loading within the shared zone may be required where there are no alternatives. In such cases, this should be limited to only a short period of the day so as to minimise conflicts with other users when the space is most used by pedestrians.
7. To cater for the visually impaired, mobility impaired and other vulnerable road users (including young and old), a safe accessible (vehicle free) zone on either side of the street, clear of obstacles and street furniture, with a minimum width of 1.8m is required. A minimum 600mm wide tactile delineator band between the safe accessible zone and adjacent areas is recommended to warn users about the possibility of street furniture and moving vehicles.
8. Street cross-sections will tend to be individual and differ from conventional streets. Therefore, special attention needs to be given to drainage, to meet serviceability for pedestrians and to avoid flood risk. There may be opportunities to combine water quality treatment devices such as rain gardens with streetscape features. Road drainage design should follow the AT Stormwater Governing Principle and ATCOP design guidance. Where possible, reliance on long lengths of drainage channels or gratings should be avoided as these can be interpreted by users, particularly motorists, as defining the edge of a carriageway. This can lead to higher than desirable vehicle speeds.
9. Designs will typically consist of a level surface continuous across the road reserve without an obvious or no vertical elevation difference (i.e. kerb) between what would normally be the road carriageway and the footpath areas. Similar paving materials and colours between the vehicle zone and the rest of the street space should be used to promote pedestrian movements over the full width of the street environment.
10. Street furniture (such as trees, art works, bollards, lighting) should be used to define the various zones within the shared space, act as traffic calming (speed and traffic volume reduction features) and provide functional aspects, such as seating, drainage or lighting. Furniture shall be strategically placed so as to reduce the appearance of the street to motorists as a straight linear feature in order to encourage slower speeds. The size, nature and placement of street furniture shall be such that it minimises the risk of being struck by a vehicle, particularly for any manoeuvring vehicle, by maximising visibility to the object at the driver's eye height. Visibility around the space should be maintained so there are no hiding places which may mask pedestrians from motorists (and vice versa) or result in CPTED (Crime Prevention Through Environmental Design) issues.
11. Choice of materials and street furniture shall be selected to enable cost effective and practical maintenance. Bespoke furniture for a scheme should ideally be avoided as this delays the replacement of the particular item and can significantly increase future maintenance costs.
12. The entry and exit points to the zone should be clearly marked in accordance with the Traffic Control Devices Manual. A gateway treatment should be implemented at the zone transition. This should include clear and unobscured regulatory signage at a height that is readily visible when entering the zone from all directions. It should be made clear to all road users, by design as well as signage, when they

are entering or leaving a shared zone. This should include points within the zone where significant numbers of path users enter the zone, from a walkway, public space or major destination. All necessary TGSIs (Tactile Ground Surface Indicators) should be provided at the entry and exit points to ensure these zones are safe and accessible for all users.

13. Traffic Control Devices (signs and road markings) should be used sparingly or avoided within the zone itself. The design should be self-evident as far as possible to reduce the need for such devices.
14. Any scheme should be accompanied by extensive education of the public to enable them to appreciate what is expected of them when using a shared space and how to behave. Design consistency of the fundamental aspects is essential to ensure users recognise the characteristics of a formal shared space when moving from one area to another. Streets should not be designed to have the look and feel of a shared space if it is not proposed to formally be designated as a Shared Zone.

4. Approval Process

It is recommended that any new shared space proposal (including those of private development to be vested as public road) should be reviewed and developed with input from Road Corridor Operations and Road Corridor Maintenance at concept stage and throughout the development of the proposal.

The design should be approved by Auckland Transport's Traffic Control Committee *before* implementation to ensure that the scheme is compliant with the above criteria, or where it departs, that this departure is approved.

5. Monitoring

It is expected that the project sponsor will ensure that the project will be monitored post implementation and ensure that there is an allocated budget to provide any modifications or fine tuning to address operational or safety issues. This is essential as both New Zealand and overseas experience has demonstrated that schemes rarely operate completely satisfactorily when first opened.

6. Additional Notes

6.1 Home Zone

For a residential shared space (i.e. home zone), another key aspect of the design considerations are inputs from the residents and local communities. Unlike a shared space in an activity centre that caters for a high number of street users, the success of a home zone predominantly depends upon the community it serves. The community involvement in the design development process will foster the sense of ownership in utilising and maintaining the public (road) space. For new development, where there is no existing community to share in design, the designer should take account of the type of homes to be provided or permitted, and the character of the community that can be expected to occupy them.

6.2 Pedestrian Mall


A pedestrian mall should be considered in place of a shared zone where there are overwhelming number of pedestrians (in comparison to motor vehicles) and the majority of them dwell within the road space (i.e. utilise the street for a place function).

A5 Academic Posters

A5.i) Poster presented at the TRB 92nd Annual Meeting, Washington, DC, January 2013

An Analysis of Pedestrian Performance in Shared Space Environments

Auttapone (Aut) Kamdacharuk, Douglas J. Wilson, Roger C. M. Dunn



Introduction

Background
The concept of Shared Space aims to reduce the dominance of the motor vehicle by promoting pedestrian and cyclist activity and utilising the road space as a place. Unlike a conventional road, a shared space encourages all road users to legally occupy the same road space with little physical separation. This study investigates three shared spaces in Auckland, (New Zealand's largest city).




FIGURE 1 Auckland CBD shared space (Elliott Street).

The cross-section of the shared space is relatively flat without an elevation difference with the use of a 600mm wide tactile delineator to assist the visually impaired.

Study Methodology

Pedestrian Performance Indicator
Pedestrian performance in a shared space can be measured by considering how well a pedestrian activity contributes towards fulfilling shared space objectives. Shared space objectives identified in this research are place(making), pedestrian (focus), vehicle (behaviour change), economic (impetus) and safety (for all users).

Objective	Key Performance Indicator	Unit	Data source
Place	Pedestrian Occupancy Ratio	%	Video survey
	User dwell time	min	Video survey
Pedestrian	Pedestrian density	p/m ²	Video survey
	Pedestrian trajectory		Video survey
Vehicle	Motor vehicle speed	km/hr	Traffic counter
	Motor vehicle volume	veh/hr	Traffic counter
Economic	Active frontage	m	Measurement
	User accessing adjacent land use	plu/rm	Video survey
Safety	User conflict	# of conflicts	Video survey
	Reported crash history	# of crashes	CAS database

TABLE 1 Shared space key performance indicators and data sources.

Data Acquisition Methods

The data collection methods include video surveys, traffic tube counters and crash history. Three road sections in Auckland's city centre, which have been transformed into a shared space are used for the analysis. Figure 3 below illustrates the video camera setup for the Fort Street area.

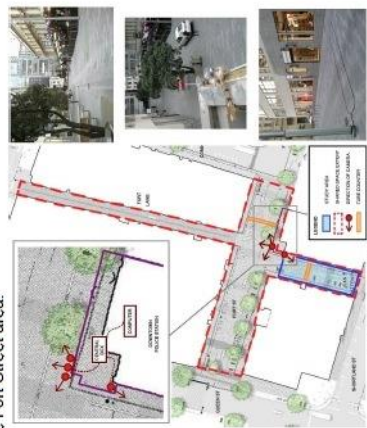


FIGURE 3 Data collection for the Fort Street area.

Place Function for Urban Streets

A shared space serves the Place function along with the two more conventional transport functions of Mobility and Access.

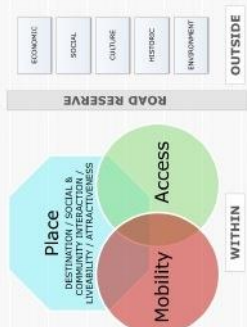


FIGURE 2 Urban street functions within and outside the road reserve.

Data Analysis and Result

Pedestrian Performance
The 'before and after' analysis and processing of pedestrian data for each site from both macro to micro time periods are described below. The analysis reveals a positive result for pedestrian performance across all sites.

a) 24-hour profile: video footage was examined for every 15min interval over a 24hr period. The pedestrian data was classified into two groups: One is Pedestrian Movement (PM) and the other is Pedestrian Occupancy (PO) i.e. remaining still within the time period. A review of a 10sec period before and after the 15min snapshot was used to differentiate the two groups.

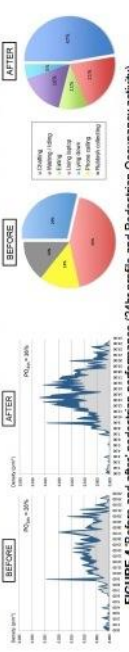


FIGURE 4 'Before and after' pedestrian performance (24hr profile and Pedestrian Occupancy activity).

b) 15-min peak zone: a peak period of 15min was identified from the 24hr profile. The analysis zone was approximately 40m in corridor length. Pedestrians (both PM and PO) within the zone were observed at the beginning, 5th, 10th and 15th minute slices of the peak period.

Pedestrian Density vs Vehicle Speed

The 'after' data of pedestrians and vehicles for the three streets was quantitatively examined. An inverse relationship can be observed for all sites during the daytime period (8am-6pm). The greater the value of the normalised pedestrian densities, the less the value of the mean vehicle speeds.

Out of the three sites, the Elliott Street section has the strongest correlation ($R^2 = 0.87$) between the two parameters. This reflects its highest portion of active land-use frontage on both sides of the road¹

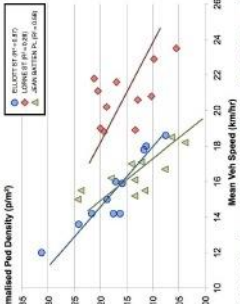


FIGURE 5 Pedestrian density vs vehicle speed for the three sites.

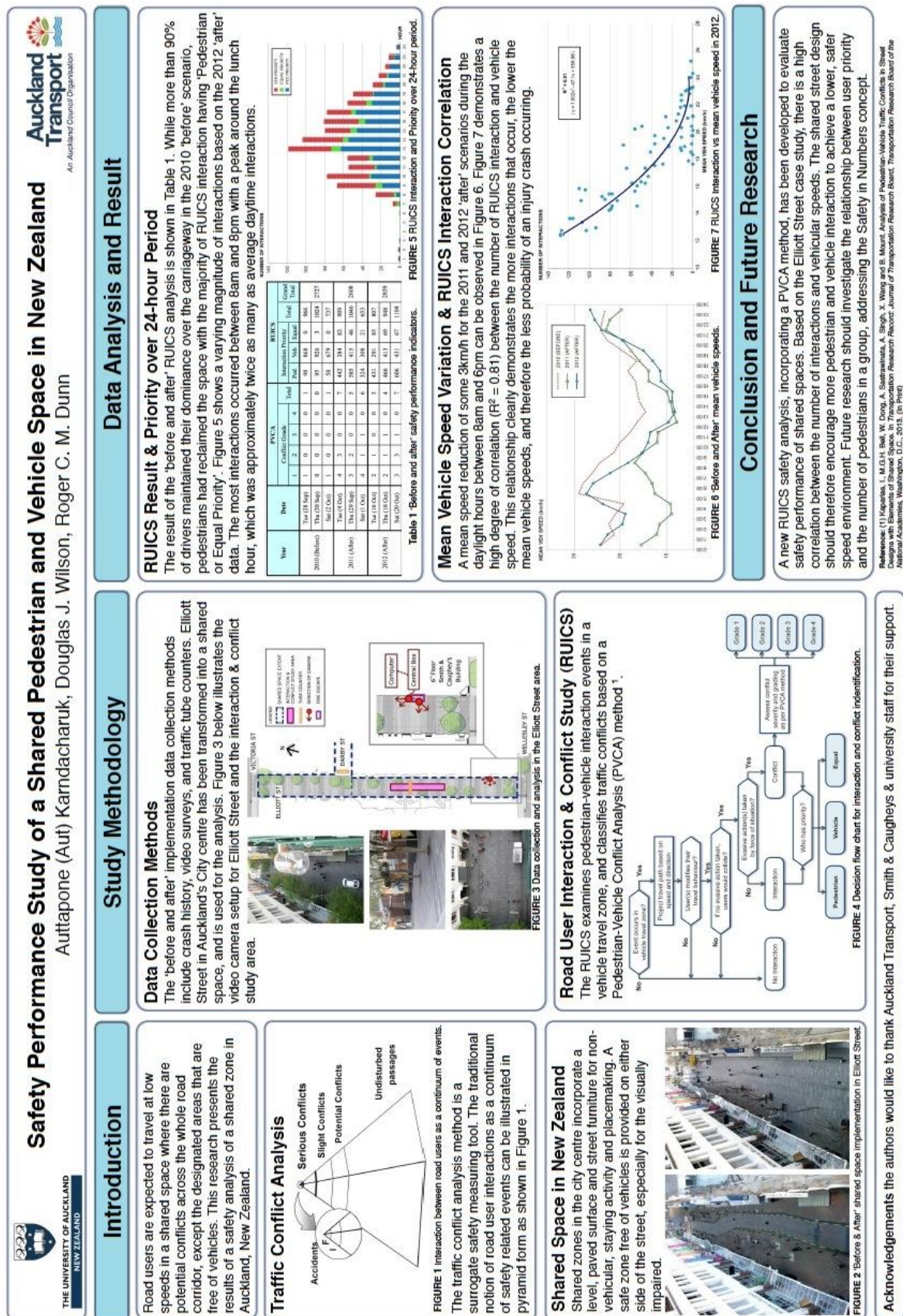
(1) Kamdacharuk, A. D. Wilson and M. T. Dunn. Shared Space Performance Evaluation: Quantitative Analysis of Pre-Implementation Data. IPENZ Transportation Group Conference, Auckland, 2011.

Conclusion and Future Research

Based on the 'before and after' data analysis of the three streets in Auckland CBD, the shared space design enables a public street to better perform the place function with enhanced priority for pedestrians. The comparison of the 'after' data indicates vehicle speeds decrease when pedestrian density increases in shared zones. Further research tasks involve a detailed safety analysis and quantitative performance evaluation.

Acknowledgements the authors would like to thank Auckland Transport for their support along with NZ Police, Smith & Caughney's, Auckland Council and university technical staff for video survey assistance.

A5.ii) Poster presented at the TRB 93rd Annual Meeting, Washington, DC, January 2014



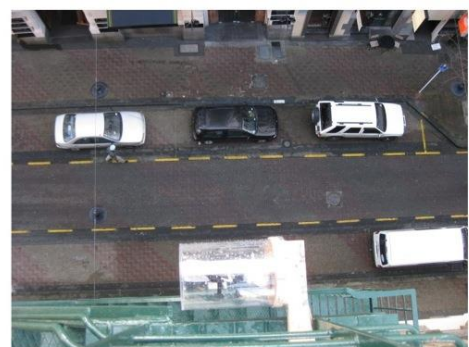
Acknowledgements the authors would like to thank Auckland Transport, Smith & Caughneys & university staff for their support.

A6 List of Presentations to Technical / Learned Society Meetings

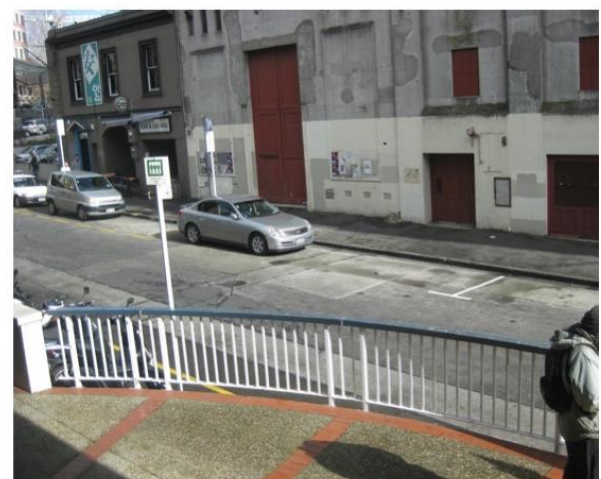
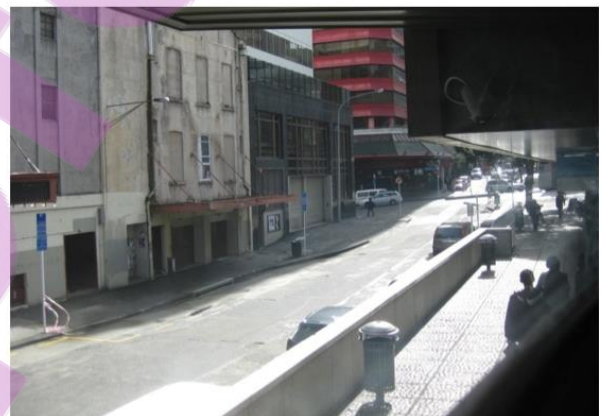
- Auckland Transport Traffic Operations Central Team Meeting, 28 February 2013
- Auckland Transport Shared Space Workshop, 1 March 2013
- Brashier Circle (26-30) Residential Shared Zone, Auckland Transport Traffic Control Committee, 14 May 2013
- Auckland Transport Mentoring Lunchtime Talk, 20 May 2013
- Long Bay – Precinct 3, Auckland Council / Auckland Transport Street Design Workshop, 10 June 2013
- IPENZ Transportation Group Technical Meeting, 6 August 2013
- Auckland Transport Traffic Operations Planning Day, 20 August 2013
- Auckland Council / Auckland Transport Shared Space Workshop, 4 December 2013

Appendix B: Quantitative Data Collection

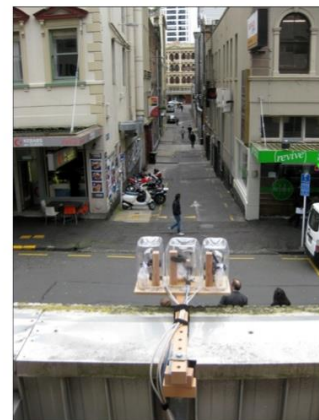
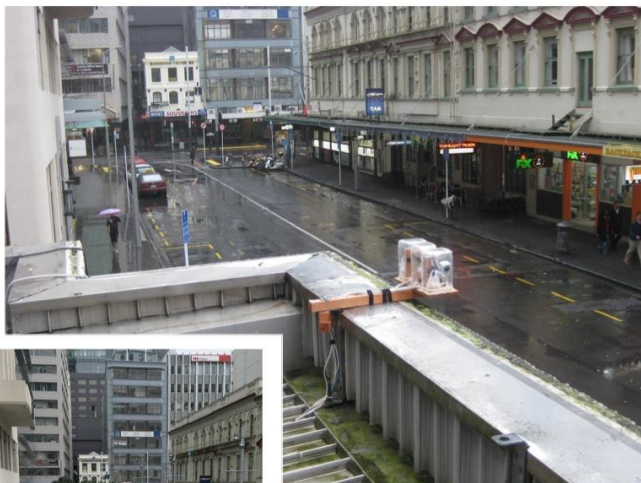
B1 Elliott Street Video Surveys and Traffic Counts



B2 Lorne Street Video Surveys and Traffic Counts



B3 Fort Street Video Surveys and Traffic Counts



Appendix C: Qualitative Data Collection

C1 University of Auckland Ethic Approvals

Office of the Vice-Chancellor
Research Integrity Unit

The University of Auckland
Private Bag 92019
Auckland, New Zealand

Level 10, 49 Symonds Street
Telephone: 64 9 373 7599
Extension: 87830 / 83761
Facsimile: 64 9 373 7432

UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE

05-Aug-2013

MEMORANDUM TO:

Dr Douglas Wilson
Civil & Environmental Engineer

Re: Application for Ethics Approval (Our Ref. 7342)

The Committee considered your request for change for your project titled **The Development of a Multi-Faceted Evaluation Framework of Shared Spaces** on 05-Aug-2013.

The Committee approved the following amendments:

1. To change the project title from 'Performance Evaluation Framework of Shared Space Schemes in New Zealand' to 'The Development of a Multi-Faceted Evaluation Framework of Shared Spaces'.
2. To add two undergraduate engineering students to the project Ben Wilshire and Michael Wu. They will assist the PhD student in undertaking the perception surveys and qualitative performance analysis.
3. To change the survey method used from a web based questionnaire to an expert interview on the topics of placemaking, pedestrian focus, vehicle behaviour change, economic impetus and safety for all users and an on street survey in general accordance with original application.

The expiry date for this approval is 30-May-2014

If the project changes significantly you are required to resubmit a new application to the Committee for further consideration.

In order that an up-to-date record can be maintained, it would be appreciated if you could notify the Committee once your project is completed.

The Chair and the members of the Committee would be happy to discuss general matters relating to ethics approvals if you wish to do so. Contact should be made through the UAHPEC secretary at humanethics@auckland.ac.nz in the first instance.

All communication with the UAHPEC regarding this application should include this reference number: **7342**.

(This is a computer generated letter. No signature required.)

Secretary
University of Auckland Human Participants Ethics Committee

c.c. Head of Department / School, Civil & Environmental Engineer



Office of the Vice-Chancellor
Research Integrity Unit



**UNIVERSITY OF AUCKLAND
HUMAN PARTICIPANTS ETHICS COMMITTEE**

Level 3, 76 Symonds Street
Telephone: 64 9 373 7599
Extension: 83711 / 87830
Facsimile: 64 9 373 7432

02 June 2011

MEMORANDUM TO:

Dr Douglas Wilson / Auttapone (Aut) Karndacharuk
Civil and Environmental Engineering

Re: Application for Ethics Approval (Our Ref. 2011 / 271)

The Committee considered your application for ethics approval for your project titled "Performance Evaluation Framework of Shared Space Schemes in New Zealand" on 30/05/2011.

Ethics approval has been given for a period of three years.

The expiry date for this approval is 30/05/2014

If the project changes significantly you are required to resubmit a new application to the Committee for further consideration.

In order that an up-to-date record can be maintained, you are requested to notify the Committee once your project is completed.

The Chair and the members of the Committee would be happy to discuss general matters relating to ethics approvals if you wish to do so. Contact should be made through the secretary in the first instance, Lana Lon, l.lon@auckland.ac.nz.

All communications with the UAHPEC regarding this application should include our reference number - 2011 / 271.

A handwritten signature in black ink, appearing to read "Lana Lon".

Lana Lon
Secretary
University of Auckland Human Participants Ethics Committee

c.c. Head of Department / School, Civil and Environmental Engineering


Auttapone (Aut) Karndacharuk
Apt 3i / 23 Emily Place
CBD
Auckland

Additional information:


1. Should you need to make any changes to the project, write to the Committee giving full details including revised documentation.
2. Should you require an extension, write to the Committee before the expiry date giving full details, along with revised documentation. An extension can be granted for up to three years, after which time you must make a new application.

C2 On-Street Perception Survey Documentation

C2.i) On-Street Perception Survey Design



Auckland Transport
An Auckland Council Organisation



THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

The Development of a Multi-Faceted Evaluation Framework of Shared Spaces

Sheet A : On-Street Perception Survey

Please circle the option best describes your opinion towards the following five statements.

	Strongly Disagree	Disagree	Tend to Disagree	Tend to Agree	Agree	Strongly Agree
	-3	-2	-1	1	2	3
1) "I like spending time in this street"	-3	-2	-1	1	2	3
2) "I can freely move around on this street"	-3	-2	-1	1	2	3
3) "Driver behaviour is appropriate in this street"	-3	-2	-1	1	2	3
4) "This street complements the economic activity"	-3	-2	-1	1	2	3
5) "I feel safe and secure in this street"	-3	-2	-1	1	2	3

Please further provide us with your impression about this street space and your background information

6) Of the five statements above, which are the most important (.....) and least important (.....) ?

7) Of the five statements above, which do you feel could be most improved, and why?

.....

8) What, in particular, do you like most about this street space?

.....

9) How often do you visit this street?

☐ First visit / Very Infrequently
☐ Around once a month

☐ Around once a week
☐ Multiple times a week


10) Why have you visited this street today? (e.g. passing through, shopping or eating)

.....

11) Age: ☐ Under 20 ☐ 20 – 34 ☐ 35 – 49 ☐ 50 – 65 ☐ Over 65

12) Gender: ☐ Male ☐ Female

13) Ethnic group: ☐ NZ European ☐ Maori / Pacific Islands ☐ Asian
 ☐ Other



The Development of a Multi-Faceted Evaluation Framework of Shared Spaces

Sheet B : Survey Information and Observations

- i) Site: ☐ Elliott St ☐ Lorne St ☐ Fort St ☐ O'Connell St (Control Street)
- ii) Surveyor(s):
- iii) Date:
- iv) Survey period (start / finish):
- v) Weather & temperature:
- vi) Number of refusal to participate:
- vii) Participant classification:
 Pedestrian Movement (PM):

 Pedestrian Occupancy (PO):
- viii) Number of vulnerable road users:
- | | |
|-----------------|----------------------|
| Child: | <input type="text"/> |
| Elderly: | <input type="text"/> |
| Disabled: | <input type="text"/> |
| Cyclist: | <input type="text"/> |
- ix) Any additional information / observations:

C2.ii) On-Street Perception Survey – Participant Information Sheet**Participant Information Sheet (On-Street Survey)****The Development of a Multi-Faceted Evaluation Framework of Shared Spaces**

Dear Participant

Researcher Introduction

My name is Auttapone Karndacharuk. I am a University of Auckland Doctor of Philosophy (PhD) degree student. Ben Wilshere and Michael Wu, both 4th year engineering students, will be assisting me in the perception survey process. Our main supervisor is Dr Douglas Wilson in the Department of Civil and Environmental Engineering of the University of Auckland.

Project Invitation and Description

You are invited to participate in our research and I would appreciate any assistance you can offer. This perception (on-street) survey forms part of the qualitative evaluation of the research that aims to develop an evaluation framework of shared space schemes. You have been systematically selected as the 5th person seen walking through the space.

Auckland Council and Auckland Transport have transformed a number of Auckland CBD streets into 'shared spaces', including Elliott, Lorne and Fort Street areas. In a shared space, all road users (e.g. pedestrians, cyclists and vehicles) can share the same public road space without obvious physical separation.

Project Procedures

We would like to invite you to participate in an anonymous five-minute questionnaire about your opinion on various aspects of the shared space. The questionnaire is made up of two parts; one involves closed-ended questions with answers (6-point rating scale) you can circle and the other open-ended questions where you can write a short answer. There is also a short demographics section, where we ask for you to outline your sex, age group, and ethnic origin, for filtering purposes. No information which could identify you as its source will be elicited.

Right to Withdraw from Participation

You have the right to withdraw from participation at any time during the survey. However, because the survey is anonymous, it will not be possible to withdraw your data after the survey has been submitted.

Data Storage, Retention, Destruction, and Future Use

Your response will be kept in a secure location on University premises for up to six years, after which it will be destroyed (digital files will be purged and any hard copies of information shredded). The analysed responses from this on-street survey may be used in other studies or for publication purposes.

Confidentiality of Responses

Your response to this on-street survey is completely anonymous and confidential. Responses will be kept in a locked file to which only the researchers and supervisor have access. If the information you provide is published, you will not be identifiable as its source.

Contact Details

Thank you very much for your time and help in making this study possible. If you wish to know more about the study, or have any concerns, please email, phone, or write to me at:

Auttapone (Aut) Karndacharuk
Department of Civil and Environmental Engineering
The University of Auckland
Private Bag 92019
Auckland 1142
Phone: +64 27 675 2959
Email: auttapone.karndacharuk@aucklandtransport.govt.nz

My main supervisor is:

Douglas James Wilson
Department of Civil and Environmental Engineering
The University of Auckland
Private Bag 92019
Auckland 1142, New Zealand
Phone: +64 9 923 7948
Email: dj.wilson@auckland.ac.nz

The Head of Department is:

Professor Pierre Quenneville
Department of Civil and Environmental Engineering
The University of Auckland
Private Bag 92019
Auckland 1142, New Zealand
Phone: +64 9 373 7599 ext 87920
Email: p.quenneville@auckland.ac.nz

For any queries regarding ethical concerns you may contact:

The Chair
The University of Auckland Human Participants Ethics Committee
The University of Auckland
Office of the Vice Chancellor
Private Bag 92019
Auckland 1142
Phone: +64 9 3737599 ext 83711

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE
on ...5/08/13... until ...31/05/14..., Reference Number ...7342....

C3 Expert Interview Documentation

C3.i) Expert Interview Script



The Development of a Multi-Faceted Evaluation Framework of Shared Spaces

INTERVIEW SCRIPT

Note to the interviewers: This interview is intended to be, as much as is practical, a free-flowing conversation between the interviewee and interviewer. Depending on the interviewee, and how the interview has commenced, some questions below will be omitted to ensure that adequate time is available to extract the most useful information.

General Questions

None of the questions in this section are to be omitted.

- What are your qualifications?
- What is your main area of expertise?
- How have you personally been involved in the development of shared spaces in New Zealand?
- What do you think a shared space is i.e. how would you define it?
- The doctoral researcher has chosen five main objectives for evaluating shared space schemes, based on overseas literature. These are: Placemaking / Pedestrian Focus / Vehicle Behaviour Change / Economic Impetus / Safety for All Users

Do you believe that these are appropriate objectives for New Zealand shared space schemes?

- If yes, why?
- If not, why not, and what are some alternatives?
- How should these objectives be prioritized?

Objective-Based Questions

When a question evaluates an aspect of the existing shared spaces, the interviewee should enquire into which spaces in particular are performing better or worse (and why) and how that aspect can be improved.

Placemaking

- A major objective of shared spaces is to be an attractive place for all users to be. Do you believe that the shared spaces are attractive?
- Do the current shared space schemes provide adequate street furniture and other facilities?
- Do the current schemes adequately provide for a wider range of street activities?

Pedestrian Focus

- Do pedestrians have adequate freedom to roam the current shared spaces?
- Are the current legal regulations around priority sufficient?

- Should the responsibility of users in a shared space be defined by law?

Vehicle Behaviour Change

- Are drivers currently behaving appropriately in the current shared space schemes?
- What is an acceptable operating speed for the Shared Space Schemes?
 - How should this speed be achieved?
- What capacity for parking should be allowed within a shared space (both in terms of volume, and parking time limits)?
 - If not, how can parking be avoided?
 - In your opinion, are the current shared spaces effective in controlling parking?

Economic Impetus

- Do the existing shared space schemes adequately complement the operation and prosperity of the surrounding businesses?
 - Which spaces are doing particularly well, and which are not?
- How do adjacent land uses affect shared spaces?
 - Are there specific land usage types that contribute more to the success of shared spaces?
- How much active frontage is needed for shared spaces to be successful?
- Does the introduction of a shared space scheme results in benefits for the surrounding businesses?

Safety for All Users

- Do the current shared spaces provide a safe environment for all users?
- Have the mobility and visibility impaired been adequately catered for in the existing shared space schemes?

Additional Questions

- What are the key design components of an effective shared space?
- Do you view the level surface as being a vital component of a shared space scheme?
- Is there an adequate knowledge base in New Zealand to undertake a wider application of the shared space concept?
- Have drivers and other users been adequately educated about shared spaces?
 - If not, how can this be improved?
- Should shared spaces be applied to residential settings in New Zealand?

C3.ii) Expert Interviews – Participant Information Sheet



Participant Information Sheet (Expert Interview)

The Development of a Multi-Faceted Evaluation Framework of Shared Spaces

Dear Participant

Researcher Introduction

My name is Auttapone Karndacharuk. I have enrolled at the University of Auckland for a Doctor of Philosophy (PhD) degree. Ben Wilshere and Michael Wu, both 4th year engineering students, will be assisting me in the interview process. Our supervisor is Dr Douglas Wilson in the Department of Civil and Environmental Engineering.

Project Description and Invitation

You are warmly invited to participate in our research and I would appreciate any assistance you can offer. You have been identified as a professional contact of the researchers who may have knowledge of the shared space concept. We are exploring how road spaces designed as a shared space perform their 'movement, access and place' functions. This research aims to develop a framework in evaluating the performance of shared space schemes, taking into account both qualitative and quantitative performance data.

This expert interview, which relates to the design, operation and impact of shared spaces is part of the qualitative evaluation. You are suitable for this study if you have academic and/or professional background in urban or transport planning, urban design, landscape architecture or transportation engineering in public or private sectors, and have a basis understanding of the shared space concept, or involved in the design, review, implementation, or monitoring of a shared space scheme.

Project Procedures

We would like to invite you to an individual interview session to share your opinions and experience, and to explore how you perceive the effectiveness of the existing three shared space schemes in Auckland's city centre, including Elliott, Lorne and Fort Street areas. The interview session will take approximately 30 minutes and up to one hour.

Since the performance of a shared space can be evaluated by considering how well a street contributes towards fulfilling the shared space objectives, interview questions for each study area will be related to the aim of placemaking, pedestrian focus, vehicle behaviour change, economic impetus and safety for all users. The interview questions are attached.

The interview will be recorded with an audio recorder and will be transcribed verbatim by Michael Wu and Ben Wilshere. You have the opportunity to view your interview script and amend it prior to analysis, if you wish. Your interview script will be provided to you within 10 days of the interview, and you will have 7 days to review and amend it, if you wish to do so.

Right to Withdraw from Participation

You have the right to withdraw from participation at any time. You may withdraw your data from the study at any time for up to one month following the interview.

Data Storage, Retention, Destruction, and Future Use

A digital voice recorder will be used during the interview. Audio recordings will be transcribed and burned onto a writeable disc and kept in a secure location (on the University of Auckland campus) separate from the Consent Forms for up to six years, after which they will be destroyed (digital files will be purged and any hard copies of information shredded). The responses from this interview may be used in other studies such as PhD or undergraduate research projects and may be used for publication purposes.

Confidentiality of Responses

We will keep all responses during the interview session completely confidential. Responses will be kept in a locked file to which only the researchers and supervisor have access. It cannot be completely guaranteed that participant anonymity will be preserved, however the researchers will strive to protect the anonymity of participants at all stages of the research. Individuals' names and other identifying information will be disguised in the research report. The researchers will report what is said, but will not attribute statements to identifiable individuals. All participants, and their employers, will be given the opportunity to review the final report before it is published externally.

Consent for this interview has been sought from your employer/principal. They have consented that any of your opinions expressed in this interview will not affect your employee-employer relationship. Your opinions will represent your own personal opinions, and not necessarily those of your employer/organisation.

Contact Details

Thank you very much for your time and help in making this study possible. If you wish to know more about the study, or have any concerns, please email, phone, or write to me at:

Auttapone (Aut) Karndacharuk
Road Corridor Operations
Auckland Transport
Private Bag 92250
Auckland 1142
Phone: +64 27 675 2959
Email: auttapone.karndacharuk@aucklandtransport.govt.nz

My main supervisor is:

Douglas James Wilson
Department of Civil and Environmental Engineering
The University of Auckland
Private Bag 92019
Auckland 1142, New Zealand
Phone: +64 9 923 7948
Email: dj.wilson@auckland.ac.nz

The Head of Department is:

Professor Pierre Quenneville
Department of Civil and Environmental Engineering
The University of Auckland
Private Bag 92019
Auckland 1142, New Zealand
Phone: +64 9 373 7599 ext 87920
Email: p.quenneville@auckland.ac.nz

For any queries regarding ethical concerns you may contact:

The Chair
The University of Auckland Human Participants Ethics Committee
The University of Auckland
Office of the Vice Chancellor
Private Bag 92019
Auckland 1142
Phone: +64 9 3737599 ext 83711

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE
on ...5/08/13... until ...31/05/14..., Reference Number ...7342....

C3.iii) Expert Interviews – Consent Form



Consent Form (Expert Interview)

The Development of a Multi-Faceted Evaluation Framework of Shared Space

THIS CONSENT FORM WILL BE HELD FOR SIX YEARS

I agree to voluntarily take part in this research.

I have read the Participant Information Sheet. I have been given and have understood an explanation of this research project. I have had an opportunity to ask questions and have them answered satisfactorily. I understand that this interview will take roughly half an hour.

I understand that I am free to withdraw my interview responses at any time up to one month after the interview date without giving a reason.

I understand that the response of my interview (including any audio recording) will be stored in a secure location, within the University of Auckland premises, for up to six years, after which time it will be destroyed.

I understand that I will be given a transcript of my interview within ten days of the interview, and I will have seven days to review and amend it, if I wish to do so.

I understand that my name will not be used and every effort will be made to ensure identifying information is not included in the research report or in any other publication relating to this study.

I understand that my responses may be used for publication purposes and in future studies such as PhD or undergraduate research project. I understand that my employer/principal and I will be offered a copy of the report and/or any other publications, if we wish.

I understand that, while the researchers will strive to retain participant anonymity, it cannot be fully guaranteed.

I understand that the opinions expressed in this interview are my own and do not necessarily represent the views of my employer/organisation. I understand that my employer/principal has consented that any of my opinions will not affect my employer-employee relationship.

I grant/do not grant permission to allow the researchers to use my identity in the published research report.

I wish/do not wish to view the interview transcript.

I wish/do not wish to view the final research report before it is published externally.

Signed: _____

Name (please print clearly): _____

Date: _____

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Appendix D: Analytical Hierarchy Process

D1 Pairwise Comparison Matrices and Consistency Ratios

D1.i) Subcriteria Level

Place (CR = n/a)

Criteria	POR	Dwell Time	Priority
POR	1	3	0.750
Dwell Time	1/3	1	0.250

Pedestrian (CR = n/a)

Criteria	Density	Walk along veh path	Priority
Density	1	2	0.667
Walk along veh path	1/2	1	0.333

Vehicle (CR = n/a)

Criteria	Speed	Vol	Priority
Speed	1	2	0.667
Vol	1/2	1	0.333

Economic (CR = n/a)

Criteria	Active Edge	Ped accessing land use	Priority
Active Edge	1	4	0.800
Ped accessing land use	1/4	1	0.200

Safety (CR = 0.019)

Criteria	Crash	Conflict	Interaction	Priority
Crash	1	2	3	0.548
Conflict	1/2	1	1	0.241
Interaction	1/3	1	1	0.211

D1.ii) Intensity Level

Place – Ped Occupancy Ratio (CR = 0.011)

Criteria	H	M	L	Priority	Idealised
H	1	2	6	0.587	1.000
M	1/2	1	4	0.324	0.552
L	1/6	1/4	1	0.089	0.152

Place – Dwell Time (CR = 0.005)

Criteria	H	M	L	Priority	Idealised
H	1	3	5	0.648	1.000
M	1/3	1	2	0.230	0.355
L	1/5	1/2	1	0.122	0.189

Pedestrian – Density (CR = 0.046)

Criteria	H	M	L	Priority	Idealised
H	1	4	7	0.701	1.000
M	1/4	1	3	0.213	0.304
L	1/7	1/3	1	0.085	0.122

Pedestrian – Ped Along Veh Path Ratio (CR = 0.005)

Criteria	H	M	L	Priority	Idealised
H	1	3	5	0.648	1.000
M	1/3	1	2	0.230	0.355
L	1/5	1/2	1	0.122	0.189

Vehicle – Speed (CR = 0.046)

Criteria	L	M	H	Priority	Idealised
L	1	4	7	0.701	1.000
M	1/4	1	3	0.213	0.304
H	1/7	1/3	1	0.085	0.122

Vehicle – Volumn (CR = 0.010)

Criteria	L	M	H	Priority	Idealised
L	1	2	3	0.539	1.000
M	1/2	1	2	0.297	0.552
H	1/3	1/2	1	0.164	0.304

Economic – Active Frontage Ratio (CR = 0.076)

Criteria	H	M	L	Priority	Idealised
H	1	4	8	0.702	1.000
M	1/4	1	4	0.227	0.323
L	1/8	1/4	1	0.072	0.102

Economic – Ped Accessing Land Use Ratio (CR = 0.020)

Criteria	H	M	L	Priority	Idealised
H	1	2	4	0.557	1.000
M	1/2	1	3	0.320	0.575
L	1/4	1/3	1	0.123	0.220

Safety – Reported Crashes (CR = 0.027)

Criteria	NI-L	NI-H	Injury	Fatal	Priority	Idealised
NI-L	1	3	4	5	0.542	1.000
NI-H	1/3	1	2	3	0.233	0.430
Injury	1/4	1/2	1	2	0.140	0.258
Fatal	1/5	1/3	1/2	1	0.085	0.156

Safety – RUICS Conflicts (CR = 0.010)

Criteria	L	M	H	Priority	Idealised
L	1	2	3	0.539	1.000
M	1/2	1	2	0.297	0.552
H	1/3	1/2	1	0.164	0.304

Safety – RUICS Interactions (CR = 0.076)

Criteria	H	M	L	Priority	Idealised
H	1	4	8	0.702	1.000
M	1/4	1	4	0.227	0.323
L	1/8	1/4	1	0.072	0.102