Tamara Bozovic

NON-WALKABILITY IN THE CAR-CENTRIC CITY

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A thesis submitted to Auckland University of Technology in fulfilment of the requirements for the degree of Doctor of Philosophy

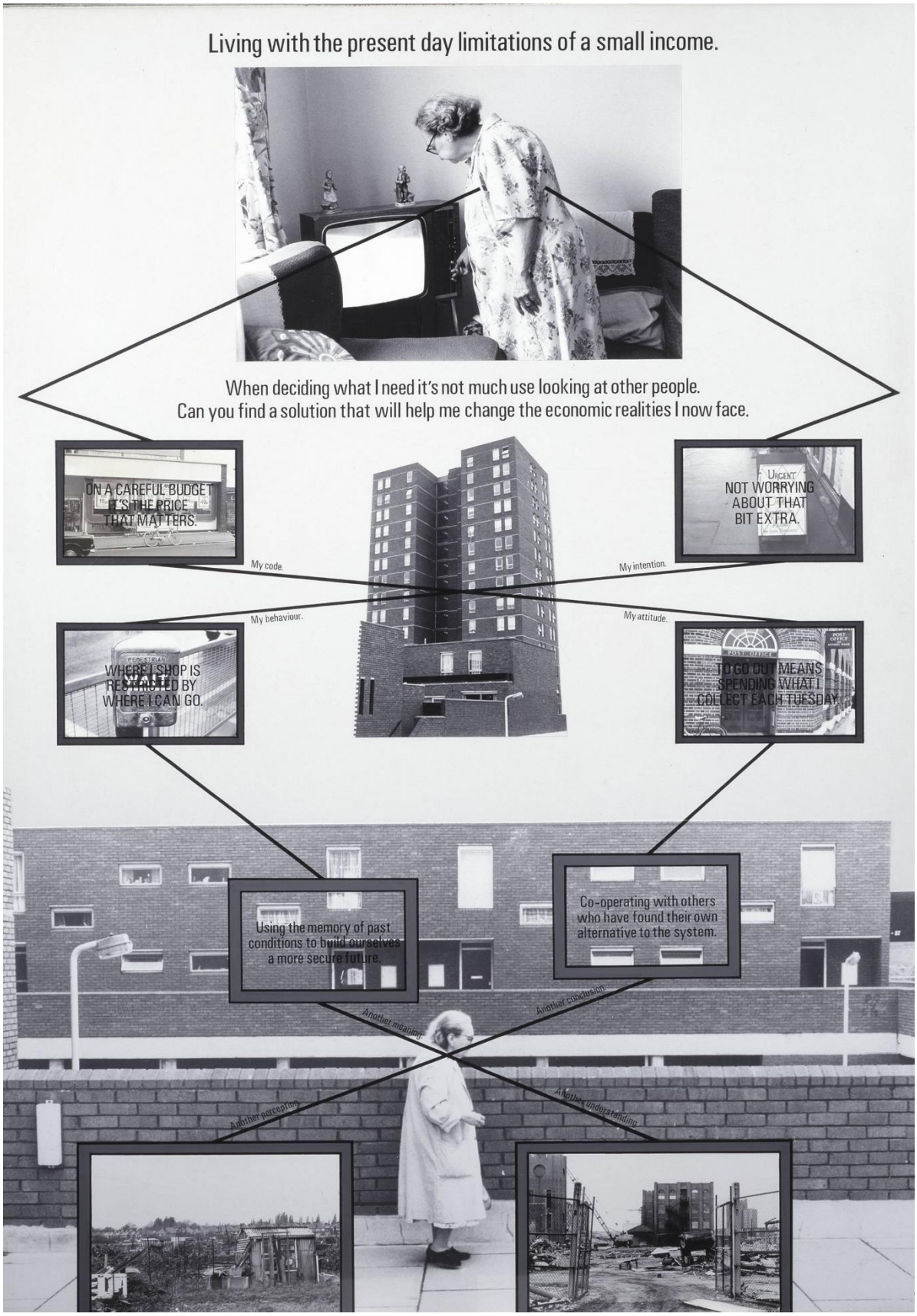
ATTESTATION OF AUTHORSHIP

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

Tamara Bozovic, 20.8.2021

Next page : "Living with Practical Realities", Willats, Stephen, 1978; Photography credit of Photo: Tate (Image ID: T03296, Client ID : AUTOMI-61, Invoice No.: 101460)

Stephen Willats' artwork, "Living with Practical Realities", made a strong impression on me when I saw it in London. The art piece is composed of three panels, all following the same older lady and putting in parallel her environment and her ideas. On the second panel, the phrase "Where I shop is restricted by where I can go." is superimposed on the push-button of a pedestrian crossing mounted on a metal fence. Design for traffic, channelling pedestrians and requiring to ask permission to cross collided with the experience of an elderly woman needing to access a necessary destination. For me, this artwork condenses in such a powerful way human experience in urban environments designed with other preoccupations in mind, but also the complexity and inter-relatedness of dimensions such as age, income, place of residence, social circles and loneliness, intentions, attitudes, and behaviours.


Living with the present day limitations of a small income.
When deciding what I need it's not much use looking at other people.
Can you find a solution that will help me change the economic realities I now face.
ON A CAREFUL BUDGET IT'S THE PRICE THAT MATTERS.
URGENT
NOT WORRYING ABOUT THAT BIT EXTRA.
My code.
My intention.
My behaviour.
My attitude.
WHERE I SHOP IS RESTRICTED BY WHERE I CAN GO.
TO GO OUT MEANS SPENDING WHAT I COLLECT EACH TUESDAY.
Using the memory of past conditions to build ourselves a more secure future.
Co-operating with others who have found their own alternative to the system.
Another meaning.
Another conclusion.
Another perception.
Another understanding.

CO-AUTHORED WORKS

Study	Authors[1], estimated contributions, qualitative statement and signatures		
Chapter 2, Literature review examining how links between the WE and walking behaviour are conceptualised and evidenced	**TB**	80%	Study design, data gathering, data analysis, writing, illustrations
	EH	10%	Study design, reviews
	MS	10%	Study design, reviews
Chapter 3, Literature review reporting the associations between specific WE characteristics and people's perceptions of walkability	TB	80%	Study design, data gathering, data analysis, writing, illustrations
	EH	8%	Study design, cross-check of studies inclusion, reviews
	MS	8%	Cross-check of studies quality rating, reviews
	MC	4%	Study design, reviews
Chapter 4, Quantitative study identifying associations between people's perceptions of their WE and walking levels, considering individual characteristics and the use of public transport	**TB**	80%	Study design, obtention of data, data analysis strategy & implementation, writing, illustrations
	EH	6%	Study design, reviews, administration of data contract (Ministry of Transport)
	MS	6%	Study design, reviews
	TS	8%	Contributions to data analysis strategy & implementation, reviews
Chapter 5, Naturalistic inquiry examining motivators and barriers to walking, comparing disabled and non-disabled people	TB	82%	Study design, participants recruitment and data gathering (interviews), data analysis strategy & implementation, writing, illustrations
	EH	6%	Study design, reviews
	MS	6%	Study design, reviews
	TS	6%	Study design, reviews

[1] TB: Tamara Bozovic, candidate; EH: Prof. Erica Hinckson; MS: Associate Prof. Melody Smith; TS: Dr Tom Stewart; MC: Dr Moushumi Chaudhury; **bold**: first author in the published paper.

Study	Authors[1], estimated contributions, qualitative statement and signatures		
Chapter 6, Characterisation of the barriers to walking as reported by people, and comparison of the results with best practice and local guidelines	TB	82%	Study design, data gathering (desktop and measures on the ground), data analysis strategy & implementation, writing, illustrations
	EH	6%	Study design, reviews
	MS	6%	Study design, reviews
	TS	6%	Study design, reviews
Chapter 7, Assessment of professionals' views relative to users' needs, priorities, challenges, and evidence gaps for delivering quality WE in a car-oriented city	**TB**	80%	Study design, data gathering (survey & focus groups), data analysis strategy & implementation, writing, illustrations
	EH	6%	Study design, reviews
	MS	6%	Study design, reviews
	TS	6%	Study design, reviews
	MC	2%	Assistance with one focus group
Chapter 8, Inquiry into motivators and barriers to walking as reported spontaneously by disabled and non-disabled participants	TB	80%	Study design, workshops with Citizen Scientists, participation to data gathering, data analysis strategy & implementation, writing, illustrations
	EH	6%	Study design, reviews
	MS	6%	Study design, reviews
	TS	6%	Study design, reviews
	MC	2%	Assistance with Citizen Scientists' workshops

Co-author agreement

Prof Erica Hinckson

Assoc. Prof Melody Smith (nee Oliver)

Dr Tom Stewart

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LIST OF ABBREVIATIONS

Abbreviation	Definition
AUT	Auckland University of Technology
AUTEC	Auckland University of Technology Ethics Committee
BE	Built Environment, refers in this case to the streets' environment in particular
CA	Content Analysis
CS	Citizen Science or Citizen Scientist(s)
CSTS	Complex Socio-Technical System
GIS	Geographical Information System
MQC	Methodological Quality Checklist
PT	Public transport
WE	Walking Environment – encompasses the Built Environment (BE), the natural features, but also the activity (e.g. traffic, people walking); refers in this case to the streets' environment in particular

NOMENCLATURE

Term/symbol	Definition
%	Percentage
AUC	Area Under a ROC [Receiver Operating Characteristic] curve "The area under an ROC [Receiver Operating Characteristic] curve is equal to the probability that a randomly selected positive case will receive a higher score than a randomly selected negative case." [1]
CI	Confidence interval
IQR	Inter-quartile range
n	Number of cases in a subsample
N	Total number of cases
OR	Odds Ratio
p	p-value, statistical significance
r	Correlation Coefficient
SD	Standard Deviation

LIST OF PUBLICATIONS ARISING FROM DOCTORAL THESIS

Peer-reviewed journal publications

The papers as published are included in the appendices, from page 125.

Bozovic, T., Stewart, T., Hinckson, E., & Smith, M. (2021). **Clearing the path to transcend barriers to walking: Analysis of associations between perceptions and walking behaviour**. Transportation Research Part F: Traffic Psychology and Behaviour, 77, 197–208. https://doi.org/10.1016/j.trf.2021.01.003

Bozovic, T., Hinckson, E., Stewart, T., & Smith, M. (2021). **How to improve the walking realm in a car-oriented city? (Dis)agreements between professionals**. Transportation Research Part F: Traffic Psychology and Behaviour, 81, 490–507. https://doi.org/10.1016/j.trf.2021.06.011

Bozovic, T., Hinckson, E., & Smith, M. (2020). **Why do people walk? Role of the built environment and state of development of a social model of walkability**. Travel Behaviour and Society, 20, 181–191. https://doi.org/10.1016/j.tbs.2020.03.010

Manuscript accepted for publication

Bozovic, T., Hinckson, E., Stewart, T., & Smith, M. (Submitted for publication). **How street quality influences the walking experience: a naturalistic inquiry into the perceptions of adults with diverse ages and disabilities**. Accepted for publication, Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 3.11.21

Manuscripts under review in peer reviewed journals

Bozovic, T., Hinckson, E., Stewart, T., & Smith, M. (Submitted for publication). **How do walking environments relate to users' perceived walkability: An umbrella review, 2009-2020**. Submitted for publication to TRF: Traffic Psychology and Behaviour, 25.5.2021.

Bozovic, T., Hinckson, E., Stewart, T., & Smith, M. (Submitted for publication**). Prepare the ground for improving walkability: triangulating barriers to walking as experienced, as measured, and as defined in guidelines**. Submitted for publication to Urban Studies, 12.8.2021.

Peer reviewed conference presentations

Bozovic, T. (2021, November 19). **Barriers to walking as experienced, measured, and seen by practitioners**. Presentation and panel discussion presented at the Australasian Society for Physical Activity (ASPA) Conference 2021, Online. Retrieved from https://aspactivity.org/aspa-conference-2021-2/

Bozovic, T. (2021, August 6). **How street quality influences the walking experience: a naturalistic inquiry into the perceptions of adults with diverse ages and disabilities**. Pecha Kucha, Virtual. Retrieved from https://annualmeeting.isbnpa.org/program/

Bozovic, T. (2021, June 15). How Street Quality Influences the Walking Experience: A Naturalistic Inquiry into the Perceptions of Adults with Diverse Ages and Disabilities. Pecha Kucha presented at the International Conference on Transport & Health, Virtual. Retrieved from http://www.tphlink.com/quick-glance-programme.html

Bozovic, T. (2020, September 28). **Why do people walk? Linking the built environment to walking behaviours**. Full length, breakout session presented at the NZ Modelling User Group Conference, Virtual. Retrieved from https://www.engineeringnz.org/courses-events/event-template/?eventtemplate=1492-nz-modelling-user-group-conference

Bozovic, T. (2019, November 10). How to shift short trips to walking? Examining the ways quality of walking environments influence decisions. Pecha Kucha presented at the Walk21 conference, Rotterdam.

Bozovic, T. (2019, August 5). **Geographies of walking: Examining how qualities of place correlate with users' perceptions and levels of walking**. Full length, breakout session, Hobart. Retrieved from https://www.conferences.com.au/category/2019-iagc/

ETHICAL APPROVAL

Auckland University of Technology Ethics Committee granted ethical approval for the studies involving human participants, as follows:

AUTEC 18/431, 12 December 2018 (Phase 1: interviews) ..... See Appendix 1a

AUTEC 18/431, 31 August 2020 (Phase 2: professionals' survey)..... See Appendix 1b

ACKNOWLEDGMENTS

At this stage it seems clear that while the thesis might look like a solo show, in my case, it would not have been possible without a small army of people. First, I would like to thank my supervisors – Professor Erica Hinckson, Associate Professor Melody Smith, Dr Tom Stewart, and Dr Moushumi (Mo) Chaudhury, for their inestimable guidance, insights, and encouragement. I could not have dreamt of a better team. Erica, thank you for the idea of doing a thesis – truly life-changing! –; for your trust, and your ongoing support. Melody, thank you for having accepted to join the team despite a more than busy schedule, for your dedication, and for the amazingly insightful feedback you kept providing. Tom, thank you for introducing me to R and machine learning - life-changing bis-, for your support with analytics and the care you put into reviews. Mo, thank you for having been part of the supervision team at the start and for having remained present afterwards, encouraging me and helping with the Citizen Science process – always with your legendary good spirits!

I feel very privileged to have been able to dedicate most of my time to this thesis in the last three years. I was able to do this thanks to being awarded a Doctoral Scholarship from Auckland University of Technology, a postgraduate study loan granted by the Alumni Association of the Swiss Federal Institute of Technology (EPFL), and a Tertiary Study Grant from the NZ Transportation Group. I would like to acknowledge the three institutions for their invaluable support.

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This thesis used two sources of secondary data: Auckland Transport's Active Modes survey, and the New Zealand Household Travel Survey. I am grateful to Auckland Transport and the Ministry of Transport for their trust and would like to thank Carol Christie, Jennifer McSaveney, Tiffany Robinson, and Kipi Wallbridge-Paea for their time and valuable feedback to my questions. I would also like to thank Dr Robin Hankin for his insights regarding analysis strategies.

The primary data collection involved number of human participants to whom I am indebted. Fifty-six Aucklanders agreed to dedicate time for interviews and provided extremely rich insights regarding their walking experiences. Some of the participants continued being part of the research as Citizen Scientists – I am most grateful for the time and energy they put into participating to workshops, familiarising themselves with the tools, gathering data, and discussing results. Twenty-eight professionals also took part in an online survey, providing a wealth of ideas which were further discussed in a focus group. The inputs provided by all the participants were inestimable. They allowed testing the theoretical model conceptually and improving the understanding of complex mechanisms.

I would also like to thank the people who contributed to the recruitment process by allowing me to present my research to groups of potential interviewees or hold drop-in sessions: Mireille Vreeburg, New Zealand Disability Support Network (NZDSN) Executive Facilitator; Keringle Park Residential Care staff and manager Elizabeth Riley; Hillsborough Village staff and managers Penny Smith; Auckland Libraries staff; and Auckland Library of Tools volunteer, Amanda Chapman.

The dissemination of research results was largely supported by two pieces of work that had not been initially planned: first, a short video illustrating the quotes of some of the interview participants, expertly realised by Dmitry Konovalov and featuring the voices of some of my friends who accepted the impromptu invitation to become actors: Aatir, Alan, Amber, Brylee, Cordelia, Jay, Joel, Margaret, Peter, Sabrina and Sarah. Thank you! This wouldn't have been possible without you. Second, I am grateful to the International Society for Physical Activity and Health (ISPAH), which has accepted the first manuscript as a Short Animation. ISPAH is funding the production of the animation, now being realised by Jennifer Duncan.

Somewhere around the world, anonymous reviewers have put time and energy in reviewing the papers submitted for publication. I not only appreciate the noble gesture of stepping up to provide a service for the science but am also very grateful for the most relevant questions and ideas they sent my way.

I could not go without acknowledging key thinkers interested in the design, transformation, systemic complexities of cities, and human perception. Naming them here would in large part duplicate the reference list, and I will therefore avoid doing it. Beyond the published works cited, I would however like to thank here the transport planners and urban designers with whom I was privileged to work and who influenced my practice and my thinking as a young engineer, namely Federico Molina, Ariane Widmer, Christophe Jemelin, Philippe Gasser, and Nathalie Henderson.

Lastly and importantly, eternal gratitude goes to my family for their unwavering support – thank you mum, Gavrilo, and Dimitri!; and to my friends, always there to discuss existential doubts, make plans to change the world, go out on adventures, organise gigs or lift some weights: Amber & Alan, Véro, Carole, Aatir, Lee, Sabrina, Laura & Ariel, Daphne & Dan, Jay & Roby, Stéph, Peter, Brylee & Mikey, Cordelia, Emilie, David, the Le Romandie gang, Andrey, Zac, Olive & Leith, M.: *"What are we going to do today, M? The same thing we do every day, T. Try to take over the world."*

THESIS ABSTRACT

Background

Increasing the levels of walking for transport is a widespread urban policy goal, aligning with actions related to climate change, public health, equity of access and participation, and more liveable cities. The walking environment (WE), including the built environment, traffic, public transport, and street life, is known to be associated with walking behaviour through the filter of people's perceptions. A historic lack of interest in, and data about users' experiences and perceptions (UX), challenges however the improvement of the WE. Indeed, there is no consensus on the deterrents to walking, and how they vary across people.

Methods

This research aims to (a) better understand what constitutes barriers to walking in a car-centric environment, for diverse people; (b) examine how professionals active in the delivery of the WE understand people' needs and the priorities for retrofit; and (c) provide insights both to research (development of the theoretical model of walking) and practice (inputs regarding improvement of the WE).

This research is based in Tāmaki Makaurau – Auckland, Aotearoa – New Zealand, a city of 1.5 million designed predominantly around the use of private vehicles. The theoretical framework named by the PhD candidate the Social Model of Walkability, was identified from previous research and further developed throughout the project.

Methods included: two literature reviews; a quantitative analysis of associations between perceived walkability and walking levels; content analysis exploring perceived barriers to walking (interviews and inputs from Citizen Scientists); characterisation of barriers reported by participants using objective measures; triangulation of experienced barriers, measures and recommendations from guidelines; and the thematic analysis of professionals' views (survey and focus group data).

Results

The findings include important aspects for both further research and the urban design, transport planning, and public health practices. Namely:

- **The importance of considering walking within the broader transport system** – the findings suggested the importance of the use of public transport and of the perceptions of walking *as compared to* other available alternatives, on walking behaviour.
- **Characterisation of barriers** that can discourage people from walking to destinations that they perceive as being within a walkable distance.
- **Insights into the moderating role of disability** in the associations between objectively measured WE, perceived walkability, and behaviour.
- **Gaps in local and international guidelines** relative to identifying barriers to walking.
- **Professionals' agreements and disagreements** on users' needs and the priorities for retrofit.

Conclusion

This thesis contributed new knowledge regarding barriers to walking as perceived by non-disabled and disabled people, objectively measured, described in technical guidelines, and understood by professionals. Associations and misalignments were outlined, and recommendations were made for research and the practice. Findings include practical insights that can help prioritise retrofit of the WE in a way that harnesses users' insights.

CHAPTER 1: INTRODUCTION

This introduction first briefly describes the background of this thesis, examining the challenges it focuses on. Second, it situates the thesis, presenting its theoretical framing and the consensus and disagreements observed in previous evidence. Third, an overview of the study context and setting is provided. Fourth, a rationale for the thesis is laid out, including a problem statement, the direction and scope of the work, the aims, and the research principles and design choices. Lastly, original contributions are indicated, and the organisation of the thesis is presented.

1 BACKGROUND

From the perspective of global heating, there is urgency to change and decarbonise current day-to-day patterns such as mobility [2, 3]. In 2017, a benchmarking activity commissioned by the World Bank's initiative *Sustainable Mobility for All* revealed that not a single country had a mobility system that could be deemed sustainable, a result described as "alarming" [4].

Cities are acknowledged as key players [2, 5, 6] and are embracing the need for change [5, 7, 8]. Walking, as the most basic travel mode accessible to almost everyone and the logical "last mile" connection to public transport is part of the solution [2, 3]. Street environments supportive of walking promote health [9], facilitate participation [4] and equalise opportunities [10], further leading to broader benefits such as enhanced wellbeing [11]. However, existing car-oriented street environments have been associated with traffic speed, road trauma, difficulties for walking, and increased driving leading to greenhouse gas emissions, noise, and air pollution. The difficulties for walking tend to be highest for disabled and older people [12], and impact most those who do not have other options. Therefore, existing car-oriented environments can contribute to inequities across different demographic groups [12–14]. Disabled people are one of these groups, facing more acute barriers to walking than the rest of the population [12, 15, 16].

It is acknowledged that built environments need to be retrofitted to support walking [2], and it is suggested that this retrofit should focus on removing existing barriers [13, 14] and improving users' experiences [17–19]. Delivering change requires addressing inequities of access that disproportionately affect some demographic groups (namely poor, older, disabled, LGBTIQ+, and ethnic minorities) [12, 20]. However, there is concern regarding the extent to which users' needs and experiences are understood [20–22], due in part to a historical lack of interest for evidence regarding the barriers to walking experienced by diverse people [12, 20].

The broad benefits of walking are well established, particularly in terms of equity of access [11, 23]; social and economic participation [16, 24–27]; physical activity and health [16, 28–31]; and urban economic efficiency [32, 33]. A modal shift from driving to walking, for short urban trips, would also align with the current urgency to decarbonise urban mobility [2].

A shift towards cities where walking is incentivised is visible in strategy documents. Both are for instance strongly promoted by C40 Cities, a world network of cities committed to addressing climate change [5]. C40 Cities stresses the need of a multi-dimensional approach encompassing improvements of public transport (PT) systems [5]. In its 2019 *City Declaration: "The New Paradigm for Safe City Streets"*, the European network of cities POLIS stressed the need for streets' environments that encourage walking for everyone, regardless of age or ability [8].

However, urban areas have been influenced with decades of planning and design having prioritised traffic volumes and speeds. These environments have continued negative impacts in terms of road trauma [34, 35], noise [4, 36], and air pollution [37–39] and present significant barriers to walking [16, 20, 24, 40–42]. Thus, walking environments (WE) in inherited, car-centric cities, can be largely non-walkable.

The difficulties for walking in car-oriented cities tend to impact most on those who lack travel options and/or have higher accessibility needs [11, 12, 20]. Therefore, existing environments can contribute to inequities across demographic groups and locations [12–14].

2 THIS THESIS

This thesis was motivated by the following factors:

- A sense of urgency for change
- A need and potentials for greener and more inclusive cities
- The idea of walking as a universal mode of transport
- The existence of environmental features that can deter walking or make it a stressful or dangerous experience
- Evidence gaps relative to people experiencing barriers to walking and the nature of those barriers
- A 14-year career in transport planning oriented towards alternatives to car, in Switzerland, Argentina, and Aotearoa New Zealand. This first-hand experience of industry standards and methods inspired research that would help answer the question “how”, by providing pragmatic insights that can support the effort to retrofit urban environments.

2.1 Theoretical framing

The thesis draws from two theoretical frameworks: the Socio-Ecological Framework and the Social Model of Disability.

The Socio-Ecological Framework is widely accepted as a sound theoretical approach to understanding health-related behaviours in general [21, 43]. The framework is helpful because it articulates multiple levels of influences on individual choices. Influential factors belong to different dimensions: individual; social/cultural; organisational; community-related; physical environment; and policy [43–45]. The Socio-Ecological Framework is on purpose high-level, aiming to explain conceptually different types of health-related behaviours [44].

The Social Model of Disability defines disability as a man-made notion calling for a critical assessment of inherited infrastructures and systems towards an evidence-based retrofit accessible to all [46]. This idea was first framed by disability advocates and was at the origin of the now widely accepted Social Model of Disability [46, 47]. In 1976, the Union of the Physically Impaired Against Segregation (UPIAS) stated that:

> *[...] it is necessary to grasp the distinction between the physical impairment and the social situation, called 'disability', of people with such impairment. Thus we define impairment as lacking part of or all of a limb, or having a defective limb, organ or mechanism of the body; and disability as the disadvantage or*

> *restriction of activity caused by a contemporary social organisation which takes no or little account of people who have physical impairments and thus excludes them from participation in the mainstream of social activities. Physical disability is therefore a particular form of social oppression. [48]*

2.2 How to enable and encourage walking: elements of consensus

Research has focused on *how to* leverage walking in urban areas, especially since the mid-2000s. Elements of consensus now exist regarding the theoretical framework and basic dimensions of walkability.

Alfonzo kick-started in 2005 the development of a specific model for walking, within the Socio-Ecological Framework [43]. Alfonzo posited that perceptions, as well as individual, social, and trip characteristics mediate the association between built environment and waking [43]. Further, Alfonzo theorised perceptions as a hierarchy of pedestrian needs, referring to Maslow's pyramid of human needs [43]. The posited pedestrian needs range from basic requirements (feasibility, accessibility, and safety) to a higher order needs (comfort and pleasure) [43]. The perceived satisfaction of the pedestrian needs becomes synonym of perceived walkability.

Alfonzo's first iteration was a response to the observation that the existing evidence presents "oversimplified relationships between two variables and are not typically useful (in terms of applied utility) as they are not part of a dynamic, theoretical model informing the walking decision-making process." [43]. This model builds on previous works explaining walking behaviour [49–51] and aligns with Mehrabian and Russell's influential *Approach to Environmental Psychology*, linking environments to behaviours through the moderating effect of emotions or perceptions [52]. Alfonzo's model was identified early in the thesis as a promising theoretical development, namely through the work of Forsyth [21]. At the start of the thesis, Alfonzo's model had undergone limited testing and development: Mehta clarified the distinction between objective features and perceived walkability [53]. Further, Buckley and colleagues examined the role of individual motivations [54].

A certain consensus applies also to two basic dimensions of walkability: firstly, destinations available within a walkable distance [22, 55, 56] (noting that the notion of "walkable distance" might vary across people). Second, walkability requires a certain lack of safety issues or barriers to access *as perceived by people* [16, 21, 22, 27, 57, 58]. The question of what constitutes barriers to access and how this varies across people is still debated [16, 21, 24]. However, researchers tend to agree that car-oriented environments can cause major challenges [22, 27] and discriminate against disabled people [16, 22, 57, 57] or those unable to "escape" those environments [11, 59].

2.3 How to enable and encourage walking: lack of consensus

While a significant body of research has reached the elements of consensus above, there is still no agreement on the importance of the quality of WE and the ways it might influence the experience and choice of walking [20–22, 55]. For instance, Frank and colleagues' influential investigation into the associations between urban form and physical activity considered only high level factors (land-use mix, residential density, and street connectivity, referred to as "3D"), equating network buffers to "the area that people that can actually access around their homes" [60]. While the authors noted that the availability of footpaths might be an important predictor, it was not clear how much the quality of street environments mattered (and to what extent it could make some destinations inaccessible, although located within a "walkable" distance) [60]. Authors are now calling for better understanding of the influences of **quality** and **ways** it influences the choice of (not) walking [61, 62]. Meher and colleagues note that "a range of issues – both personal and environmental – change perceptions of risk and generate safety concerns that may go unseen by people without mobility impairments, including transport professionals" [20]. Researchers examining disabled people's experiences note a dearth of research interest in the barriers they encounter [16, 21, 24, 57]. . Further, the diversity of disabled people's needs and experiences is poorly addressed both in research [15, 16, 57] and in national transport data [12].

While it is understood that the same environment can be experienced differently by different people, there is a lack of research into the interplay between individual characteristics and the perceived importance of certain features or obstacles [16, 57, 62]. Further, objective and perceived characteristics of the WE tend to be used simultaneously or interchangeably to describe "what matters" and to predict physical activity and walking [63–65]. There is a lack of evidence regarding how objective characteristics of the WE influence the perceptions of walkability across people of different ages, abilities, and backgrounds.

2.4 Definition of terms and concepts

The definitions of key terms and concepts used throughout the thesis is provided in Table 1 below.

Table 1: Definition of terms and concepts

Term / concept	Definition applied in this thesis
Built environment (BE)	Encompasses the availability of the destinations (i.e., land use), the networks allowing the access to destinations (i.e., roads and paths, networks and connectivity), and the qualities of the street environment (e.g., footpaths, street trees, architecture). All the components of the BE can be either objective or perceived (see definitions below). Given that the perceived quality of the BE can be influenced by aspects that are not built (e.g., traffic volumes or greenery), the notion of Walking Environment (WE) was preferred in this thesis from Chapter 3 onwards.
Car-centric or car-oriented	Refers to environments designed primarily around the use of private vehicles. The notion can refer to street environments (provision for driving and parking, constraints to pedestrian movements, traffic volumes and noise) but also to urban form (low density housing or shopping centres accessible mainly by car), urban systems management (prioritising for instance the maintenance of carriageways over the footpaths, or monitoring and providing for drivers' experiences more than for experiences of the users of other modes) or policies and rules (e.g., investment focusing on infrastructure for traffic or provision of "free" parking).
Disability	In line with the Social Model of Disability [46, 47], disability is understood as resulting from barriers encountered in society, and not an inherent characteristic of the person. This understanding stems from disability rights' statement that "disability is a situation, caused by social conditions, which requires for its elimination" [48]. This thesis focuses on ways how to remove socially constructed barriers, and not on "improving" people through medical or technical fixes. See also 'A note on language', below.
Impairment	A "diminishment or loss of function or ability" [66] relative to motor or sensory skills, cognition, or broader mental health. As noted above, this thesis does not focus on the reasons or possible "cures" but only considers impairment as a factor that can be associated to the risk of being disabled by socially constructed barriers.
Objective (O)	Present or measurable characteristics. Used here to describe the BE, WE, and the transport system. O factors are key inputs into the Social Model of Walkability (see below).
Perceived (P, Pw)	Characteristics as experienced by people. Used here to describe the BE, WE, and the transport system. In the Social Model of Walkability (see below), P characteristics are mediating the relationship between O and walking behaviour. When perceptions relate specifically to walkability (e.g., feasibility or convenience of walking), they are noted Pw.
Social Model of Walkability (the model)	Theoretical framework identified from previous research, further developed throughout this thesis and underpinning its empirical studies.

Term / concept	Definition applied in this thesis
Transport system	The Social Model of Walkability acknowledges that people might choose to walk or not depending on their satisfaction with the WE, but also with the comparative satisfaction relative to other modes (e.g., is driving seen as more convenient or more comfortable?). The transport system was included as input in the model and encompasses the provision and quality of services of transit, driving, bicycle riding, shared mobility, and micro-mobility.
User experience (UX)	UX is now a buzzword in human-computer interaction and design [63]. Similarly, as tech companies focus on UX and its improvements, to sell more devices and applications, the concept is applied here to the walking experience, the thesis focusing on identifying the factors that might, in the current state, lead to poor walking experiences. Negative UX might include a sense of difficulty, stress, or feeling unsafe.
Walkability	Walkability is a complex and debated concept (see Chapter 2). The following working definition underpins this thesis: "Walkability is a quality of the built environment and the transport system, measured by the ease of daily walking as experienced by people of all ages, abilities, and backgrounds. Walking includes the use of any mobility device a person might need. The reference to the transport system acknowledges walking as a companion mode of public transport, and public transport as a facilitator and enabler of walking. The assessment of walkability or a lack thereof is subjective and expected to vary across people." [67] This definition takes some distance from high level assessments based on factors such as land-use mix, residential density, and street connectivity, proposed in 2005 by Frank and colleagues [60] and still widely used in research, namely regarding physical activity (see point 2.1 Theoretical framing, p. 31).
Walking	The verb is understood here in a broader than the Marriam-Webster's definition (*to move along on foot* or making*; advance by steps* [68]). Within this thesis, walking encompasses by default any mobility device a person might need. Both walking for pleasure or transport were considered, with a particular interest in the latter, given its potentially necessary nature (e.g., accessing public transport or other essential services). Public transport was understood as an enabler of walking and natural companion mode. Therefore, walks to and from public transport were included.
Walking behaviour	Encompasses the choice of walking or not, the duration, frequency, distance of walking trips, as well as the choice of routes. A key interest of this thesis was whether the choice of walking or not to destinations within walkable distance
Walking environment (WE)	Encompasses BE, natural features, as well as activity, composed of traffic, people walking, oversight from the nearby buildings. All the components of WE can be either objective or perceived.

2.5 A note on language

Disability can be conceptualised in ways that can hide the everyday marginalisation, and language is seen as an important aspect of this process [69]. It is suggested that the language should refer to the disablement - "something that is experienced when people encounter restrictions due to disabling social barriers (and/or bodily impairment)" [69], rather than to the characteristics of a person [69, 70]. People-first language ("person with disabilities") suggests that some individuals "just happen to" have "abnormal" limitations [70]. This discourse participates to the idea that disability is not to be understood as a complex social and political phenomenon [70]. People-first – or person-first language is seen as presenting "pitfalls of political correctness" [71] or even relating to an "unholy crusade" [72].

Researchers and disability advocates suggest to use the terminology **disabled people** [69–73]. The word "disabled" is used for instance in the name of New Zealand's Disabled Persons' Assembly, and owned by disabled people on social media, sometimes with the hashtag #SayTheWord[2].

The document will differentiate between **disabled people** and **non-disabled people**, whenever disability is relevant as a characteristic.

3 STUDY CONTEXT AND SETTING

The empirical studies focus on Tāmaki Makaurau-Auckland, Aotearoa-New Zealand (further: Auckland), New Zealand's largest and growing city (1.47 million residents in 2020 [74]).

Auckland is located on New Zealand's North Island, with access both to the Pacific and the Tasman Sea. The area had been occupied by the Māori populations since the 14th century, with pā (fortified settlements) located on the inactive volcanic cones [75]. The city was founded by European colonisers in 1840, first as a military camp and capital [75]. Auckland has been a growing city ever since, with a boom in the post-war period (500,000 habitants in 1961 [75]) and an expansion that lasted until the 1980s. The growth was characterised by urban sprawl, slum clearance and gentrification, and was fuelled by a network of roads and motorways developed in large part during the 1950s [75]. During this phase, Auckland Council rejected the idea of building a light rail system, and opened the car-only Harbour Bridge, connecting the city to a new area of development on the Northern side of the harbour [75]. The focus on infrastructure for traffic led to car-dependency and

[2] For instance: https://twitter.com/SeeMiaRoll/status/1212941462142369792

underpinned the low density (in 2006: 1.210 people per square km, a density more than two times lower than Los Angeles and Sydney, and almost four times lower than London [75]).

Auckland's growth continues, and the region is expected to welcome approximately 720,000 new residents (+43%) in the 30-year period until 2048 [76]. Auckland is also an ageing city: it is anticipated that the number of people aged 65 and over (currently 11.4% of the population) is going to be more than doubled between 2013 and 2043 [76]. The ageing population suggests higher future rates of disability and lower rates of driving [77].

3.1 Transport system and outcomes

Auckland's car-centric development has led to poor quality of street environments [78] associated with significant barriers to walking [12, 20, 41]. Unsurprisingly, Aucklanders' travel is heavily reliant on cars in a way that is not aligned with people's preferences: 71% Aucklanders drive to work at least once per week while 33% prefer commuting by car [79]; conversely, 10% use PT as a primary mode vs 28% who declare it as a preferred mode [80], and walking levels are approximately two times lower than the declared preference (27%). Aucklanders walk less than 450 m per day for transport, with an average of 0.54 walking for transport trips per day [81] (compared to for instance 2.7 trips per day in London [82]). Barriers to walking as perceived by non-disabled Aucklanders relate to a range of issues including walking not being quick enough (39% agreement), feeling unsafe in the dark (37%), being encumbered (31%), living too far for walking to be practical (26%, 13% for city centre residents), hills (16%), footpaths condition (12%), or unattractive walking routes (8%) [83]. Barriers experienced by disabled people are acute and related to ableist physical environments and transport service, including non-navigable or stress-inducing environments or insufficient public transport [12, 20, 84]. Thus, disabled people experience wide-ranging negative outcomes in terms of inability to participate, relationship to land, and ultimately wellbeing [20, 41, 84].

Walking levels are poorly correlated with the WalkScore™ in Auckland (Figure 1, analysis from the Household Travel Survey data, described in Appendix 1C), suggesting the interplay of other parameters, hypothesised to include WE quality and barriers to access.

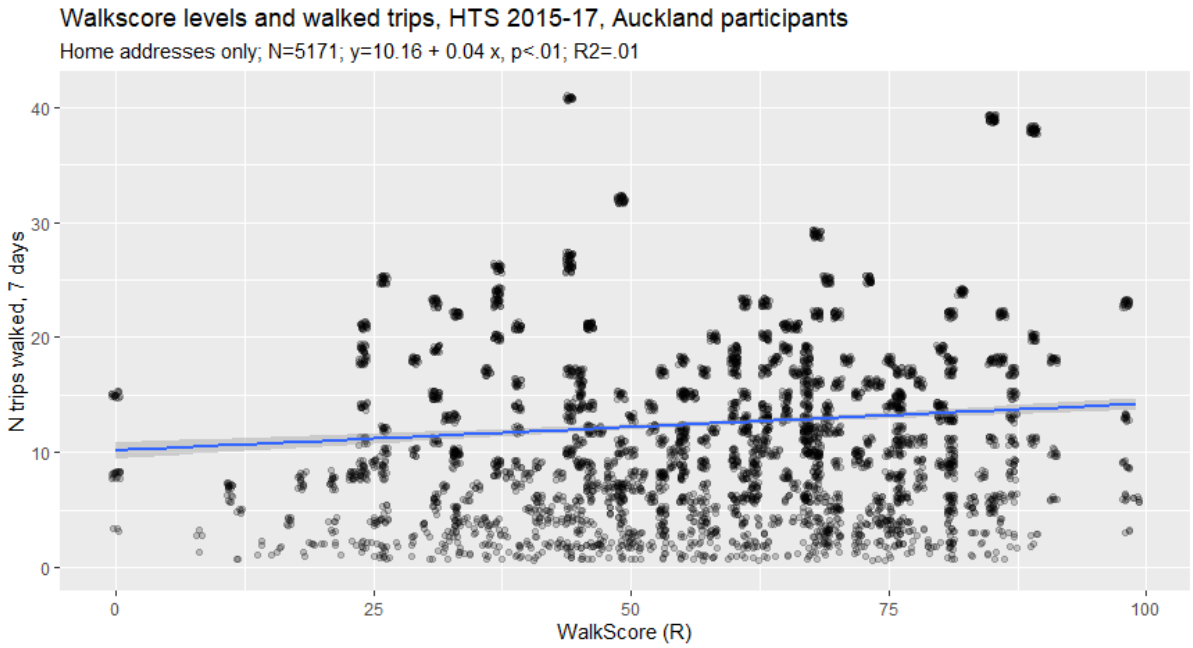


Figure 1: WalkScore ™ levels and trips walked, from New Zealand's Household Travel Survey 2015-2017

The current transport system and travel behaviour in Auckland are associated with unacceptable levels of road trauma [85, 86], major inequities of access impacting most on those having a low income and/or being disabled [12, 20], and consequences in terms of climate change [87, 88] and public health [36, 85, 86]. Addressing these outcomes is an important policy objective [76]. However, researchers note that newly developed special housing areas failed to achieve desired modal shift and intensification, "a disappointing result given the stated Auckland Council ambition to cut carbon emissions significantly" [80]. This aspect links back to the previously identified need of targeted interventions and raises the question of how individuals' choices related to transport modes are understood and influenced.

3.2 Auckland as an interesting case study

Investigating people's experiences and perceptions of WE in Auckland is interesting for several reasons. Firstly, Auckland faces systemic challenges common to many post-industrialised cities, namely the needs to: transform an inherited traffic-oriented infrastructure, reduce reliance on cars, reduce transport inequities, and to provide equitable transport options for an ageing population. Second, Auckland has ambitious strategic objectives relative to improving ease of walking and transport decarbonisation [76], in line with visions of other progressive cities [7]. Thirdly, there appears to be a disconnect between policy objectives relative to walkability, understanding of users' needs, and delivery of more walkable environments [13, 80, 89], which are systemic challenges experienced in other cities as well [90–92]. An interim guidance was published recently on the national level, estimating the value of different aspects of pedestrian amenity, acknowledging however that "[t]here is little research examining the valuation of factors among subgroups, such as the disabled or children, who may have substantially different needs as compared to the general population." [42]

Auckland appears therefore as an interesting ground for examining barriers to walking experienced by diverse people, and professionals' perspectives on addressing those barriers. The findings can contribute to local practice but also help shape recommendations for other cities where walking has been neglected through traffic-oriented planning and design.

4 THESIS RATIONALE

4.1 Problem statement

As seen above, the WE likely plays a key role in walking as an outcome. Enabling and supporting walking therefore requires revisiting and adapting the WE. Environmental features deterring from walking contribute to key current issues, namely climate change, public health, and inequity.

It is suggested that retrofit of inherited infrastructure should focus in priority on removing existing barriers [13, 14] and improving users' experiences [17–19]. Therefore, an evidence-based, prioritised improvement of the WE should be based on the understanding of who experiences difficulties of walking to their destinations or PT stops, and what these difficulties are [11, 14, 21, 78].

While the research on walkability has made significant progress, the observed lack of consensus relates precisely to the nature of the barriers of access as perceived by diverse people, and the moderating effects of individual, social, and trip-related characteristics.

The problem statements underpinning this research are as follows:

- The existing WE can have wide-ranging negative outcomes, especially in car-oriented cities
- There is an urgent need to retrofit inherited WE in order to enable and support walking
- The retrofit should be evidence-based and address the most salient barriers to walking
- There is no consensus on the nature and objective characteristics of the barriers to walking as perceived by diverse people
- These associations between objective features, perceptions, and walking behaviour are expected to vary across individual, social, and trip-related characteristics, yet the moderating roles of those characteristics are not clear
- Disabled people are likely to experience highest challenges relative to access. Therefore, their perspectives are key for equalising accessibility.

The research question for th e thesis is:

What is the role of the quality of urban walking environments in walking trips foregone or negative walking experiences, from the perspectives of disabled and non-disabled people, and professionals involved in delivering walking environments?

To answer different dimensions of the research question, four sub questions were developed:

Question 1 How is the relationship between walking environment and walking behaviour conceptualised, considering individual, social, and trip-related characteristics?

Question 2 What features of the walking environment contribute to perceived difficulty or impossibility of walking to destinations within reachable distance, and how do they vary between disabled and non-disabled people?

Question 3 To what extent do existing local planning guidelines enable the identification of barriers to walking reported by people?

Question 4 To what extent do practitioners from different disciplines involved in the design of the walking environment and public health agree on the barriers to walking in Auckland, and the priorities and challenges regarding retrofit? What aspects are consensual, what others might be more debated, and how do they align with users' insights?

4.2 Thesis direction and scope

This thesis sought to better understand the associations between the WE and walking behaviour and provide specific feedback to transport and urban design professionals. **The initial assumption was that environmental barriers to walking are numerous, complex, systemic, and diverse across individuals, but not understood well enough to inform an evidence-based improvement of the WE.** Early engagement with local stakeholders (see Appendix 1D) confirmed the need for practical insights that can support the improvement of the WE. The contact with the stakeholders was maintained through the thesis, providing feedback on the results and findings (see Appendix 1E).

The thesis firstly established, based on a review of existing literature, a preliminary version of a theoretical model linking the WE to walking behaviour. The model was named here Social Model of Walkability (draft theoretical model). Components of the model were further developed through a second literature review and the subsequent quantitative and qualitative analyses.

4.3 Thesis aims

Five specific aims were formulated to answer the research questions and guide the specific studies as presented below. At the end of the introduction, specific studies are presented against the aim(s) they contribute to.

- **Aim 1:** Identify associations between people's perceptions of their WE and walking levels, considering individual characteristics and the use of public transport
- **Aim 2**: Identify features of the WE that can be perceived as difficulties or barriers to walking, comparing findings for disabled and non-disabled people
- **Aim 3**: Characterise objectively barriers to walking as reported by people, and compare the results with best practice and local guidelines
- **Aim 4**: Test and develop the draft theoretical model (Social Model of Walkability) through the findings
- **Aim 5**: Examine how professionals understand users' needs and how they see priorities, challenges, and evidence gaps for delivering quality WE in a car-oriented city

The studies were designed as a sequence, each building on the last. All studies revolved around the model, its development and testing, with a particular focus on the barriers to walking. The first two studies examined international peer-reviewed publications, while the four empirical studies focused on Auckland. The aims, data, and analyses for each study are presented in Table 2 below.

Table 2: Studies, data, and analyses

Study	Methods and data
Literature review examining how links between the WE and walking behaviour are conceptualised and evidenced	Systematic umbrella review; data: published peer-reviewed evidence
Literature review reporting the associations between specific WE characteristics and people's perceptions of walkability	Systematic umbrella review; data: published peer-reviewed evidence
Quantitative study identifying associations between people's perceptions of their WE and walking levels, considering individual characteristics and the use of public transport	Use of machine learning to predict walking levels based on perceptions of the WE and individual characteristics. Data: secondary data, Auckland Transport Active Modes Survey
Naturalistic inquiry examining motivators and barriers to walking, comparing disabled and non-disabled people	Interview data, site visits, and content analysis
Characterisation of the barriers to walking as reported by people, and comparison of the results with best practice and local guidelines	Choice of ad hoc metrics for each type of barriers, data collection (desktop and in situ), search for a minimal quantitative definition of each type of barrier and qualitative comparison with recommendations from guidelines and best practice
Assessment of professionals' views relative to users' needs, priorities, challenges, and evidence gaps for delivering quality WE in a car-oriented city	Online survey, focus group, and content analysis
Inquiry into motivators and barriers to walking as reported spontaneously by disabled and non-disabled participants	Use of participatory action research (Citizen Science), where participants collected insights from their neighbourhoods, content analysis

4.4 Original contributions

This thesis resulted in six original contributions to knowledge:

1. **The theoretical model linking WE to walking behaviour-The Social Model of Walkability- was tested and developed** through four studies examining its different characteristics. The role of the broader transport system was namely specified.
2. **The key importance of the broader transport system on walking levels was identified**, noting the importance of perceiving walking *as compared to* alternatives and the synergies with public transport. This investigation also showed potentials of machine learning for the investigation of complex phenomena and the problem of dealing with a large number of potential explanatory variables presenting multiple pairwise associations.
3. **People's perspectives were leveraged to identify critical barriers to walking** and compare difficulties experienced by disabled and non-disabled participants, using both interviews and Citizen Science.
4. **Critical barriers were objectively characterised**, identifying the most helpful metrics and establishing numeric thresholds beyond which an environmental feature such as a non-signalised intersection can be perceived as a barrier to walking.
5. **Design guidelines** [93, 94] **and the Healthy Streets approach** [95] **were critically examined in the light of the identified barriers to walking,** outlining misalignments, or: cases reported by people as non-walkable but considered conform by the practice. This contribution can directly assist with the development of guidelines that are more in line with users' experiences.
6. **The systemic complexity and the challenges of delivering walkable environments were tested** with professionals from a range of disciplines, identifying systemic barriers to implementation and suggesting pragmatic directions to addressing them.

4.5 Research principles and design choices

The thesis builds on three key principles. First, the thesis questions what matters, and in particular: what WE features can discourage walking or make it a difficult experience. This stance takes distance from noted tendencies to assume what matters and then test these assumptions [63]. Second, all investigations are contextualised using the draft Social Model of Walkability and are used to further develop the model. This means renouncing the examination of associations between two variables (e.g., a feature of the WE and a perception) without considering the context (e.g., individual characteristics). Third, WE is reality-checked based on people's perceptions of walkability, informing what is perceived as difficult or non-walkable and providing pragmatic insights for improving design. All three principles explore perspectives seen as both promising and under-used, in the current walkability research landscape, and therefore bring elements of originality.

Important design decisions regarding data gathering and analysis conditioned the scope of the different studies and of the thesis as a whole. First, previous evidence and research gaps were summarised using two umbrella literature reviews. A first umbrella review (chapter 2) examined how links between WE and walking behaviour are conceptualised and evidenced. A second umbrella review (chapter 3) summarised the evidence on the associations between specific WE characteristics and people's perceptions of walkability. The umbrella review methodology was chosen due to its utility in addressing broad questions and outlining research gaps [96]. The choice also acknowledged that a number of specific reviews had been published recently on the topic, enabling the reviews presented in this thesis to build on their findings, and to examine critically research needs to which this thesis could contribute. For the empirical studies, the decisions were motivated by the aim(s) each study targeted, presented in Table 3 below.

Table 3: Empirical studies and aims they are contributing to

Aims	Empirical studies[3] Quant	UX	WE	Pro	CS
Identify associations between people' perceptions of their WE and walking levels, considering individual characteristics and the use of public transport	■				
Identify features of the WE that can be perceived as difficulties or barriers to walking, comparing disabled and non-disabled people		■			■
Characterise objectively barriers to walking as reported by people, and compare the results with best practice and local guidelines			■		
Present a draft version of the Social Model of Walkability and inform it through the findings	■	■	■		■
Examine how professionals understand users' barriers to walking, and how they see the complexity, priorities, challenges, and evidence gaps relative to delivering quality WE in a car-oriented city				■	

The empirical studies built on previous research, examined through the two umbrella reviews. They focused on different components of the model, exploring and developing them through both qualitative and quantitative methods.

- **The associations between perceived WE and walking levels (aim 1)** was analysed quantitatively (chapter 4). The study design acknowledged and leveraged the Auckland Transport Active Modes Survey (capturing perceptions of walkability, demographic characteristics, and walking levels for over 4,100 Aucklanders [83]). Machine learning was used to find patterns in this large dataset with number of intercorrelated variables.
- **The identification of environmental features perceived as barriers (aim 2)** was grounded in the idea that the perceptions of diverse people of their environments depend on the context and can be explained by multiple interacting factors. Two forms of naturalistic inquiry were used to explore perceived barriers as a "multiple, intangible, divergent, holistic" reality [97]. First, 56 adults of all ages, disabled or non-disabled, and living in Auckland, were interviewed in 1-1 structured face-to-face interviews. Data and analysis were both quantitative (collection of categorical items and numeric ratings, analysis of distributions and frequencies of mentions), and qualitative (open-ended questions and their content coding). Second, a

[3] Quant: Quantitative associations perceptions – walking; UX: Perceived barriers and deterrents; BE: Objective measures of perceived barriers; CS: Citizen Scientists' inputs; Pro: Professionals' views on users' needs, priorities, and challenges

subset of interview participants continued being involved in the project as Citizen Scientists (CS), providing insights of their walking environments in a freer way, using a smartphone app [98] to capture photo and impressions (via voice recordings). In both cases, deductive content analysis [99] was used to code the results against the model.

- **The characterisation of WE features people consider as barriers to walking (aim 3)** was based on objective measures of barriers pointed out by interview participants. For each type of barrier, a minimal definition was established from the gathered measures. The results were then compared with the local guidelines and best practice, providing a reality-check anchored in people's experiences. The investigation namely sought to understand why certain environmental features might be experienced as hurdles while being conform by the planning documents.
- **The testing and development of the draft Social Model of Walkability (aim 4)** was achieved across the whole thesis, designing empirical studies to assess specific components, analysing their results from the perspective of the model, and using the findings to critically examine and develop the model.
- **Examining the complexity, challenges and priorities of delivering the walkable city (aim 5)** used first an anonymous survey of professionals working either in Auckland or at the national level. The disciplines targeted were urban design, urban strategy, transport planning, road safety, and public health. Analysis involved content coding and comparing the frequency of responses across professional groups. The results were discussed with the CS, outlining two topics to further investigate in a focus group. The focus group included four professionals and one CS, and data were analysed using inductive content analysis.

The studies are presented in Figure 2 (next page) against the questions and aims they contribute to, with an indication of the specific input they bring to each research question.

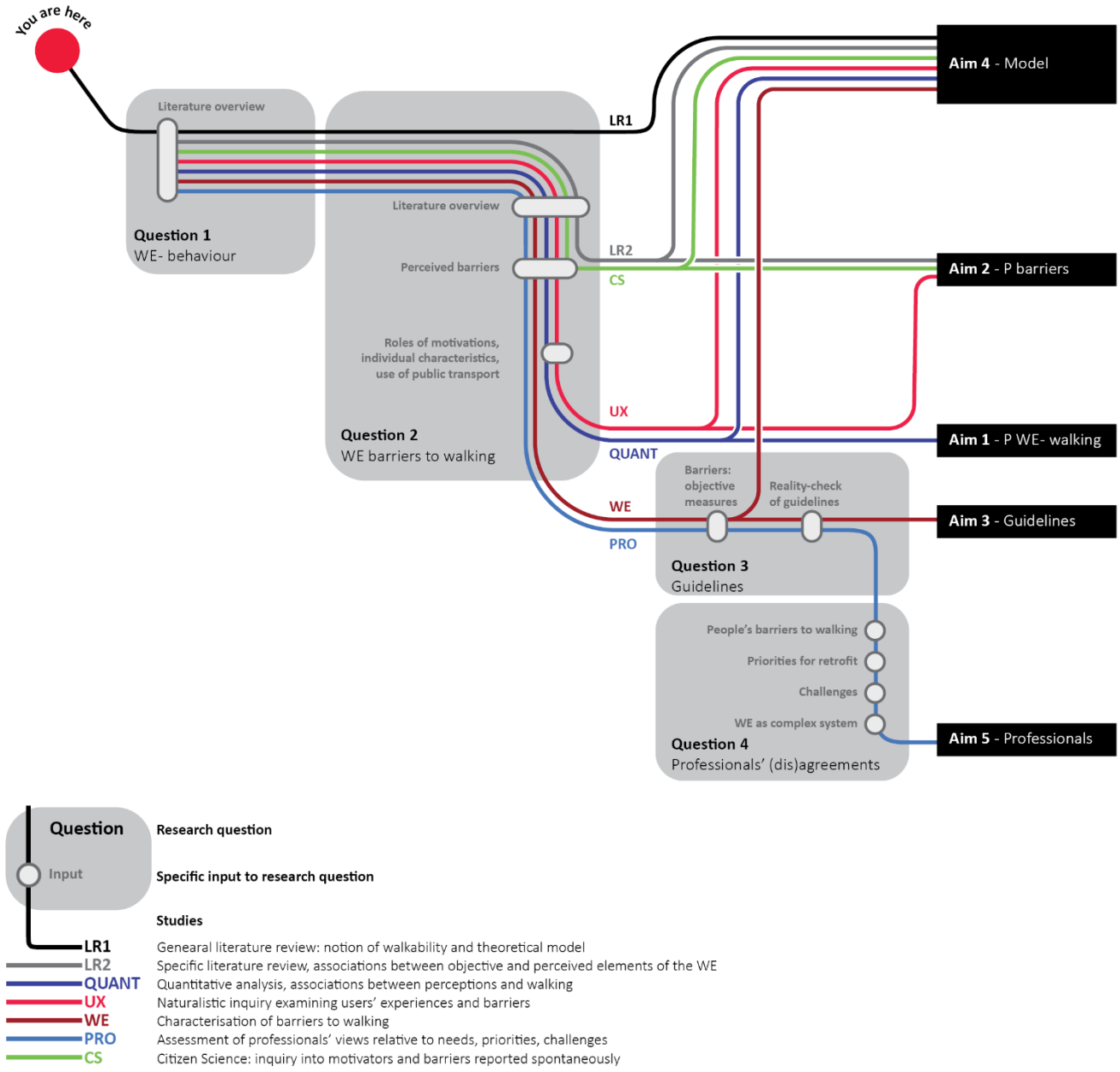


Figure 2: Studies and contributions towards aims and research questions

5 THESIS ORGANISATION

The thesis is organised as follows:

Chapter 2, p. 50 Examines how links between walking environments (WE) and walking behaviour were conceptualised and evidenced in the previous literature. The methodology of an umbrella review was chosen given the breadth of the topic and the variety of academic disciplines involved. The chapter is based on a published paper, and an update of the search is provided as postscript.

Bozovic, T., Hinckson, E., & Smith, M. (2020). Why do people walk? role of the built environment and state of development of a social model of walkability. Travel Behaviour and Society, 20, 181–191. https://doi.org/10.1016/j.tbs.2020.03.010

Chapter 3, p. 77 Summarises the evidence on the associations between specific objective WE characteristics (O) and people' perceptions of walkability (Pw), the first key link of the draft Social Model of Walkability. The umbrella review was chosen to provide an overview of a broad question, parts of which have been treated by recent systematic reviews. This work provides an overview of the findings, approaches, and research gaps. The chapter is based on a paper submitted for publication:

Bozovic, T., Hinckson, E., Stewart, T., & Smith, M. (Submitted for publication). How do walking environments relate to users' perceived walkability: An umbrella review, 2009-2020.

Chapter 4, p. 99 Identifies associations between people' perceptions of walkability and walking levels in Auckland, considering individual characteristics and the use of public transport. This empirical study tests the second key link of the draft Social Model of Walkability, using data from Auckland Transport Active Modes Survey [83]. The chapter is based on a published paper:

Bozovic, T., Stewart, T., Hinckson, E., & Smith, M. (2021). Clearing the path to transcend barriers to walking: Analysis of associations between perceptions and walking behaviour. Transportation Research Part F: Traffic Psychology and Behaviour, 77, 197–208. https://doi.org/10.1016/j.trf.2021.01.003

Chapter 5, p. 113 Examines the choice of walking (or not) to usual destinations and identifies features of the WE that can be perceived as difficulties or barriers to walking, comparing disabled and non-disabled people living in Auckland. This naturalistic inquiry provides another perspective on the two key associations of the draft Social Model of Walkability controlling for familiarity and examining the role of disability as a moderating factor. The chapter is based on a paper submitted for publication:

Bozovic, T., Hinckson, E., Stewart, T., & Smith, M. (Submitted for publication). How street quality influences the walking experience: a naturalistic inquiry into the perceptions of adults with diverse ages and disabilities.

Chapter 6, p. 135 Characterises objectively the barriers to walking as reported by people (chapter 5) and compares the results with best practice and local guidelines relative to the provision of walking environments. This chapter revisits the association O-Pw previously examined through the published literature (chapter 3), informed by the evidence gaps noted. Recommendations from the local guidelines and the Healthy Streets approach [95] are examined against the findings, and misalignments are discussed. The text is based on a paper submitted for publication:

Bozovic, T., Hinckson, E., Stewart, T., & Smith, M. (Submitted for publication). Barriers to walking: Relating walkers' experiences to measurable built environment characteristics.

Chapter 7, p. 155 Examines how professionals involved in the delivery of WE and public health understand users' needs and how they see priorities, challenges, and evidence gaps for delivering quality WE in a car-oriented city. This work is a form of retroaction loop in the draft Social Model of Walkability, examining how the low observed levels of walking are understood and addressed through changes in the WE. The text is based on a published paper:

Bozovic, T., Hinckson, E., Stewart, T., & Smith, M. (2021). How to improve the walking realm in a car-oriented city? (Dis)agreements between professionals. Transportation Research Part F: Traffic Psychology and Behaviour, 81, 490–507. https://doi.org/10.1016/j.trf.2021.06.011

Chapter 8, p. 190 Examines associations between objective characteristics of the WE, people's perceptions of walkability (O-Pw) and the declared outcomes in terms of walking, this time through CS inputs. The use of CS provides a different lens, allowing a different form of investigation of people's perceptions, freed from the formal structure of the interview (chapter 5).

CHAPTER 2: BUILDING THE THEORETICAL MODEL LINKING BUILT ENVIRONMENT TO WALKING – GENERAL LITERATURE REVIEW

PREFACE

This chapter examines the notion of walkability – how it is understood and conceptualised, and develops a theoretical model based on previous findings. The material presented here stems for an umbrella review published in Travel Behavior & Society (title: Why do people walk? Role of the built environment and state of development of a social model of walkability [100]). The identification of a drafted theoretical model [43] and its developments [49, 53, 54] played an important role in this thesis: the following studies built on this base and continued testing and developing the model.

The original paper (Appendices, from page 125) has undergone minor edits aiming to:

- Bring one correction (word “confounder” instead of “moderator”);
- Improve readability, for instance referring to chapters of this thesis instead of publications and making minor changes of wording; and
- Present the studies having identified and developed the theoretical model in some more detail (tabular form, with more insight on the contributions and limitations).

Given this key importance of the draft Social Model of Walkability in this thesis, it seemed appropriate to provide an update relative to findings published after the cut-off date of the published paper. A post-script to this chapter was added for this purpose, examining publications having cited at least one of the four mentioned papers, and adding relevant findings to the table presenting the contributions to the model.

1 INTRODUCTION

Technological development is contributing to new forms of mobility (e.g. shared vehicles or scooters); its ease of use (information, payment); and possibilities to replace trips altogether [101]. While the concept “mobility as a service” (i.e., shift from privately owned vehicles to shared solutions that are consumed on a subscription base) is gaining traction, walking and walkable places appear to be high on the priority list of cities and citizens [102–106]. The broad benefits of walking are well established, namely in terms of equity of access and independent mobility [11, 59, 107, 108]; social and economic participation [16, 24–27]; physical activity [16, 28–31]; and urban economic efficiency [32, 33]. A modal shift towards walking and other low carbon modes is also a key part of the response to the global climate crisis and meeting sustainable development goals [5, 6]. In a rapidly urbanizing world [109], “walking as a choice” is therefore likely to be an increasingly important topic. The underlying question will be what to build, retrofit and provide, for diverse people to choose walking against alternatives?

Research on walking has made significant progress in understanding the dimensions influencing individual choices. The Socio-Ecological Framework is widely accepted as a sound theoretical approach to human activity behaviours, capturing the importance of the Built Environment (BE) in conjunction with individual; social/cultural; organizational; community; and policy dimensions [21, 43, 45]. The framework provides an overall principle of multiple dependencies under which to develop a specific model for walking [43, 45]. Multiple calls for a better understanding of pathways through which BE correlates with walking behaviours have been made [21, 43, 110–113].

There is at the moment no commonly agreed model explaining walking as a choice. For instance, as recently as 2016, Buckley and colleagues examined the question why people walk [54]. There is also uncertainty regarding what people pay attention to and how they adjust their behaviour. For instance, in 2018, Read and colleagues studied two relatively simple and well-defined pedestrian situations (road crossing and railway level crossing), comparing walking as done by study participants and as imagined by transport practitioners [114]. They noted that "a gulf exists between pedestrian activity ‘as imagined’ and ‘as done’" [114]. The study highlighted the high level of diversity and complexity of pedestrian behaviour and a certain unawareness of it from the professionals [114].

The understanding of a "walkable" place remains debated [21, 55, 58]. A variety of indices measure environmental "walkability" using diverse sets of metrics [115–118]. As existing evidence generally focuses on non-disabled people, there is a need to better understand the barriers experienced by people with diverse types and levels of disability [16, 24, 57, 119, 120]. Disability is one lens, with evidence suggesting the need to consider other "customer segments" differing for instance in their familiarity with the area [121], usual modes of transport [49], ages [122], or cultural and socio-economic backgrounds [20].

Cities with an inherited car-centric BE are understood to contribute to difficulties for walking [123–126]. Retrofit and better design offer important potentials towards providing places that support human well-being and walking as a choice [123, 126, 127]. However, certain confusion remains as to the best way to improve environments for walking, health and wellbeing.

It is not clear if a single definitive model linking walking to the built environment is a reasonable quest, given the evolution of the alternatives to walking [101] or the simple fact that a "perfectly walkable" environment might not exist. However, better understanding the influences of BE on the choice of walking would help assess what is non-walkable, and aid specifying the *"minimal definition of physical walkability"* [21].

The main objectives of this chapter are to:

- Examine how the BE has been conceptually related to walking behaviours;
- Examine how the posited models are supported by evidence; and
- Present a new version of a model named the Social Model of Walkability based on the findings. The name is an intentional nod to the Social Model of Disability [47], acknowledging the importance of the BE in supporting or hindering walking as a choice.

In addressing the objectives, the following questions were asked:

1. **How is the notion of "walkability" understood**, and what are the elements of consensus / disagreement? Are theoretical models linking BE features to walking behaviour identified?
2. **Which correlations between specific BE features and walking behaviou**r have been examined, and what are the results?
3. **How are the BE features measured**, and to what extent are they comparable across studies?
4. **How does the available evidence inform the possible moderating factors** relative to the person or their trips?

Given the scope of the questions, the volume of research produced in the last decade, stemming from different fields, and the anticipated heterogeneity of publications, the methodology chosen is a critical umbrella review [96]. Umbrella reviews, otherwise known as reviews of reviews, are useful for compiling findings relative to broad questions into one usable document [96]. This approach was complemented by examining primary studies developing or informing theoretical models linking BE to walking as a behaviour. This critical umbrella review focuses on adults living in post-industrialised urban environments.

2 MATERIALS AND METHODS

2.1 Search strategy

Scopus and Science Direct databases were chosen for this critical Umbrella review because they offered a large coverage of the published literature across disciplines specifically related to the research question [21, 55] including health, urban design, sociology and transport planning. Two searches were made, with the following search terms:

(walkability AND built AND environment)
OR
(walking AND (choice OR neighbourhood OR neighborhood OR parameters OR determinants)).

The search included literature reviews published in the 10 years, up to 18.4.19.

2.2 Selection of reviews

Articles were first screened on titles and abstracts, before a full text review. The inclusion criteria were: (a) adult population, or providing separately results for adults; (b) urban or suburban environments, or providing separately results for urban or suburban environments; (c) examines associations between BE aspects and walking, or examines critically the notion of walkability;
(d) refers to environments that can be compared to post-industrialised car-centric societies, defined as having a high or very high human development index (HDI); and having a car ownership over 200 per 1,000 residents.

2.3 Data extraction

Two types of data were extracted for each study:

a. **Focus and scope**, noting (a) what aspects of built environment were considered (destinations availability and/or quality of walking realm, objective and/or perceived); (b) if these aspects correlated to walking levels or experienced barriers and facilitators; (c) if disability, old age and self-selection were controlled for; (d) if a theoretical model was developed or tested; and (e) if walkability as a concept was examined.
b. **Reviews findings linking BE and walking**.

It was expected that the volume of evidence for the associations between BE and walking would be both low and difficult to compare across reviews, given namely (a) the absence of a commonly agreed set of indicators of walkability that are specific, comprehensive, and mutually exclusive; and (b) the diversity of measures of outcomes (walking distances, times, trips, etc.). After the full text review of the papers, it was decided to harness the strength and volume of evidence provided by the two recent meta-analyses sharing the same methodology [64, 65] by keeping both their BE categories and their method for the synthesis of findings, i.e.: categorising BE-walking associations as significantly positive (P), significantly negative (N), or not statistically significant (Ø); allowing single articles to contribute several findings; and giving fractional weights in case of multiple associations found by a study for a same BE attribute (e.g., if one attribute is positively associated for walking in men but non-significant for women, it will be noted as P: 0.5, and Ø: 0.5). Where p values were provided, results significant at $p < 0.05$ were recorded. BE categories were assimilated to those of the meta-analyses unless they referred to a slightly different or more specific BE feature (for instance: the meta-analyses speak of “safety from traffic”, while others speak of “safe and convenient crossings” [128]). Categories relative to people’s perceptions were re-ordered under the broad topics of feasibility, safety from crime, accessibility, comfort and pleasure, posited by Alfonzo as levels of walkers’ needs [43]. The needs range from the most basic to the most sophisticated [43]. Statistically significant positive and negative correlations were noted, as well as non-significant findings ($p > 0.05$).

2.4 Data processing

Positive, negative, and non-significant (where reported) findings for each BE category were summed separately for overall walking and walking for transport. Ratios of positive, negative, and non-significant findings were calculated for all studies, as well as ratios of findings in unexpected directions.

3 RESULTS AND DISCUSSION

The search identified 194 titles. After screening of titles and abstracts, 54 reviews were retained for full review. Of these, 17 met the inclusion criteria. The screening and filtering process of the papers is presented in Figure 3 below.

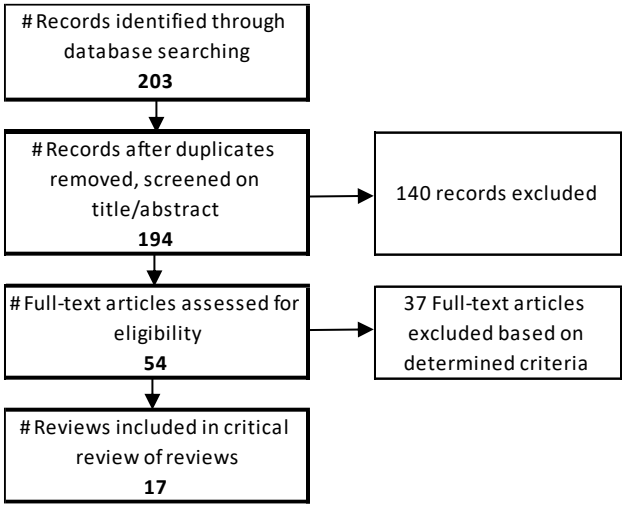


Figure 3: PRISMA diagram for article screening and inclusion process

Of the identified 17 reviews, eight analysed the notion of walkability, and nine focused on the BE-walking correlates. From these, three were specific to urban or suburban environments, while six others (including the two recent meta-analyses) also included some rural contexts and did not differentiate the findings for both groups. Given the limited evidence identified specific to urban/suburban areas, it was decided to broaden the scope, keeping for analysis the reviews that were not exclusively urban. To limit the risk of bias, differences by type of setting were investigated and reported.

3.1 Question 1: How is the notion of "walkability" understood?

The eight identified reviews provide essential and in-depth insights into the definitions and meanings of the term walkability [22] along with the concept of walkable suburbs [55] and neighbourhoods [58]; the different dimensions of "walkability" [21]; the understanding of barriers to walking for diverse population groups [57, 62]; and a critical analysis of the professional practices [55, 63] and operational measures of accessibility [56]. The findings are synthetized below under four aspects: complexity, elements of consensus, dissensions, and contributions to a theoretical model.

3.1.1 Walkability as a complex phenomenon

Authors agree on complexity, noting that "overall, walkability is a complex and contested phenomenon" [21], or that *"the research landscape now crowded with competing claims about what the walkable neighborhood can be expected to do"* [58]. A vast array of potential benefits is described, ranging from enhancing social interaction and the sense of community [55] to improving liveability and equity of access [57] or supporting residents' daily activities [58]. Different professions such as urban design, health, or transport were also found to focus on different aspects of walkability such as the outcomes in terms of physical activity or the quality of design [21, 63]. This is problematic when attempting to identify specific assets that should be built or improved, as diverse aspirations and focuses can contribute to the diversity of recommendations for delivering "walkability" [21].

Acknowledging this diversity of views, Talen and Koschinsky nonetheless had an attempt at defining the "walkable neighbourhood" as *"a safe, well-serviced neighborhood, imbued with qualities that make walking a positive experience*."[58]. Beyond a broader dissension on what a "neighbourhood" is and how it is defined [57, 63, 129, 130], a pertinent question is what does "positive experience" look like, and does this differ across ages, disabilities or other characteristics?

3.1.2 Elements of consensus regarding walkability

Authors generally agree that walkability includes:

- Destinations within a walkable distance [22, 55, 56];
- An absence of barriers to access [27, 57] and
- A form of safety from crime and traffic [21, 22, 58].

These are in a way minimum requirements [21]. Taking a holistic perspective, the reviews note (a) the importance of people's perceptions of difficulties or barriers [16, 27, 57]; (b) the current high levels of difficulties of walking in car-oriented environments, with high traffic exposure and limited appropriate crossings [22, 27]; and (c) inequities of access [16, 22, 57, 57]. These elements of consensus align with evidence regarding the barrier effect caused by traffic, identified since the 1960s [125, 131]. Overall, providing street environments supportive of walking requires a better understanding of the determinants of walking behaviour [16, 21, 22, 57, 63].

3.1.3 Lack of consensus: Quality of the walking environment

Lack of consensus has been noted mainly around the quality of the BE and its importance for walking [21, 22, 55]. Andrews and colleagues note two difficulties. First, findings outline an apparent "mismatch between objective and perceived measures of neighbourhood walkability", otherwise said: objective measures fail to capture users' perceptions people's perceptions [63]. Second, perceptions are often considered less legitimate than the objective measures [63]. In the absence of an agreed theoretical model, research might consider objective and perceived measures as interchangeable and veer towards the objective features only.

The diversity of used tools and methods makes it difficult to aggregate results and find consensus. Major methodological issues are noted in ways walkability is assessed and measured. For instance, studies use diverse scales for assessing BE quality (e.g. [62, 95, 123, 132, 133]) and apply them to diverse geographical areas (e.g., 400m from home). Further, there is no guarantee that the characteristics usually positively associated with walking cover indeed all that matters to people in a non-redundant way [21]. There is a lack of understanding of why these features matter, how much they matter [56], and how individual characteristics might moderate this importance [16, 57, 62]. Andrews and colleagues speak of 'neo-environmental determinism' [63] to describe this vast array of assumptions, further discussed under Question 3, below.

3.1.4 Identified contributions to a theoretical model of walkability

Forsyth outlined the work of Alfonzo as a major contribution to the understanding of the relationship between BE and walking [21, 43]. Alfonzo posited a hierarchy of pedestrian needs, referring to Maslow's pyramid of human needs [43]. The posited needs range from the most basic (feasibility and accessibility) to a higher order (pleasure); safety and comfort are placed in between [43]. Further, Alfonzo's model considers that objective BE characteristics are filtered by users' perceptions, which inform the satisfaction of needs for walking. The decision to walk depends on the satisfaction of needs but also on individual characteristics [43]. Alfonzo posited that people first assess the satisfaction of most basic needs, before considering higher order ones, noting that the (non) satisfaction of the needs could be associated with walking through the moderating effects of individual constraints, available options, trip purposes or preferences [43]. Alfonzo's model was further developed and tested by Mehta [53] and Buckley and colleagues [54]. Although not formally referring to Alfonzo's model, Ma and Cao's study was included given its conceptual proximity (testing the associations between objective features, perceptions, individual characteristics and behaviours) [49]. An overview of the studies and findings is provided in Table 4 below.

Table 4: Testing and development of Alfonzo's model

First author and year	Aspects of the model tested	Methods and setting	Findings	Limitations
Mehta, 2008 [53]	Association between BE (microscale urban design qualities), perceptions, and route choice.	Interviews of adults who visit the three chosen sites (three Main Streets in US East Coast towns and cities). N = 51	The model was overall supported **Detail, O-P** ▪ Human presence added to the pleasure of walking ▪ Holistic environments: appeal of human presence and visual interest of the street, together ▪ Suggested that the order of the hierarchy of walking needs might vary depending on the situation **Suggested additions:** ▪ The sense of belonging or familiarity - knowing shops and cafes turned those places in social destinations, increasing their appeal ▪ The usefulness of available destinations	Low sample number Participants including few older and no disabled adults Trip purpose not considered Interview of people who visit the setting – no information regarding barriers faced by those unable to access it
Buckley, 2016 [54]	Agreement with 15 potential motivators to walking chosen, considering demographic and trip-related differences	Intercept surveys on a major street in Vancouver. N = 318	The model and the levels of hierarchy of walking needs were overall supported **Suggested additions:** ▪ Internal motivations ▪ Personal values **Detail, O-P** ▪ Importance of visual appeal (motivation) Basic needs (e.g. good footpaths, crossings) have a low motivational interest Detail, individual characteristics: ▪ Familiarity as a motivation	Chosen motivators tested were not necessarily mutually exclusive or complete Participants including few older and no disabled adults Interview of people who visit the setting – no information regarding barriers faced by those unable to access it

First author and year	Aspects of the model tested	Methods and setting	Findings	Limitations
Ma and Cao, 2019 [49]	Associations between travel behaviour, perceived neighbourhood characteristics, attitudes to travel modes and demographic data	Self-administered survey of residents living in five chosen corridors in Twin Cities, US. N = 1303	Availability of destinations associated with travel behaviour through perceptions, supporting the model. **Modal preferences** were associated with perceptions of accessibility (small effect) and travel behaviour (large effect) Demographic characteristics moderate: ▪ The associations between O and P (gender, age, level of education, having children) ▪ The modal choice (level of education)	No data regarding possible disability O measures of proximity of destinations were poorly aligned with people's perceptions. The association was better after including travel preferences but still imperfect, indicating other possible moderators

3.2 Question 2: Which correlations between specific BE features and walking have been examined?

3.2.1 Identified reviews and scopes

Nine reviews examining the correlations between BE and walking were identified. Seven reported walking for all purposes [16, 30, 64, 65, 113, 128, 134], three reported walking for transport [113, 134, 135] and two for recreation [113, 134]. Two recent reviews [64, 65] stand out for being meta-analyses with sophisticated methods for weighting articles by quality and sample size, a control for non-duplication of primary findings, and estimates of strengths of associations between each examined BE construct and walking. This effort is of high importance, given the difficulty to compare primary data as it shows a vast diversity in ways BE or walking as an outcome are operationalised [64, 136]. Both reviews focused on older adults (defined as mean population age higher than 65 years) and examined how objective and self-reported measures of BE compared, as correlates to walking.

Overall, the identified reviews considered specific sets of BE attributes and operationalised them in different ways. None of the reviews claimed to have a set of attributes that was comprehensive, minimal, and non-redundant. They generally tested aspects identified by previous studies as being potentially correlated with walking, with the caveats that those studies themselves warned against potential bias, redundancy or gaps (e.g. Frank's 3D walkability index [116]). The variety of scopes is summarized below against the broad types of attributes and the ways they were measured. The five reviews that examined both high level and qualitative attributes included the two meta-analyses focusing on older adults [64, 65]. The other three examined non-disabled adults [113, 128] and adults with disabilities [16].

Table 5: Numbers of reviews considered split by the attributes and the type of measure they considered; the two meta-reviews are noted in bold

	Attributes considered			
Type of measure	**Both high level (a) and street-scale (b)**	**High level (a) only**	**Street-scale (b) only**	**Total**
Objective only	1	2	-	**3**
Perceived only	1	-	-	**1**
Objective or perceived	1	1	1	**3**
Objective and perceived	**2**	-	-	**2**
Total	**5**	**3**	**1**	**9**

(a): Neighbourhood or area-level aggregate measures such as land use mix, street connectivity or number of destinations; (b) Street-scale (micro-scale) attributes such as presence of street furniture or traffic volumes/speeds

The overall poor quality of the primary studies is to be noted: for instance, only 9% of the 100 papers examined by Barnett and colleagues were considered “high quality” [65]. Both meta-analyses noted that two thirds of the papers could not demonstrate representativeness of the population, and that papers had diverse levels of adjustment for socio-economic characteristics or appropriateness of analytical methods. Findings are further difficult to compare directly across reviews, given (a) the differences of approaches (weighting of findings as done in the meta-analyses vs simple reporting of findings); (b) the widely diverse ways BE was operationalised (see above); and (c) the potential redundancies of primary data. The issue of quality had been previously outlined [130, 137].

3.2.2 Built environment correlates with walking

The BE characteristics were classified using the Neighbourhood Environment Walking Scale (NEWS) [115] in the meta-analyses [64, 65], while the other reviews used own categories and definitions. The results are here examined using the NEWS categories complemented with additional dimensions that were examined. It should be noted that the results are influenced by (a) a strong focus of the reviews on the domains of feasibility of walking trips and safety from crime, with less investigation into aspects relative to comfort and pleasure; (b) same primary data were sometimes included in more than one reviews.

Overall, strong support was found for the elements of trip feasibility and some of the elements of street environment quality. When different reviews examined the same BE aspect, their conclusions were sometimes a mix of statistically significant and non-significant findings. When examining constructs individually, the reported findings from the primary studies show generally large proportions of non-significant findings (for instance, “overall access to destinations” is noted as strongly and positively significant in both studies but respectively 77% and 54% of weighted primary inputs are non-significant). Counter-intuitive results were also found, such as negative influence of safety from crime and of residential density [65], or positive influence of littering, vandalism and decay [64]. Some examined aspects are not part of the NEWS scale, namely: retail floor area ratio [134]; presence of jobs [134, 135]; connected pedestrian infrastructure as a better measure of connectivity than road centre lines [128, 134]; presence of other people walking, different possible barriers to walking, adequate crossing facilities, and noise [128]. All were supported as correlates of walking without counter-intuitive primary findings but based on low numbers of primary studies. Importantly, many of the qualitative aspects that are associated with walking outcomes (e.g. accessibility, availability of green spaces, aesthetics) have also been associated with the broader quality of place and further outcomes in terms of health, social connectedness, or neighbourhood satisfaction [138]. Overview results for total and transport walking are detailed in the table below, while details are in Appendix 2B.

Table 6: Associations WE- walking

		Associations with walking overall (a)							Associations with walking for transport		
		Meta-analyses									
		Barnett et al 2017	Cerin et al 2017	Salvo et al 2018	Ewing, Cervero, 2010	Eisenberg et al 2017	Mccormack et al 2011	Haselwandter et al 2015	Ewing, Cervero, 2010	Grasser et al, 2013	Mccormack et al 2011
		Population: older adults (>65)	Population: older adults (>65)		Urban or suburban only	Adults with disabilities	Urban only		Urban or suburban only		Urban only
	(b) **3D - Destinations availability**										
!	Composite walkability index*	**P**	**P**	na	na	Ø	na	P	na	P	P
!	Residential density/urbanisation*	**P**	**P**	na	Ø	Ø	na	na	na	P	P
	Land-use mix—destination diversity*	Ø	**P**	na	P	na	P	na	P	Ø	P
	Retail floor area ratio	na	na	0	P	0	0	0	P	na	na
Feasibility	Street connectivity*	Ø	**P**	na	**P**	Ø	P	Ø	na	P	na
	Connected pedestrian infrastructure*	na	na	P	P	na	na	na	P	na	P
	Overall access to destinations & services (distance to, availability)*	**P**	**P**	na	na	P	P	na	na	na	N
	Acess to public transport (distance to, availability)*	**P**	**P**	P	na	na	Ø	na	na	na	na
	Parks/public open space (distance to, availability)*	**P**	**P**	P	na	na	Ø	na	na	na	na
	Detail - availability of specific destinations (distance to, availability)*										
	Shops/commercial*	**P**	**P**	**P**	na	Ø	na	na	P	na	na
	Food outlets*	Ø	Ø	na	na	na	na	na	na	na	na
	Education*	Ø	Ø	na	na	na	na	na	na	na	na
	Health & aged care*	Ø	Ø	na	na	na	na	na	na	na	na
	Recreational facilities*	P	Ø	na	na	na	na	na	na	na	Ø
	Social recreational facilities*	P	P	na	na	na	Ø	na	na	na	na
	Jobs*	na	na	na	P	na	Ø	na	na	P	na
	Street environment										
Safety from crime	! Safety from crime*	**P**	Ø	na	na	na	na	na	na	na	na
	Design - "eyes on the street", active facades*	na	na	na	na	na	na	na	na	na	na
	Lighting* (! Could be also comfort)	na	Ø	**P**	na	na	P	na	na	na	na
	Littering, vandalism, decay* (in "aesthetics", Haselwandter et al)	na	**N**	**N**	na	na	na	na	na	na	na
	Presence of people seen as threatening*	na	Ø	**N**	0	na	na	na	na	na	na
	Presence of other people walking*	na	na	P	na	na	na	na	na	na	na
	Presence of other people walking OR driving*	na	P	na	na	na	na	na	na	na	na
	Presence of police*	na	na	Ø	na	na	na	na	na	na	na
Accessibility	! Barriers to walking*	na	na	0	0	na	na	0	na	na	na
	Barriers - incomplete walking infrastructure*	na	na	N	na	na	na	na	na	na	na
	Barriers - not sufficient crossing facilities*	na	na	N	na	na	na	na	na	na	na
	Barriers - footpaths design*	na	na	na	na	na	na	na	na	na	na
	Barriers - footpaths maintenance / cluttering*	na	na	N	na	na	na	na	na	na	na
	Detours, pedestrian network not allowing convenient use	na	na	na	na	na	na	na	na	na	na
Comfort	Safety from traffic*	Ø	Ø	na	na	na	Ø	na	na	na	P
	Safe and convenient crossing facilities*	na	na	P	na	na	na	na	na	na	na
	Room for walking	na	na	na	na	na	na	na	na	na	na
	Possibility to sit	na	**P**	na	na	na	na	na	na	na	na
	Availability of public toilets	na	Ø	na	na	na	na	na	na	na	na
	Protection from sun/rain/wind	na	na	na	na	na	na	na	na	na	na
	Low levels of noise	na	na	na	na	na	na	na	na	na	na
	Air pollution	na	na	N	na	na	na	na	na	na	na
	Noise	na	na	N	na	0	na	0	na	na	na
Pleasurability	Greenery, landscaping, "aesthetically pleasing" scenery*	**P**	Ø	**P**	na	na	na	na	na	na	Ø
	Attractive zones for sitting / public spaces*	na	na	na	na	na	P	na	na	na	na
	Liveliness, activation, diversity, complexity (interesting walking realm)*	na	na	na	na	na	na	na	na	na	na
	! "Walk-friendly infrastructure" or "pedestrian-friendly features"*	**P**	**P**	na	na	Ø	Ø	na	na	na	Ø
	! Good design (e.g. human scale, right enclosure)	na	na	na	na	na	na	na	na	na	na

Notes

a Directions of associations after full adjustment for sample size and study quality; P = positive (p<0.05), Ø = non-significant, N = negative (p<0.05). Bold: 5 or more findings

b Sign "!" placed in front of indicators not referring to a specific BE feature but rather a cluster of features; the associations with walking do not allow to assess the relative importance of specific

* Indicators reflecting the authors' categories; caution, authors' clustering and primary studies' ways of measuring components might vary, and some overlaps exist (e.g. "safe and convenient

3.3 Question 3: How are BE features measured, and to what extent is this comparable across studies?

Major methodological issues are noted in ways walkability is assessed and measured. Three types were identified: the use of proxies, poor and inconsistent assessment of BE quality, and lack of consideration of needs of disabled and older people.

- **Use of proxies.** Elements such as connectivity index or residential density can be considered as proxies: while the direct causal link might be absent (i.e. someone might not choose to walk because there are 230 people per square hectare in their neighbourhood), correlations might be found with levels of walking because these proxies code for other aspects not considered, such as for instance availability of destinations or difficulty of driving [58].

- **Poor and inconsistent assessment of BE quality**. The quality of BE often only captures the presence/absence of assets assumed to be important [63]. As noted above, scales and tools used are diverse and applied to diverse geographic environments, and features tend to be examined in a vacuum (as opposed to a holistic assessment of street environments). BE characteristics were reported under different "labels" by different reviews, making them difficult to compare. Specific BE attributes were often clustered under review-specific umbrella-terms (e.g., presence of graffiti, litter or abandoned buildings against the construct "safety" [139]). The reviews outlined also the heterogeneity in ways primary studies assessed similar constructs: investigations based on objective and/or perceived measures, and the objective measurements themselves could vary (e.g. "connectivity" - sometimes also called "design" [134]- can relate to block sizes, intersection densities, or a ratio of four- or three-way intersections to all intersections, while the land use mix can be calculated as the entropy index, the Herfindahl–Hirschman index or other measures such as the number of different land uses [135]). The measures also relate to diverse perimeters (e.g., various distances from home, an administrative area, or else a perceived territory reachable within 10 or 20 minutes [64, 65]).
- **Lack of consideration of needs of disabled and older people**. The needs of disabled people and older people are broadly overlooked. The identified reviews did not present results by types and levels of disabilities, nor provide an overview of how needs might vary across age groups. This is problematic as it is known that these groups can be sensitive to specific environmental attributes such as for instance the presence of physical barriers (see points 3.4.2 and 3.4.3 below).

The analysis of objective versus perceived measures showed significant differences between the two constructs. Findings from Cerin et al. [64] are summarised in the table below. For the six overall significant correlations, only the residential density and the access to public transport were significantly correlated with both objective and perceived measures. For land use mix diversity and availability of parks, only the perceived measure was significant, and the objective measure was the only correlated with street connectivity.

Table 7: Associations BE-walking from Cerin et al, 2017, detailed by type of measure, objective/perceived

		Directions of associations (a) by type of measure	
	BE attributes	**Objective only**	**Perceived only**
!	Residential density/urbanisation (?)	**P**	**P**
	Land-use mix—destination diversity (?)	Ø	**P**
	Street connectivity (?)	**P**	Ø
	Access to public transport (distance to, availability) (?)	**P**	**P**
	Parks/public open space (distance to, availability) (?)	Ø	**P**
	Safety from traffic (?)	Ø	Ø
	Greenery, landscaping, "aesthetically pleasing" scenery (?)	Ø	Ø
!	"Walk-friendly infrastructure" or "pedestrian-friendly features" (?)	Ø	Ø

Notes

a Directions of associations after full adjustment for sample size and study quality; P = positive ($p<0.05$), Ø = non-significant, N = negative ($p<0.05$).

! Indicators not referring to a specific BE feature but rather a cluster of features; the associations with walking do not allow to assess the relative importance of specific features

(?) Indicators reflecting the authors' categories; caution, authors' clustering and primary studies' ways of measuring components might vary, and some overlaps exist (e.g. "safe and convenient crossing facilities" is part of a broader "safety from traffic construct)

Overall, a high level of “noise” was observed resulting of comparing results of associations between BE and walking. A possible explanation relates to primary findings, representing an extraordinarily vast number of possible combinations between BE constructs and walking measures. This complexity is illustrated in Figure 4 below.

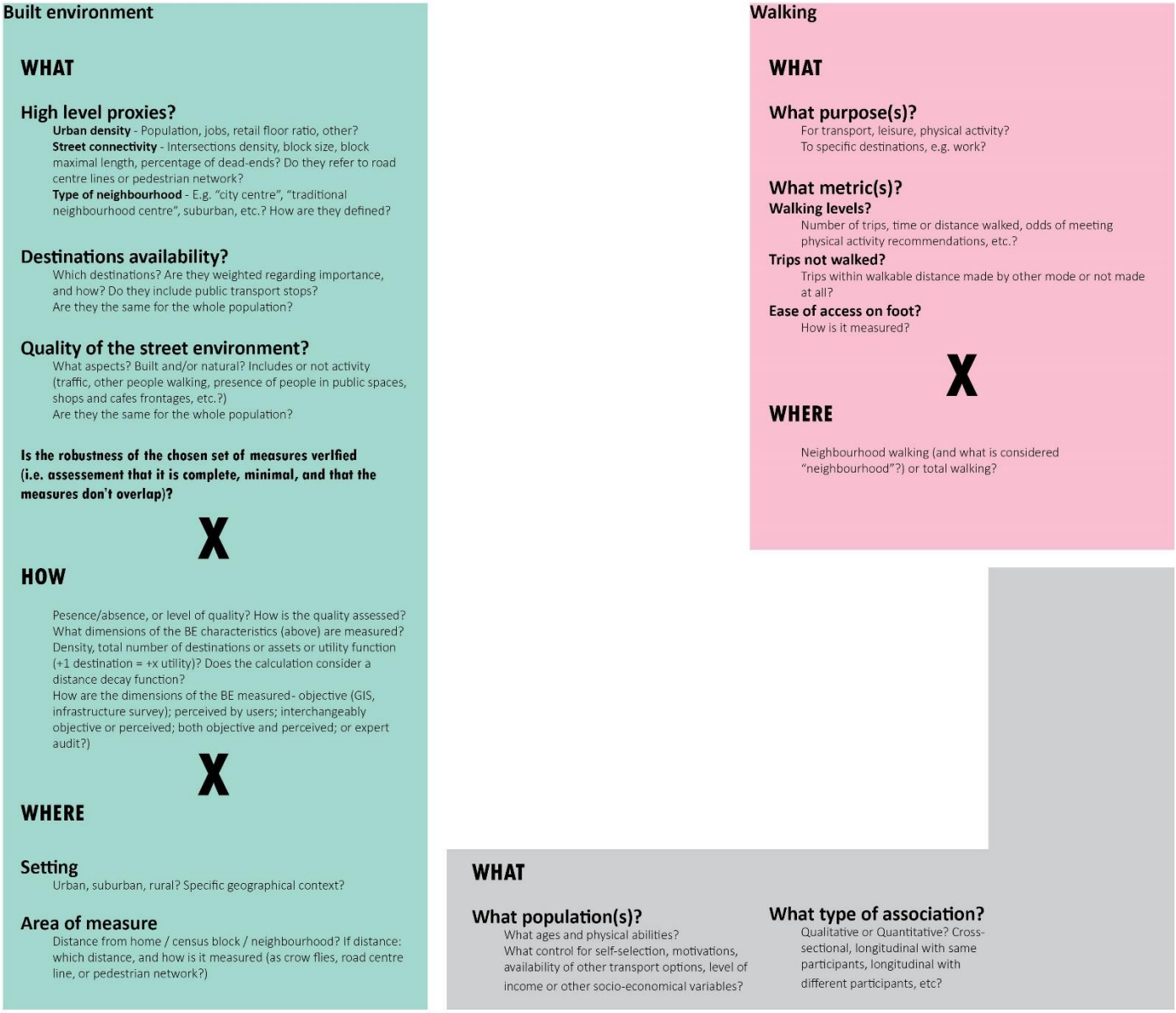


Figure 4: Complexity of the BE-walking behaviour correlations as informed by the evidence: diversity of measurement of BE characteristics and walking behaviours; multiplying the possible choices considered here and considering that 5 options are possible for open questions such as "what destinations are considered", the indicative number of possibilities is nearly 800 billion.

3.4 Question 4: How does the available evidence inform the possible moderating factors?

Multiple types of moderators of the association BE-walking were examined. Below, dimensions identified as potentially important (see above, discussion on walkability) have been assessed, namely: typology of residential area, age, impairments, trip purposes, driver status, and self-selection.

3.4.1 Typology of residential area

Cerin et al [64] detailed one study that analysed possible moderating effects on walking and reported that for older adults living in urban or rural areas there were no significant associations between access to destinations/services; availability and accessibility of public transport; public toilets; benches/sitting facilities; safety from traffic and crime; pedestrian-friendly features; street lights; littering/vandalism/decay; pollution; and greenery and aesthetically pleasing scenery with total walking. The only significant difference related to the availability of shops, it was less important for those aged less than 75 years living in rural areas, in comparison with younger people and those living in urban areas. In the examined studies, two focused on urban areas specifically [113, 134], but the low numbers of primary findings reported and the fact that the other reviews mixed the results of both urban and rural realms did not enable conclusions to be drawn.

3.4.2 Age

Age was noted as a moderator of the relationships between both the proximity to destinations and the quality of the environment with perceived walkability [30, 128]. The proximity to destinations was noted as more important for older adults [30, 128], especially when they don't drive or anticipate not being able to drive anymore. Distance related to the ability to participate in the life of the community [128]. Within cohorts with a median age above 65 years, those aged 75 and over were also more sensitive to the presence of nearby parks [64]. Overall, older adults also found safety from the traffic [128], good footpath conditions [30, 128], and possibilities to sit [30, 64] more important than younger populations. However, those preferences might be influenced by a lower self-efficacy and/or higher frailty, and not be an exclusive outcome of age [128].

3.4.3 Impairments

The quality of the BE is critically important in the notion of disability itself: in the widely accepted Social Model of Disability, BE is seen as a determinant of a person's ability to function, alongside the impairments [47]. Disability thus relates to the interaction between a person and their environment. Eisenberg and colleagues studied adults with disabilities specifically, noting that (a) the presence of local destinations is an incentive to neighbourhood walking/wheeling; but (b) the quality of the built environment can discourage individuals from making the journey; and (c) the qualitative aspects that represent barriers to access are still not well understood [16]. It is namely not clear how different types and levels of disability are associated with the ease of access: there is a lack of data for disabilities other than ambulatory and younger disabled adults [16]; insufficient consideration of different forms of ambulatory disabilities [24]; and no agreed overview of potential barriers and their potencies [16, 24, 43, 140].

3.4.4 Trip purposes

Trip purposes were globally poorly accounted for. Distinct associations between BE characteristics and different types of walking were however noted: (a) the availability of reachable destinations might be correlated with walking for transport but not recreation, in older adults [129]; and (b) the level of acceptance of barriers to walking might be higher for important trips – for instance, disabled people are likely to find strategies to achieve necessary trips, while the optional ones might be foregone [16]. When comparing proxies such as land use mix or street connectivity however, Ewing and Cervero found however little differences between associations with walking for transport or recreation [134]. A study by Salbach and colleagues supports the importance of purpose on walking, for older adults, identifying that the distances could significantly vary [141].

3.4.5 Driver status

Little evidence about the driver status or the availability of transport options (and their relative qualities to walking) was identified. The findings of one study on older adults [142] were reported [64]: while the proximity of destinations and public transport, and pedestrian-friendly features were important regardless the driver status, proximity of parks and street connectivity was more important for those who do drive.

3.4.6 Neighbourhood Self-selection

In 2010, Ewing and Cervero had noted that at least 38 studies had tested the moderating effect of self-selection on the relationship between BE and travel behaviour in general. The studies found a strong association between BE and travel behaviour in general, which tended to be attenuated by self-selection [134]. More recently, and examining specifically walking in older adults, Cerin and colleagues found that self-selection was poorly controlled for (it had been done in only 4 of the 42 identified studies) [64].

3.4.7 Moderators, summary

In summary, individual characteristics were diversely and not systematically accounted for, in studies examining the relationships between BE and walking. It seems important to ensure a robust control of types and levels of disabilities, trip purposes, driver status or self-selection, characteristics that can moderate the relationship between the walking environment and walking behaviours. This idea had been supported by Gebel and colleagues in their recommendations for better quality systematic reviews in this field [143].

3.5 Updated draft Social Model of Walkability

Contributions to the draft Social Model of Walkability have been outlined under Question 1. Most findings from the reviews report associations between walking behaviour and BE (considering its objective and/or perceived characteristics). Some elements also helped better understand the decision pathways relative to walking. These are:

- **Objective characteristics can contribute to perceptions of non-feasibility or poor safety, further leading to journeys foregone or diverted routes** [16, 62, 128]. This finding echoes the warnings against interchangeable use of objective and perceived aspects [50] and aligns with the draft Social Model of Walkability.
- **Trip purposes can moderate the relationship between perceived quality and decisions to walk**: Eisenberg and colleagues report that adults with disabilities are likely to find ways to achieve a journey or forego it, depending on if it is seen as necessary or not [16].
- **Further, some evidence outlined individual characteristics as possible moderating factors**, namely age, availability of alternatives, impairments and self-selection. There is, however, a broad lack of evidence on how these characteristics moderate the BE-walking relationship.

The findings were used to propose an updated version of the framework originally developed by Alfonzo, Mehta, Buckley and colleagues. In the figure below, posited associations are noted in grey, while findings from this review of reviews have been added with black lines. A need to better understand users' decision pathways is identified.

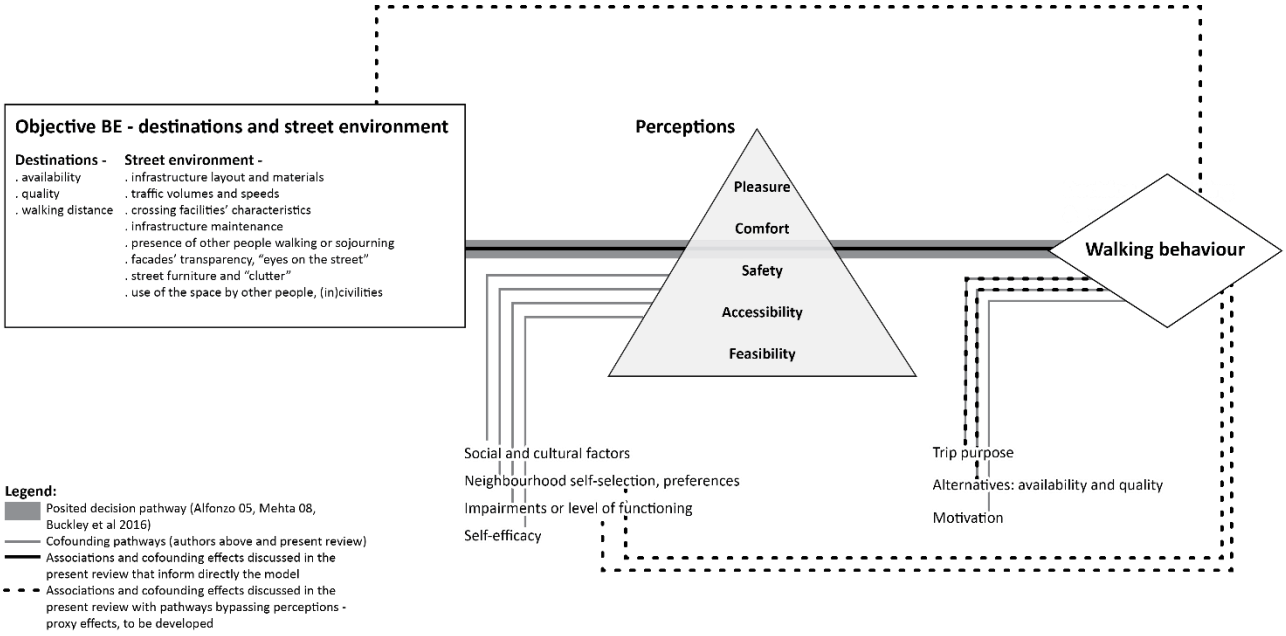


Figure 5: Draft Social Model of Walkability, developed from the works of Alfonzo (2005), Mehta (2008), Buckley and colleagues (2016)

4 CONCLUSION

A critical review of reviews was realised to examine the current understanding of "walkability" as a concept and of Built Environment (BE) characteristics as determinants of walking behaviours. "Walkability" appears as a complex phenomenon, having various possible outcomes and components. Studies of "walkable places" examine different aspects of the BE and use diverse ways of measuring and assessing them, making it difficult to grasp the relative importance of different characteristics. Often, studies assume what characteristics matter ("neo-environmental determinism" [63]), and test them against walking behaviours, without guarantee that the set of characteristics is comprehensive and non-redundant. This practice is problematic given that the street space of each city is finite and requires therefore a consensus on what needs to be adapted and how.

Overall, the analysis of the BE is skewed towards objective aspects, often high-level measures used as proxies (e.g. residential density). Quality is overall poorly assessed and valued, and some dimensions that have been known to be important for decades now routinely get missed (e.g. traffic volumes

and speeds [125, 131]; active facades, right level of enclosure and presence of other people walking [123–125]). Findings from previous studies have often been inconclusive or inconsistent. An explanation could be that the approaches used are not methodologically sound (for instance, considering interchangeably objective and perceived aspects of BE, or considering some characteristics such as "littering" but leaving aside aspects that could counter-balance them, such as the presence of an active night life). Another difficulty is the comparing of results relating to diverse BE characteristics in diverse ways to diverse types and levels of walking. Due to the lack of a theoretical framework to be tested and measures that offer sufficient comparability and control for cofounders, causal links between the walking environment and walking behaviour are still not clear. Severance (i.e. inability to participate due to difficulties of access) is even less understood, because of a lack of evidence and of the difficulty of capturing trips that could have been walked but were not. The inability to provide clear outputs regarding walkability represents a key issue if research is to support cities providing environments supportive of walking as a choice, for all populations, regardless of their age, level of income or physical ability. However, the identified associations between BE quality and walking and broader outcomes such as health and participation, strengthen the case for better understanding how the walking environment can support or deter walking as a behaviour and choice.

The main strength of this chapter is that it presents an overview of the understanding and conceptualisation of walkability, basing on a systematic review of reviews and bridging across various disciplines. A robust stocktake on this question is particularly important now, given the importance of urban retrofit supportive of walking as a mode of transport and further public health, liveability and lower environmental impacts.

This chapter also has limitations. Firstly, as per nature of the umbrella review, it relies on the pre-existence of narrower component reviews [96]. However, this aspect can also bring an interesting insight regarding needs for targeted component reviews. Second, the quality of the papers has not been formally assessed, although limitations encountered have been described above. Lastly, the analysis is constrained by the mentioned limitations. Again, this aspect can provide a useful stocktake of the body of component reviews, echoing recommendations for an improved practice such as outlined by Gebel and colleagues [143].

This umbrella review pointed towards the urgent need of a systemic approach to walking, as suggested in the socio-ecological model. The roles of BE, social context, individual characteristics, motivations and needs should therefore be considered together in relation to walking behaviours. For that, the theoretical model outlined by Alfonzo, Mehta, Buckley and colleagues appears as a sound platform to be informed through findings and further developed. The model has been further

developed through the identified evidence and named Social Model of Walkability. However, an overall lack of evidence needed to test the posited causal relationships is noted. Understanding people's needs and expectations will be a core element of investigation, and participatory methods are recommended as a way forward, as previously recommended by Andrews and colleagues, amongst others [63]. This approach would reflect practices that have been developed and employed by the consumer market with great success, in the last decades [19, 144].

POSTSCRIPT

This thesis identified from previous research the theoretical framework linking BE to walking, first presented by Alfonzo [43]. The theoretical framework was named in this thesis the Social Model of Walkability and was further developed throughout the project. Given the key importance of the framework, it seemed appropriate to provide an update relative to studies testing the framework and published after the cut-off date of the umbrella review (April 2019).

For this purpose, an additional search for papers citing Alfonzo's publication was performed in Scopus and ScienceDirect. This search focused on papers published between 2019 and the end of May 2021. As in the first iteration, papers testing the O-P-w relationship and considered at least some individual, trip-related or social characteristics as moderating variables were included.

The search yielded 62 papers that were assessed on title/abstract and full text for inclusion. Two additional papers informing the model were included, from Cambra and Moura [61] and Shatu and colleagues [145].

The five pieces of work testing the model overall supported the associations between (a) availability of destinations and quality of the WE; (b) perceived walkability; and (c) walking behaviour (examining numbers of people present [53, 61], route preferences [53, 145] or declared motivations for walking [49, 54] or for route choice [53, 145]).

The authors suggested important developments relative to:

- The environmental characteristics that should be considered;
- The hierarchy of walking needs; and
- Individual characteristics as possible moderators

These aspects are briefly discussed below, differentiating between the testing previously identified [49, 53, 54] and the new contributions [61, 145].

Environmental characteristics. Previously, the importance of holistic environments, human presence and visual appeal were suggested. The umbrella review identified however that previous evidence tended to examine environmental features in isolation, rather than as components of a holistic environment. Within the new contributions, Cambra and Moura [61] precisely focused on the effects of a holistic street redesign. Their findings support the potentials of holistic streets redesign to improve walking experience, drawing however attention on the need to better understand:

- **The relative importance of different characteristics and its variations across people** (see individual characteristics, below); and
- **Possible synergies between environmental factors resulting in higher perceived walkability.**

Both teams reported difficulties associating O and P: Cambra and Moura noted that the relationship was probably not a simple dose-response [61], while Shatu and colleagues identified discrepancies between measured and perceived environmental attributes [145]. The authors also make important considerations regarding scale and outcomes, suggesting that small scale improvements might improve walking experience but not necessarily increase walking levels. Shatu and colleagues highlight for their part the difficulty of measuring accurately objective features of the BE (almost a third of their participants were satisfied with objective features defined as "low quality") [145].

Hierarchy of walking needs. Previously, Mehta had suggested that the order of the hierarchy of walking needs might vary depending on the situation and had added a level relative to belonging [53]. Mehta questions the positioning of this new level in the hierarchy of needs. However, it could also be argued that belonging relates to familiarity with the area, which is an individual characteristic rather than an attribute of the environment. Familiarity had already been identified as a moderator of the O-P association [49, 121, 146]. The new identified contributions do not suggest altering the hierarchy of walking needs. Shatu and colleagues [145] identify however an association between habits relative to the choice of routes (which further suggests familiarity) with the observed route choices, indicating a moderating effect of habits on the sequence linking the BE to walking.

Individual and trip-related characteristics. Previously, authors had identified the importance of (a) familiarity with the area as an enhancer of the walking experience [53] and a motivation to walking [54]; (b) gender, age, level of education, and parental status as moderators of the associations O-P [49]; and (c) the level of education, as an influence of the modal choice [49]. In the new contributions, Cambra and Moura support the importance of trip-related characteristics, suggesting that the importance of quality might vary across trips (lower for necessary, utilitarian trips) [61]. Shatu and colleagues identified level of education, gender, age, availability of motor vehicle, drivers'

license, household size and presence of children, personal income, motivations and beliefs as explanatory variables for diverse O-P discrepancies [145]. The two additional papers outline however the need to better understand the mechanisms through which individual characteristics moderate the O-P relationships:

> *Further research is needed also to better understand the role of experience as a mediator between the perceived environment and active travel behaviour and to discern which population groups may be more reactive to changes in the built environment. The understanding of which factors are more influential to whom and which synergies between the factors can provide more accomplished results are key to guide future urban interventions and policies aimed at increasing walking. [61]*

The retrieved literature also included papers testing elements of the model and not the whole sequence O-P-w. Fancello and colleagues [147] suggested that the relative importance of different levels of the hierarchy of needs can vary across demographic groups. Nakamura [146] suggested the importance of different demographic characteristics on the association between objective BE and perceptions, as well as associations between levels of the hierarchy of walking needs. An overview of their findings is presented in Appendix 2C.

Table 8 below reminds of the testing initially identified and includes the contributions of the two additional papers.

Table 8: Testing and development of Alfonzo's model (update, May 2021)

First author, year	Tests	Methods and setting	Findings	Limitations
Mehta, 2008 [53]	Association between BE (microscale urban design qualities), perceptions, and route choice.	Interviews of adults who visit the three chosen sites (three Main Streets in US East Coast towns and cities). N = 51	The model was overall supported **Detail, O-P** ▪ **Human presence** added to the pleasure of walking ▪ **Holistic environments:** appeal of human presence and visual interest of the street, together ▪ Suggested that the order of the hierarchy of walking needs might vary depending on the situation **Suggested additions:** ▪ The sense of belonging or familiarity - knowing shops and cafes turned those places in social destinations, increasing their appeal ▪ The usefulness of available destinations	Low sample number Participants including few older and no disabled adults Trip purpose not considered Interview of people who visit the setting – no information regarding barriers faced by those unable to access it

First author, year	Tests	Methods and setting	Findings	Limitations
Buckley, 2016 [54]	Agreement with 15 potential motivators to walking chosen, considering demographic and trip-related differences	Intercept surveys on a major street in Vancouver. N = 318	The model and the levels of hierarchy of walking needs were overall supported **Suggested additions:** ▪ Internal motivations ▪ Personal values **Detail, O-P** ▪ Importance of visual appeal (motivation) ▪ **Basic needs** (e.g. good footpaths, crossings) have a low motivational interest Detail, individual characteristics: ▪ **Familiarity** as a motivation	Chosen motivators tested were not necessarily mutually exclusive or complete Participants including few older and no disabled adults Interview of people who visit the setting – no information regarding barriers faced by those unable to access it
Ma and Cao, 2019 [49]	Associations between travel behaviour, perceived neighbourhood characteristics, attitudes to travel modes and demographic data	Self-administered survey of residents living in five chosen corridors in Twin Cities, US. N = 1303	Availability of destinations associated with travel behaviour through perceptions, supporting the model **Modal preferences** were associated with perceptions of accessibility (small effect) and travel behaviour (large effect) Demographic characteristics moderate: ▪ The associations between O and P (gender, age, level of education, having children) ▪ The modal choice (level of education)	No data regarding possible disability O measures of proximity of destinations were poorly aligned with people's perceptions. The association was better after including travel preferences but still imperfect, indicating other possible moderators

First author, year	Tests	Methods and setting	Findings	Limitations
Cambra 2020 [61]	Changes in perceived walking experience and walking levels after a holistic urban improvement	Test of one improved area and two test areas in Lisbon. Assessment of O dimensions of walkability (IAAPE framework [122]), on-street quasi-longitudinal retrospective survey, and pedestrian counts. N = 802 (survey)	The model was overall supported. Namely, redesign of the WE was associated with improved walking experience and higher levels of walking. **O-P**: no clear dose-response relationship - walking experience improved even with small changes. The moderating effect of trip purposes is assumed. Hypothesis: utilitarian, necessary trips less sensitive to quality.	Non-representative sample: 84% having completed university or higher education; only 6% people aged 65+; only 1% unemployed, 0.2% stay at home parent. While the study considered four demographic groups (adults, children, seniors, mobility impaired) and two trip purposes (utilitarian and recreation), the results were not provided by group or puprose.
Shatu 2019 [145]	Association between BE, perceptions, and route choice, and moderating effects of individual characteristics.	University campus in Brisbane. Assessment of O dimensions of walkability and intercept survey (route mapping, factors perceived as important for the route choice, attitudes to walking, demographics. N = 178	**O-P:** relatively poor agreement for all the tested features of the WE except "good crossing facilities"; difficulties of measuring accurately O also resulted in apparent deviations (27% participants were satisfied with features being measured as low quality) **P-w** associations supported, namely: importance of distance and different aspects of quality of the WE. **Habits** identified by participants as important for route choice **Individual characteristics** suggested as explanatory variables of the apparent mismatches between O and P; namely: level of education, gender, age, availability of motor vehicle, drivers' license, household size and presence of children, personal income, motivations and beliefs.	Non-representative sample (students, 54% aged 18-24, 37% aged 25-34, 9% aged 35 and above) Disability status not noted

CHAPTER 3: INFORMING THE THEORETICAL MODEL THROUGH A SPECIFIC LITERATURE REVIEW

PREFACE

Following the establishment of the draft Social Model of Walkability (chapter 2), this umbrella review examines how objective characteristics of the street environments were associated to perceived walkability and walking, in previous research.

This chapter is based on a paper submitted for publication in Transportation Research Part F: Traffic Psychology and Behaviour. Introductory elements relative to the notion of walkability and the draft Social Model of Walkability were slightly shortened, to reduce redundancies with the previous chapter.

1 INTRODUCTION

A modal shift towards walking aligns with cities' responses to climate change, existing barriers to participation, or sedentary lifestyle-related illnesses [5, 9, 105, 106, 148]. As seen previously (chapter 2), it is agreed that the walking environment (WE) influences human behaviours in conjunction with individual, social/cultural, organisational, community, and policy dimensions. There is a general consensus on the need for availability of destinations, absence of barriers or safety. There is however also a broad lack of consensus on the role that the quality of the WE plays in the choice of walking [100].

Given the associations between WE and walking, authors call for targeted retrofit of the built environments, aiming at addressing problematic aspects [11, 106, 149]. Prioritising improvements requires however an understanding of how the environment influences walking, and what are the relative potencies of different features. The draft Social Model of Walkability, linking WE to walking, was identified from previous literature and updated (Chapter 2, Figure 5, p. 69). The draft Social Model of Walkability is accepted as the theoretical framework for this chapter.

The lack of agreement on the notion of a "walkable" place [21] and the poor understanding of the mechanisms through which WE influences behaviour [150] lead to variability around what is investigated and reported (Chapter 2). Variability relates to (a) WE characteristics assumed to be important but not necessarily corresponding to users' lived experiences [19, 21, 57, 63, 151, 152]; (b) the relative importance of different aspects (e.g., safety, presence of destinations or design features) across demographics [21, 43, 54]; and (c) the measurement of WE features, that can be objective, perceived, or a mix of both [63–65].

The draft Social Model of Walkability and previous evidence consider objective and perceived aspects as two distinct contributors to walking as a behaviour (Chapter 2). The mechanisms through which objective characteristics of the WE influence perceptions and further walking behaviour need however to be better understood [49, 50, 63]. While the cognitive processes of perception are beyond the scope of this thesis, I refer to Alva Nöe's Action in Perception as a helpful in-depth analysis, making the case for perceptions resulting from an ongoing process of "skilful probing" of our environment, in which inputs from the objective features are analysed against previous experiences and sensorimotor knowledge (enactive approach) [153]. The enactive approach frames perceptions as largely related to individual characteristics (different bodies as different probing machines, and different past experiences and sensorimotor maps).

The aim of this umbrella review is to summarise evidence and identify gaps from published reviews on the associations between specific WE characteristics and users' perceptions of walkability – how walking needs are met, from the walkers' perspective. The review intentionally focuses only on and aims to better understand this specific element of the draft Social Model of Walkability.

2 METHODS

The umbrella review was chosen to provide an overview of a broad question [96] and because a number of specific reviews have been published recently. The methodology has been registered with PROSPERO (ID 132319). Reviews published between 2009 and 2020, inclusive, are considered. The start of the period of search relates to the fact that the rate of publication on walkability increased strongly after 2009 (74% of the entries re "walkability", in Scopus, date from 2009 or after). Starting from 2009 allowed therefore to capture most of the evidence while reducing the risk of primary results being repeated.

The identified reviews result from (a) a systematic database screening using defined search terms and (b) a database screening for reviews citing the papers from Alfonzo, Mehta, and Buckley and colleagues, having developed or tested the model [43, 53, 54]. I performed the filtering for inclusion, data extraction and quality control of the included papers. The quality of the present review was controlled by the involvement of at least one additional member of the team at each stage (filtering for inclusion: EH 10%; data extraction: MC 10%; quality control of the included papers: MS 50%). Discrepancies were resolved by discussion.

2.1 Scope

In this review, the scope is defined as the association between specific **objective characteristics** of WE **(O)**; and **people's perceptions** of the satisfaction of their walking needs **(Pw)**. **O** can be measured (e.g., distance to destinations) or audited (e.g., presence of greenery in the street) and does not refer to clusters of inputs (a walkability index is here considered as a cluster of inputs, as are other indices mixing measured and perceived elements). Excluding clustered, or composite indices, is a methodological choice related to the objective of identifying how specific features relate to perceived walkability. Although walkability indices have had a large role in previous research and had been associated to walking levels [64, 65], this association does not provide insight as to how each of their components (typically, availability of destinations and road network geometry) associate with perceptions.

Pw were grouped against the dimensions of the hierarchy of walking needs, from the most basic to the aspirational (feasibility, accessibility, comfort, convenience, pleasure; Chapter 2). Associations between O and perceptions other than the walking needs (noted P - e.g., happiness) were also noted and briefly discussed, so to provide a view of potential "side effects" of features of the WE.

2.2 Search strategy

The search strategy was designed considering the strategies used by recent related systematic reviews, sensitivity tested and checked with the institution's subject liaison librarian. The search terms used for the systematic database screening focus on three topics:

1. **Walking environment:** Local street environments and elements of street quality
2. **User:** Users' perceptions of walkability (e.g. accessibility) but also broader perceptions
3. **Mode of travel:** Walking, with or without assistive device, or wheelchair use

Given the interdisciplinary nature of this research topic, databases relevant to several fields were screened (both systematic screening and search for reviews citing either of the three papers of interest):

- **Health** (CINAHL Complete, MedLine, PsycInfo, Sage Journals Public Health and SPORTDiscus);
- **Urban design** (Art & Architecture Complete); transportation (Transportation Research Board); ergonomics and human factors (Ergonomics Abstracts); and
- **Social sciences** (Humanities International Index, SocINDEX, and Sage Journals Social Sciences and Sociology).

The Journal of Transport and Health is a recent publication not indexed in these databases. Given its importance, it was added to the sources above. The detailed search strategy is presented in Appendix 3A.

2.3 Inclusion and exclusion criteria

Included records satisfy the following conditions: (a) **Document type:** Systematic review, non-systematic review or thematic synthesis; (b) **Geographical context:** Urban or suburban environments in post-industrialised countries, defined as having both a high or very high Human Development Index (HDI) and levels of car ownership of 200 or more vehicles per 1,000 population; (c) **Participants:** Adults (defined as 18+); (d) **Intervention(s), exposure(s):** Objective characteristics of the street environments; (e) **Outcome(s)**: Participants' perceptions of the walking environment.

2.4 Data extraction and quality control

The extracted data covers all aspects relevant to the quality control and the analysis of findings. The full data extraction table is available in Appendix 3B.

The quality of the reviews was assessed using the Methodological Quality Checklist (MQC) as adapted by Bambra and colleagues [154]. The MQC was developed for umbrella reviews, allowing a pragmatic assessment of potential sources of bias, and used recently by Bird and colleagues in an umbrella review addressing related topics [155]. The MQC examines the definition of scope and inclusion/exclusion criteria (population, interventions and outcomes), reporting processes, the internal control by the review team and the adequacy of the results presentation. The assessment of quality was expanded for this study by adding two criteria recommended by Gebel and colleagues [143] for reviews in this field. Specifically, noting if older adults and those with disabilities were considered as separate groups, with results reported specifically for these groups. The full quality assessment with the scoring framework is available in Appendix 3C.

In the absence of a consensus on what environmental features are important to define a "walkable" place, evidence was extracted against WE features that have been associated with walking, or that are assumed to be associated but for which evidence is not yet sufficient (Chapter 2). The features and the reasons for their inclusion are presented in Appendix 3D.

2.5 Levels of analysis

The results have been organised by the level of review quality, and also by type of perception. These types are:

- **Perceptions of WE characteristics** (e.g. perception of the availability of destinations);
- **Perceived walkability** (Chapter 2) – feasibility, accessibility, safety, comfort and pleasure; and
- **Broader perceptions not related to/broader than the walking needs** (e.g., happiness or social connectedness).

Following Gebel and colleagues' recommendation [143], the findings were stratified by important individual characteristics such as old age or impairment (where possible), to avoid artificially masking potential moderating effects.

3 RESULTS

3.1 Overview of the examined studies

Twenty-one papers were included after the search and filtering process, outlined in Figure 6 below. Interestingly, 40% of the unique papers identified were published after April 2019. The identified reviews reported on 73 associations O-Pw or O-P.

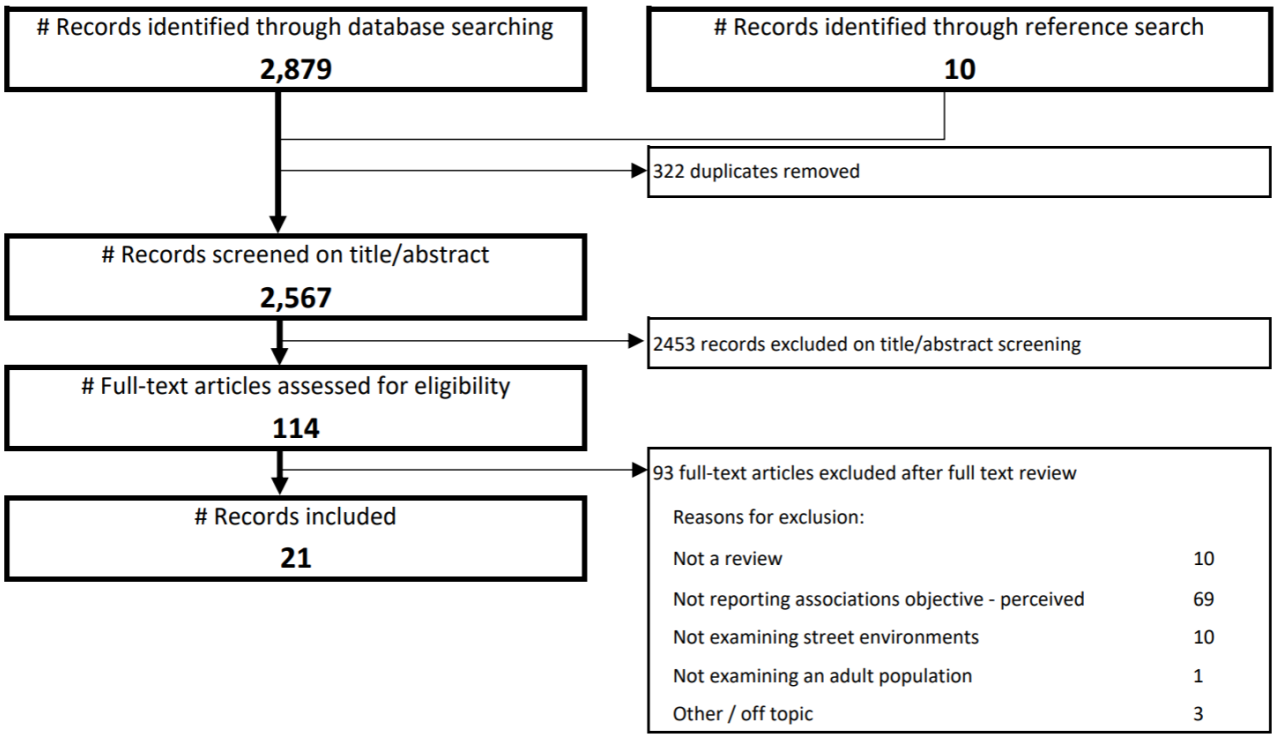


Figure 6: PRISMA flow diagram for article identification, screening, and inclusion

3.1.1 Methodological quality

The Methodological Quality Checklist (MQC) score [154] ranges from zero to seven, higher values representing higher quality. Thirteen studies (62%) scored 2 or below [156–167] and eight scored 4 or more [50, 168–174]. The quality of the primary studies was assessed in four reviews (19%) [168, 169, 171, 172]. Only one review indicated that more than one author had been involved in each stage of data collection, filtering, and analysis [172] while six reviews indicated involvement of several authors in some of the stages [50, 168–171, 174]. The reviews rated as having a lower quality typically did not specify the search strategy, the inclusion/exclusion criteria, or the designs of each primary studies.

3.1.2 Studies' settings

Ten of the reviews examined mixed settings (i.e., urban, suburban, or rural), ten focused exclusively on urban environments [157, 162, 165, 169, 171, 172, 174, 175] and one on suburban areas [159]. Given the relatively low number of identified reviews and the fact that less than half of them targeted urban environments**,** the initial focus on urban or suburban environments was broadened, considering also studies that examine a non-specified mix of urban, suburban, and rural environments.

The countries or regions were specified in 39 of the cited primary studies reporting on associations O-Pw or O-P (22%) and related to North America (17 primary studies), Europe (11), South America and Caribbean (4), Middle East, Africa and Asia (2 studies each), and Australia/New Zealand (1 study).

3.1.3 Individual characteristics

Population sub-groups were treated differently. Four reviews focused on older adults [156, 160, 168, 170] while the other reviews did not specify any age group. Nineteen reviews (90%) did not specify inclusion criteria relative to disability. Two of those reviews did indicate results from primary studies that related to disabled people [50, 163]. One review focused on older adults using mobility devices [156], and another on people with chronic health conditions [170], both suggesting frailty or impairments. The types and levels of disability or chronic health condition were not reported, which could lead to results aggregated across a diversity of mobility needs.

3.1.4 Objective and perceived walking environment

From the 21 included reviews, 11 reported associations between O and Pw [156, 159, 161, 163–165, 167, 170, 172–174], while the 10 others reported associations between O and other perceptions (P), such as happiness [167]. The associations O-Pw were often noted as a side note, for instance in reviews examining associations between BE and behaviour. This is important because it suggests that not all O-Pw associations from the primary studies have necessarily been reported.

3.1.5 Considered objective characteristics of the walking environment

The majority of the 73 associations reported between O and diverse perceptions related to the availability of destinations (n = 28, 38%) or features of street design (n = 25, 34%; e.g. greenery in six cases, or lighting, in five). Other aspects were less frequently examined: traffic flows (n = 8, 11%), characteristics of the pedestrian network such as connectivity or wayfinding (n = 4, 5%), maintenance and degradation (n = 4, 5%), and activation – presence of people, transparent facades (n = 2, 3%). Only one study examined holistic environments, namely shared streets [165], while the other studies examined isolated features of the WE.

3.1.6 Considered perceptions

Seven reviews considered perceptions as outcomes: four included perceptions relative to the hierarchy of walking needs (Pw: accessibility [156] and safety or reassurance [161]); to the characteristics of the walking environment [50, 173]), and three examined broader concepts (fulfilment of social needs, for older adults [168], happiness [167], and self-rated health and quality of life [169]). Within the 73 identified associations between O and any perception, 27 (37%) related to Pw, the other 46 associations relating to broader concepts. Fourteen of the identified reviews considered non-perceptual outcomes such as walking behaviour or physical activity and noted some perceptual aspects as illustration. For instance, Hunter and colleagues focused on physical activity in green urban spaces, and noted that greening vacant urban land can be positively associated with higher physical activity but also lower stress levels [171]. As for the environmental characteristics, the evidence appears as heteroclite and [172, 173] largely influenced by the scopes of individual reviews (e.g. focusing on the determinants of happiness [167]).

3.2 Association between objective characteristics of the walking environment and perceived walkability

From the 27 associations between O and Pw, eight were from studies with quality scores of 4/7 and above (Table 9) and nineteen from reviews with a quality score of 2/7 and below (Table 10). Strengths of associations were not indicated in most cases (25, 93%). Detailed findings are presented in Appendix 3B. The associations are briefly summarised below against the levels of the hierarchy of walking needs.

- **Perceived feasibility and accessibility** were informed through findings related to older people from one review of higher quality [170] and two reviews of quality ≤2/7 [156, 163]. Reported barriers related to diverse dimensions of the WE:
    - **Availability of destinations** – lower land use diversity or residential density [170];
    - **Walking network** – low street connectivity [170], forced detours, stairs [163];
    - **Poor public transport service** [156];
    - **Footpaths design** - inappropriate curb cuts [156] or conversely: a sense of ease when crossing streets without elements seen as “blocking” [163] ;
    - **Poor footpath maintenance** – for instance snow not removed [156]; and
    - **Inadequate wayfinding** [156].

- **Perceived convenience** was noted in three associations, each relating to crossing traffic flows. People had the feeling of wasting time (low convenience) when crossing roads where they had to make a detour to use a pedestrian overbridge [163] or where they faced heavy volumes of traffic [164]. One of the primary studies cited by Hasan and Napiah specified that pedestrians were comparing using the overbridge with crossing at level, against the traffic [163]. This possibly higher relative convenience could contribute to not choosing to use pedestrian overbridges, however the nature of the level crossings (traffic volume, speed, carriageway width) was not informed.

- **Perceived safety** was associated with the traffic environment, lighting conditions and the street design / greenery. Participants felt safer in better lit environments [159, 161], in streets with a higher natural surveillance (transparent facades) [167], or in re-greened streets [171, 174], while the presence of incivilities was associated to a higher fear of crime and an increased perception of risk [173]. Some characteristics triggered mixed feelings: footbridges were associated with perceived safety regarding traffic but also to inconvenient (indirect) walking routes and a higher fear of being assaulted [163], while shared streets raised concerns regarding traffic but were associated with higher personal safety [165].

- **Perceived comfort** was higher in environments illuminated with brighter street lights, perceived as inviting and more comfortable [159]. Presence of green spaces or their improvement was associated to lower experienced stress levels [166, 171, 172, 174] – this perception is understood here as not directly related to walkability but to a broader experience, however it could be argued that it includes an element of comfort.

- **Perceived pleasure** was higher in streets with calmed traffic and associated with the sense of place (more human interaction and a general idea of enjoying a given space) [165]. Greenery was associated with uplifted mood [162], happiness [167] and a sense of belonging [166] – perceptions broader than the walking needs but probably contributing to the walking experience.

Overall, the reviews did not provide sufficient information regarding how disability, age, familiarity or self-selection might moderate the associations between O and P. Atoyebi and colleagues provided an interesting insight in difficulties experienced by older users of mobility devices [156], although they grouped users who might have different needs (e.g. manual or power chair [40]). The information provided regarding the design of primary studies does not allow to comment on the causality of the associations O-P or O-Pw. When detail regarding primary studies was provided, these were cross-sectional.

An overview of the numbers of primary studies having established different associations is provided in Figure 7. The findings suggest research gaps in terms of (a) what is studied; (b) how it is studied; and (c) the overall volume of evidence:

- **What is studied:** many environmental features were not examined in terms of perceptions they might trigger (for instance, no information was reported regarding how people feel about availability of destinations, presence or absence of other people walking, noise levels, pollution, number of traffic movements to watch when crossing, or the presence or absence of design cues aimed at blind people).
- **How it is studied**: studies tend to report on associations between presence/absence of certain features and perceptions, only few reporting on the qualities of these features. Most of findings report also on isolated features, with only one study having examined holistic environments (traffic calming and street redesign [165]).
- **Volume of evidence**: 11 of the associations (41%) relate to the results on one primary study only.

The associations between O and Pw are presented below for the studies with quality scores of 4/7 and above (Table 9) and the studies a quality score of 2/7 and below (Table 10). An overview of the associations O-Pw in terms of numbers of primary studies cited is presented in Figure 7, following the tables.

Table 9: Associations between objective WE characteristics and perceived walkability (review quality ≥ 4/7)

First author, year	Aim	Population, ages	Population, impairments	Setting	Association between objective BE characteristics (O) and perceptions (P)	Strength of association	N primary studies	Associated pedestrian need
Hand C., 2012 [170]	Identify neighbourhood characteristics related to participation, in older adults	Older adults - at least half the sample was age 55 years or more	People with chronic health conditions, without further detail regarding associated impairments	urban	Low neighbourhood economic status associated with low independent participation in activities of daily living (ADL) or instrumental activities of daily living (IADL)	N/A	1	Accessibility
					Low land-use diversity associated with lower independent participation in IADL	N/A	1	Accessibility
					Street connectivity (density of intersections) associated with less difficulty in independent participation in ADL or IADL	N/A	1	Accessibility
					Low housing density associated with lower independent participation in IADL	N/A	1	Accessibility
Hunter, R F, 2019 [172]	Review of the evidence associating urban green spaces to health, wellbeing, and equity	not specified	no restriction/ focus	urban	Greening of vacant lots: removal of debris, grading, adding topsoil, planting grass and trees, and building a wooden fence associated with feeling safer	Good	1	Safety
Vos, M.C., 2018 [173]	Overview of the associations between objective and perceived cleanliness	not specified	no restriction/ focus	urban	Signs of disorder (e.g. graffiti, unreturned shopping carts and visible violation of rules) associated with lower personal safety (risk, fear of crime)	N/A	1	Safety
Wilkie, S., 2019 [174]	Summarise the effects of BE on health and behaviours	not specified	no restriction/ focus	urban	Creation of small parks on single plots of land, in socio-economically disadvantaged areas associated with safety	N/A	1	Safety
					New cycleway (2.4km) associated with perceived aesthetics	N/A	1	Pleasure

Table 10: Associations between objective WE characteristics and perceived walkability (review quality ≤2/7)

First author, year	Aim	Population, ages	Population, impairments	Setting	Association between objective BE characteristics (O) and perceptions (P) [strengths of association not reported]	N primary studies	Associated pedestrian need
Atoyebi, O.A, 2019 [156]	Present an overview of the mobility difficulties faced by older people using mobility devices	"older adults", ages not specified	users of mobility assistive devices, without further detail	unclear	Poor public transport service associated with perceived barrier to access	1	Accessibility
					Limited or inappropriate curb cuts associated with perceived barrier to access	1	Accessibility
					Wayfinding - signs placed in a way that is difficult to see, and/or poorly designed associated with perceived barrier to access	2	Accessibility
					Insufficient footpath maintenance (snow and ice removal) associated with perceived barrier to access	1	Accessibility
Bullough, John D, 2017 [159]	Examine the effects of brighter lighting at pedestrian crossings	not specified	not specified	suburban	Bollard luminaires in pedestrian areas associated with comfort - "inviting public realm"	1	Comfort
					Illumination from bright light sources (mercury vapor lamps, metal halide (MH) lamps, fluorescent lamps, and LEDs), compared with the more yellow light from high-pressure sodium (HPS) lamps associated with personal safety	4	Safety
					Neighbourhoods illuminated by MH [metal halide] lamps associated with comfort	1	Comfort
Fotios, S., 2015 [161]	Identify evidence on correlations between road lighting and reassurance	not specified	not specified	unclear	Improved lighting (e.g. 10 lux average and 5 lux min, as opposed to 3.5 lux previously - Painter 26,27), or better lit scenes (from photos); in one case (Koga et al): better lighting AND "busy" street associated with safety	5	Safety
					Street lighting (diverse situations) associated with security	1	Safety
Hasan, R., 2017 [163]	Identify factors influencing the use of footbridges	not specified	no restriction/ focus	unclear	Footbridge associated with effort, or low convenience	1	Convenience
					Route involving stairs associated with difficulty	1	Accessibility
					Footbridge associated with safety	3	Safety
					Footbridge, compared by pedestrians with the possibilities of crossing at level associated with ease	1	Convenience

First author, year	Aim	Population, ages	Population, impairments	Setting	Association between objective BE characteristics (O) and perceptions (P) [strengths of association not reported]	N primary studies	Associated pedestrian need
Jacobsen, P.L., 2009 [164]	examine effects of traffic on walking and cycling	not specified	no restriction/ focus	unclear	Traffic volume (increase) associated with increased delay for crossing	1	Convenience
Karndacharuk, A., 2014 [165]	Inform the evolution of the concept of shared spaces, from a NZ perspective	not specified	no restriction/ focus	urban	Traffic calming - a priori mainly speed reduction - through techniques such as Liveable Streets, Living Streets, Civilised Streets, Complete Streets, and Road Diet associated with a sense of place	11	Pleasure
					Street redesign with level, paved surface; minimum signage and marking; majority (72%) of the intersection space accessible to vehicles, with little provision for sojourning; speed limit of 20 mph (32 km/h) associated with concern, or being worried about sharing the space with vehicles	2	Safety
					Street redesign with a level, paved surface, minimal signage and marking, new trees, lighting, and fountains; roundabout with road surface marking, and provision of formal pedestrian crossings (zebra) and informal crossings with speed tables. Use of different materials to delineate pedestrian and vehicle areas. associated with safety regarding traffic and personal safety	3	Safety
Pfeiffer, D., 2016 [167]	Identify how planners can contribute to residents' happiness, at the neighbourhood level	not specified	no restriction/ focus	unclear	Buildings with transparent facades overlooking the street (more or less) associated with personal security, which in turn correlates with happiness	1	Safety

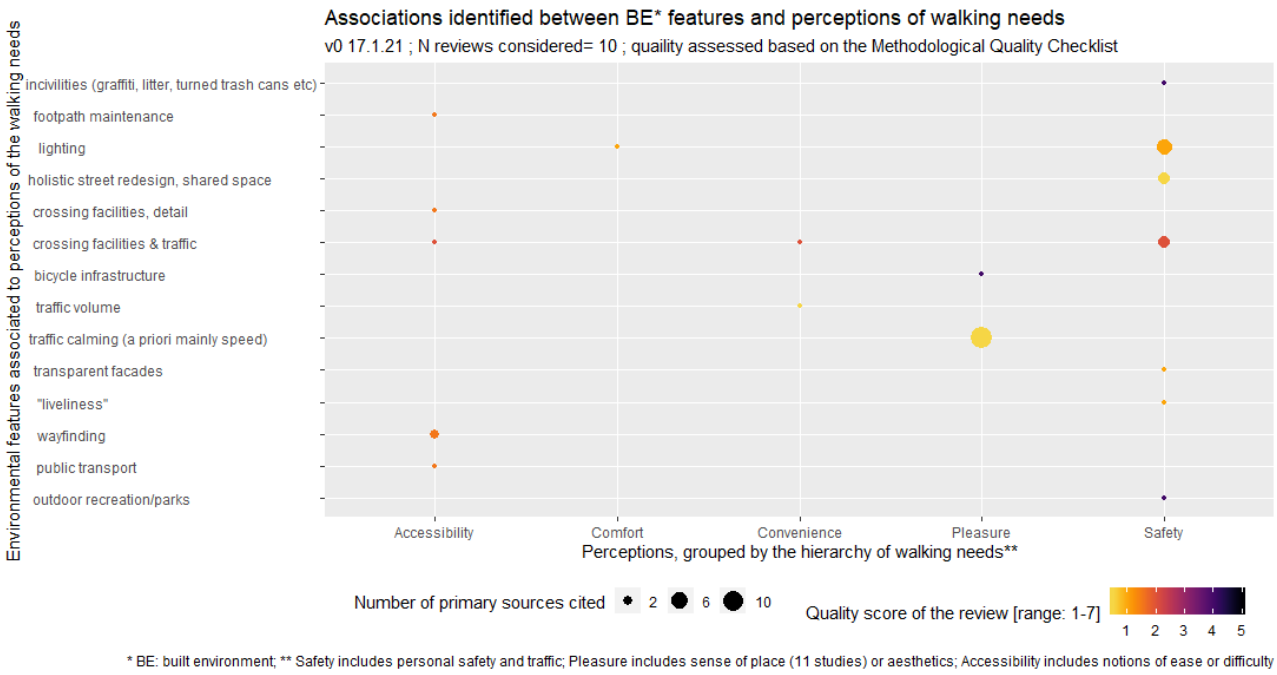


Figure 7: Overview of the associations between objective BE characteristics and perceptions of walking needs for the included reviews (n = 21)

3.3 Association between characteristics of the walking environment as measured vs as perceived

The review by Orstad and colleagues [50] was unique in that that it examined the levels of agreement between WE characteristics as measured and as perceived by users. This review showed that current measurements of objective characteristics of the WE were very loosely correlated to people's perceptions of those same characteristics and that the associations with broader perceptions were poorly informed [50]. For instance, it was shown that objective and perceived "neighbourhood traffic" had a virtually non-existent linear correlation whereas in others, agreement between them was moderate (r=.01-.03) [50] . These results could mean that users have thresholds related to their ability to deal with that traffic to cross the street. The levels of agreement between objective and perceived were inconsistent and generally poor. Among the 165 associations where kappa statistics were provided (50%), levels of agreement were slight or poor in 119 cases (72%; kappa ≤ 0.2), fair in 41 cases (34%, 0.2 < kappa ≤ 0.6), and moderate in six cases (0.6 < kappa ≤ 0.8). None of the associations had substantial or high agreement (kappa >0.8) [50]. The objective measures relied on GIS, audit, or other data. The perimeters within which these measures were obtained were diverse and did not necessarily corresponded to people's "roaming areas".

3.4 Association between objective characteristics of the walking environment and perceptions not related to / broader than walkability

The reported associations between O and P bring an interesting insight into what "side effects" features of the WE can have. They could inform if there are trade-offs to be made between walkability and other desired outcomes.

Overall, all the associations reported support the idea that features contributing to better perceptions of walkability also contribute to broader positive outcomes. The reviews indicated the importance of the presence of nature, destinations, public transport. Conversely, traffic and traffic-related infrastructure were detrimental to health and well-being.

Green streets and the availability of nearby green spaces were associated with stress reduction [166, 171, 172, 174], uplifted mood [162], happiness [167], a sense of belonging [166], health-related quality of life [169], a higher perceived social cohesion [166], lesser depression scores [158] and more "positive feelings" [175].

Presence of third places such as pubs and churches was associated to a higher perceived social connectedness, for community-dwelling adults aged 65 and over [168].

Availability of public transport near home was linked to well-being [157] and happiness [167], although the reviews did not provide insight regarding distances to the stops or the quality of service. Badland and Pearce reported also that a lack of public transport was also perceived as transport disadvantage [157].

Traffic, and traffic-related infrastructure were detrimental to health and well-being: high traffic volumes were associated to less neighbourhood trust [164], the presence of important roads was negatively related to happiness [167] and air pollution (fine particulate matter) was linked to anxiety [158]. Conversely, interventions aiming at reducing traffic speeds on sections of city centre streets were met with an overwhelming support from both users and business-owners [165].

There was one exception to the broad idea that better walkability contributes to better broader outcomes: Carr and colleagues noted that older adults could feel segregated against and stigmatised as a senior or disabled person, if they had to use special accessibility design features [160].

4 DISCUSSION AND CONCLUSION

4.1 Summary of aims

To my knowledge, this umbrella review is the first to addresses the broad question of how objective WE characteristics are related to perceptions of satisfaction of walking needs. Informing this association is crucial for four reasons. Firstly, people's perceptions are likely to influence their decisions on walking [49–51], as conceptualised within the draft Social Model of Walkability (Chapter 2) and Mehrabian and Russell's framework linking environments to behaviours through the moderating effect of emotions or perceptions [52] (Stimuli-Organism-Response framework). Secondly, a focus on people's experiences constitutes a needed step away from what Andrews and colleagues named "neo-environmental determinism" [63] and towards environments that are satisfying for their users [19, 57, 152, 176, 177]. Thirdly, people's insights can be used to identify the specific WE characteristics that need to be improved or provided, to provide for walking as a comfortable and pleasant mode of transport. Finally, people's perceptions are known to be correlated with broader outcomes such as health and well-being [138, 178, 179], and there is a need to understand determinants of these perceptions.

A review of peer-reviewed reviews was undertaken, examining publications from the last 11 years associating specific objective WE characteristics with users' perceptions. A systematic approach was taken for the identification of the records, the quality control and the data extraction. From the 2,889 identified records, 114 were assessed on full text and 21 were included. The evidence is limited, especially considering the importance of this topic in the current situation of rapid urbanisation [5, 109] coupled with the need to leverage walking as part of the response to climate urgency, sedentary lifestyles and the need for more liveable, inclusive cities [5, 14, 91, 104]. Eight of the papers were considered as being of higher quality. Controlling for the type of environment (urban or rural), population ages and impairments was poor overall. Dimensions of safety were examined more frequently than accessibility or comfort.

4.2 Association between objective WE characteristics and perceptions

The evidence related objective WE characteristics to perceptions of (a) the same characteristics; (b) the satisfaction of walking needs; and (c) broader constructs such as happiness. Results from the three types of reviews are discussed below in the light of previous findings.

4.2.1 Association between objective and perceived WE characteristics.

The review by Orstad and colleagues was the only one that examined objective measures of features of the WE against people's perceptions of the same features [50]. It is to be noted that this association has been informed only for a few WE characteristics. The authors note that "Current measures may capture different constructs, and seemingly comparable variables may be conceptually distinct" and suggest the causal sequence linking objective features to perceptions should be better understood [50]. Low agreement could relate to the diversity in the measurement of both objective characteristics and perceptions or to aggregation of results across diverse populations. This review sought to extract for each individual association data relative to the measuring protocols, the setting, the population (number, impairments, ages, gender, and other characteristics noted) and the measure of strength of association. However, none of the associations was reported with all those characteristics (for instance, none reported explicitly on disability).

Poor levels of agreement between O and Pw could be due to two aspects. Firstly, insufficient accounting for differences across pedestrian groups known to or suspected of acting as moderators – the list (by no means exhaustive) includes different types of disability and mobility devices used [16, 24], age groups [122], or habits and familiarity [152, 180, 181]. Another limitation relates to inefficient accounting for "walkers' playgrounds" which might lead to assessing areas that are in fact not relevant to users, or missing ones that are [57, 63, 179]. Such elements refer to constructivist theories developed in the 1960s that argue that the city is in part an acquired and therefore crucially personal construct [125, 176, 182, 182–184]. The findings also relate to the theory of affordances, seeing the environment through the possibilities it offers users [185]. Some authors have suggested that the concept of affordance should be extended to specifically address the aspect of experiential quality they can represent for different users, varying with their constraints and motivations [186]. Future research should inform the O-Pw associations separately for diverse users, split namely by type of disability / non-disabled, mobility device used, and age groups, controlling for familiarity and habitual travel modes.

4.2.2 Association between objective WE characteristics and perceived walkability

Chapter 2 had identified that past research had put a considerable effort into understanding the links between WE and walking as a behaviour, but that the results showed significant inconsistencies. It was suggested that the consideration of people's perceptions could be part of the issue: perceptions can be used interchangeably with objective measures or not at all, and most often without considering the moderating effects of individual, social or trip-related characteristics (e.g., disability, availability of modal options, or trip purpose).

The present chapter aimed to fill this gap by examining how specific measures of the WE are associated with perceived walkability. The noted associations were overall conceptually consistent with previous research. For instance, land use, street connectivity and crossing facilities were associated to perceived feasibility or ease of walking, which is consistent with the consensus on the importance of the availability of destinations within walkable distance and a certain lack of barriers to access (Chapter 2).

The results were unsurprising in the light of previous research but also often reported in ways that are too vague to draw conclusions. In addition, the dearth of reviews focusing on the associations O-Pw induces the risk that the reported results are incomplete, potentially failing to include non-significant findings that could have helped the understanding of association mechanisms. This chapter outlined however evidence gaps relative to ways objective characteristics correlate with people's perceptions, providing a rationale for much needed (a) multi-disciplinary research aiming at relating walking experience / UX to the WE, and (b) retrofit of the WE in a way that enables and encourages walking. The five types of evidence gaps encountered are briefly presented below.

Lack of evidence regarding what O features are associated with each level of the hierarchy of walking needs

Only one of the identified reviews questioned what features of the WE contributed to a specific perception of walkability (difficulty of access, for older mobility-device users; [156], quality score 1.5). The associations O-Pw reported by other reviews were reported mostly as illustrations, to explain why certain features might influence examined outcomes (e.g., walking and cycling [164] or use of footbridges [163]). Therefore, the identified results cannot be assumed to be complete, and there is a significant risk that contradictory or non-significant O-Pw associations had not been reported.

Insufficient evidence relative to holistic environments

Few of the reported associations considered holistic environments. Karndacharuk and colleagues provided most of the evidence identified, as their review examined shared spaces and therefore reported on a range of measures relative to design and traffic calming [165]. The other review reported on single aspects, with the exception of one association reported by Fotios and colleagues (feeling of safety associated with streets that are both well-lit and lively [161]). As already noted in Chapter 2, examining single aspects can be problematic given the loss of contextual and systemic elements that could have been important for understanding the associations. For instance, Hasan and Napiah reported some perceptions of footbridges, noting however that the footbridge can seem like an extra effort *when* crossing at level is seen as feasible and more desirable [163]. Examining the footbridge *in comparison with* the at-level alternative, informing both alternatives (e.g., distance, directness, difference of level, or risk) could have provided better insight regarding why people prefer risking to cross the road at level and how the choice they make compares with the alternative. Equally, more evidence would be needed to better understand how specific aspects of a holistic environment contribute to a type of perception. For instance, a non-signalised crossing could be seen as manageable in a low speed and low traffic environment, but difficult on a multi-lane high traffic road. Mariela Alfonzo had also illustrated the antithesis of the holistic approach as studying perfectly designed footpaths in a vacuum and trying to establish correlations with walking: if those footpaths are designed in vastly car-dominated environments and lead to nowhere, it can be reasonable to think they won't be used, no matter their quality [187].

Lack of certainty regarding what characteristics of O features should be measured and how

The initial aim to consider only specific and measured WE features had to be broadened given that the vast majority of the identified evidence related to vaguely described features. For instance, when Atoyebi and colleagues mention poor public transport service [156], it is not clear if they refer to the distance to bus stops, the frequency of services, the number of destinations reachable, the travel times, the onboard comfort, or a combination of different of those parameters.

The difficulty of measuring the quality of street environments was illustrated by Carr and colleagues' finding that special accessibility design features could make older adults could feel stigmatised as a senior or disabled person [160]. As noted earlier (Chapter 2), beyond the presence/absence of a feature, its characteristics should be examined. Here, the issue might not be the presence of the accessibility feature as such, but its design and integration to the environment: it is possible that a given plaza designed either with a continuous and smooth gradient or with a main access with stairs and a small side access ramp might have different outcomes regarding perceived accessibility and feelings of stigmatisation, for disabled people. In this example, the gradient would not be a sufficient measure: objective assessment would have to address the whole space and capture barriers (e.g., stairs).

Insufficient reporting on the objective measures of O features

The noted poor association between WE characteristics and people's perceptions of those same characteristics present a major difficulty for the associations between WE as measured and perceived walkability. The challenge is in the question whether we are measuring the appropriate parameter, in the appropriate way. For instance, examining how people perceive "greenery" requires certainty around how "greenery" is to be captured – is it the number of trees, their density, the canopy coverage, a combination of those, or something else? The problem becomes even more complex for assessing holistic environments, where research needs to identify the features to be informed and the metrics to inform each of them.

Insufficient consideration of individual characteristics

Few of the associations reported provided any information about the people whose perceptions were reported. Some spoke of "older adults", often without providing information about age, and disability was never informed regarding types and levels, as recommended by the Washington Group on Disability [188]. Disability was indirectly addressed in two reviews: Atoyebi and colleagues reported on users of mobility devices [156] and Hand and colleagues focused on people with chronic health conditions [170], but neither review characterised the populations in terms of disability. Knowing that disabled people are a diverse group and that their needs can be largely varied [16, 24], findings should be reported against types and levels of disability, using a validated approach such as the Washington Group on Disability statistics' questionnaire, based on the World Health Organization's International Classification of Functioning, Disability, and Health (ICF) [188]. Recent findings also showed that characteristics such as modal preferences interfered with perceptions of accessibility of destinations on foot [49]. Overall, and as already identified in Chapter 2, associations for O-Pw aggregated across potentially diverse demographic run the risk of generating noise in the results and hiding features of importance for specific groups.

4.2 Strengths and limitations

This chapter presents three main contributions. Firstly, this umbrella review identified a limited reporting of the mechanisms through which WE influences people's perceptions and provided a rationale for much needed multi-disciplinary research. Secondly, existing evidence was systematically searched and summarised so to inform the draft Social Model of Walkability, developing on the understanding of how features of the walking environment associate with the hierarchy of needs. Thirdly, the findings can support practitioners and decision-makers in their work towards leveraging potentials for walking, as they identify features associated with different levels of the hierarchy of walking needs, starting with the most fundamental ones. Identifying local deterrents to walking (e.g., stretches of high traffic roads without signalised crossings) and overlaying them with a vision of potential demand (e.g., applying tools like Space Syntax [189, 190]) can provide local authorities with a draft retrofit program.

This work presents several limitations. First, a broad overview is provided and does not offer specific understanding. Second the umbrella review design meant that while the quality of the identified reviews was considered, the qualities of their primary sources were not. Third, limiting the inclusion to the past 11 years means that some evidence was not considered because too old for the inclusion criteria of the examined reviews. Fourth, grey literature was not considered, excluding possible valuable evidence from local transport authorities for instance.

4.1 Future research

This umbrella review suggests the need for research improving the understanding of the pathways linking WE features to perceived walkability, for different people. Similarly to Pfeiffer and colleagues examining happiness as an outcome and identifying its determinants [167], there is a need for review examining what contributes to each of the big categories of pedestrian needs (feasibility, accessibility, safety, comfort and pleasure [43]). No such review was identified here. There is also a need for research that considers the specific roles of numerous important WE characteristics missing from the identified evidence. For instance, reviews should examine how the presence of other people walking or sojourning is associated with perceptions of safety, comfort or pleasure (associations observed ethnographically by Jane Jacobs in the 1960s already [125]), or how combinations of traffic volumes, speeds and crossing facilities are associated with perceived ability to cross the street, comfort or safety, and how these vary across demographics. In parallel with informing the associations between objective and perceived features, the causal relationships with the choice of walking need to be strengthened, examining choices in the light of both dimensions.

Future research and evidence collection will necessarily suffer of the complexity relative to linking the vastness of WE characteristics and attribute to the extensive breadth and complexity of human perceptions. Five aspects seem important to consider, for the quality of the future results and their usability by practitioners.

1. **Results should disentangle the "what" (what WE characteristics contribute to (non) satisfaction of walking needs) from the "how much" (how much they matter).** The dimension of importance is often missing although capturing it can strongly contribute to focus attention on the key features to be addressed [19].
2. **Objective WE characteristics considered should be clearly defined at an appropriate scale**, and ideally draw from a list that is comprehensive, minimal, and mutually exclusive [21], so to provide specific insights for the transport planning and urban design practices. Current evidence is difficult to aggregate as findings relate to slightly different constructs. As an example, examining separately traffic speed, volume, and geometric characteristics of the street could be more informative than talking about "heavy traffic".
3. **Ensembles of BE characteristics should be related to perceptions of walking needs**. This recommendation relates to both the need of holistic pictures (above) and framing perceptions in a way that relates to the draft Social Model of Walkability.
4. **Studies examining walking as an outcome should also consider it as an input** (presence of people in the public space, contributing to its attractiveness [123–125, 191]).
5. **The points above should be examined separately for different demographics** across important individual characteristics noted above but also across cultural and social groups. It is recommended to start filling the evidence gaps by focusing to those populations having highest difficulties of access, given the potential of this approach to deliver environments that are inclusive and work for broad populations [11, 16, 57].

Given the complexity of the associations between objective characteristics of the WE and perceived walkability, including number of moderating factors, it is recommended the points above be addressed through systematic literature reviews designed based on the draft Social Model of Walkability. Meta-analyses are expected to face the difficulty of the diversity of methods and measures noted. The work of systematic evidence assessment is nonetheless necessary for helping prioritise urban improvements and raising the awareness in academia regarding the importance of comparable methodologies and measures for capturing O and P. It is recommended the methodologies and metrics be developed by an international research group including walkability researchers from public health, transport planning, urban design, geography and sociology namely.

CHAPTER 4: STUDY 1 – STREET ENVIRONMENTS' BARRIERS TO WALKING IN AUCKLAND, QUANTITATIVE ANALYSIS OF LOCAL EVIDENCE

PREFACE

This chapter examines how the perceptions of the walking environment vary between people who don't walk and those who do, in a car-oriented environment. It builds on the findings from the previous chapters, namely (a) the draft Social Model of Walkability; and (b) the acknowledged lack of consensus around what WE characteristics matter, how much, and for whom. The relative importance of perceptions as well as person-related variables are explored. This study develops the understanding of walkability as a complex construct, focusing on the associations between perceptions and behaviour.

The chapter is based on a paper published in Transportation Research Part F: Traffic Psychology and Behaviour [192], included in the appendices (from page 125). The text presented here has undergone minor edits to improve readability (e.g., shortening the contextual elements presented in the introduction). The initial paper referred to Urban Environment (UE), which was here reframed as Walking Environment (WE), a more specific construct applied in the upcoming chapters.

1 INTRODUCTION

Chapters 2 and 3 identified that while walkability research has made important progress in understanding walking behaviour and barriers to walking, there is no consensus on the *relative* importance of diverse WE characteristics on walking. It is unclear if an ideal of walkability exists and can be linked to walking behaviour. Nonetheless, it is important to also understand what is *not* walkable and might shift people to use another mode or avoid trips within walking distance [21, 43, 54]. The draft Social Model of Walkability was identified based on previous research and developed. Chapter 2 concluded that little attention had been given to environmental perceptions in both research and in the modernist approaches to urban design and transport planning, despite their importance as moderator of the relationship between WE and behaviour. This chapter builds on the findings of chapters 2 and 3, exploring the associations between perceptions, individual characteristics and walking behaviour in Auckland.

Auckland Transport (AT) is the agency charged with urban transport planning and operations. Data from Auckland Transport's Active Modes online survey (AT survey) were used with the permission of AT[4]. The AT survey aims to understand behaviours, attitudes and perceptions of different modes of travel, over time [193], capturing perceptions of the walking environments, as well as a vast array of possible motivators and deterrents, and travel behaviour.

This chapter considers walking levels as outcome, comparing the relative importance of:

- **Perceptions of the WE characteristics** and namely those perceptions relative to the satisfaction of the walking needs;
- **Public transport (PT) use** and
- **Individual characteristics**.

The individual variables used as inputs all relate conceptually to walking, however the novelty of the present approach was to consider them simultaneously against the walking behaviour. The assumption was that all three aspects play a role in predicting walking levels, the focus being on their relative importance.

[4] Email from Carol Christie, Customer Insights Advisor, Customer Experience team; Email from Friday, 23 November 2018 3:34 pm cc Lily Linton (AT); Jena Western (AT); and Rebecca Ellery (AT)

2 METHODOLOGY

2.1 Setting and data

Auckland's development, prioritizing driving, resulted in car-centric mobility patterns with broad consequences on public health, social isolation, productivity, climate change and discrimination against those who do not drive (see Chapter 1, study setting). Adults walk about 450m on average per day [194] and 17% of trip legs [195], versus for instance 25 to 28% of all trips for the cities of London [196], Vancouver [197] or Vienna [198]. Walking is often perceived as complicated or stressful [199, 200]. For non-disabled people, identified deterrents include environments perceived as unpleasant [78, 201], or dangerous regarding traffic and crime [201–204]. Disabled people face acute barriers to access [84], a situation common in New Zealand [205–207].

The AT survey is conducted on an annual basis. The complete survey methods are provided elsewhere [83]. Briefly, participants are contacted by an independent organisation through email invitations. Representativeness is sought by age, gender, and neighbourhood of residence. In this study, data collected between 2016 and 2018 (inclusive, N=4,114) were examined. Table 1 shows the characteristics of the dataset relative to the total Auckland population.

Table 11: Overview of the survey population vs. total Auckland population

Data category	N	N%	Total Auckland population
Participants (aged >14 years)	4,114		1.26 m[5] [6]
… with difficulties walking	398	9.7	13% [77] [7]
… aged >18 years	3,996	97.1	95% [5]
… aged >65years	317	13	15% [5]
Number of trips made [8]	92,071		
… walked	23,814	26	
… driven	52,616	57	

[5] Census 2018, http://nzdotstat.stats.govt.nz

[6] 0.33% of Auckland's 2018 population aged 15+

[7] The NZ 2018 Census data on disability types and levels for Auckland are not available at this stage (July 2020). Data from the 2013 Disability survey are noted for reference

[8] Survey: trips made in the previous week; 3.2 trips per person per day. These cannot be directly compared with the total trips made in Auckland as the survey methods differ. The driving age limit is 16, therefore the 25 participants aged 15 were not drivers.

2.2 Survey questions

The 2018 survey included 28 questions on cycling and 16 on walking. Questions of specific interest for this study include: **(a) walking behaviour** – number of trips for transport in the previous week, walked or done by other modes, by purpose; **(b) attitudes to walking and overall satisfaction**; **(c) perceptions of the walking environment**: perceived safety and agreement/disagreement with 14 possible deterrents to walking; **(d) internal motivations for walking** (potential motivations presented with options to agree or disagree); as well as individual characteristics. The ten survey questions that were examined in relation to the points above are presented in Appendix 4A, and a few examples are presented in Table 12 below for illustration.

Table 12: Subsample of survey questions, for illustration (see Appendix 4A for the full list)

Code	Question	Possible answers
S7_1	Do you have any disability or impairment that affects your ability to walk?	y/n
Q10	From the list below, what are the key reasons you choose to walk? Please select all that apply o There's no other way to get where I need to go o Keeps me fit / helps me get fitter o It's fun o Saves money o Saves time o More consistent travel time o Avoids parking hassles o Availability of paths / walking routes o Helps reduce traffic congestion o Helps address environmental concerns o Provides me with some 'me time' o Allows me to enjoy the weather o Better routes are available than previously o Other (please specify)	y/n for each possible motivator
B8	Which of the following statements best describes you when it comes to walking, and the amount of walking you do? Please select one only o I only walk if I have to o I would like to walk less o I am happy with the amount of walking I do o I would like to walk more	One choice

Most variables were dichotomous (yes/no), while for some, participants were asked to give a rating between 0 and 10 (e.g., in the question B14, about the perceived safety, 0 corresponds to "Not at all safe" and 10 to "Extremely safe"). The ten considered survey questions correspond to a total of 41 variables: for instance, the question Q10, “From the list below, what are the key reasons you choose to walk? Please select all that apply”, offers 14 possible items, responded yes or no. Each item is considered as one variable. Two limitations should be noted: (a) "walking" doesn't include using a wheelchair; and (b) respondents with "any disability or impairment (affecting their ability to walk)” or those who don’t walk at least monthly were not asked about walking/wheeling behaviour and barriers.

2.3 Data preparation and analysis

Prior to analysis, participants were excluded if they reported difficulties walking or declared walking ‘never’ or ‘almost never’, as these individuals were not asked questions about their perceptions of the environment or their motivations. An upper threshold of 30 trips walked was set, excluding 2.9% of observations (103 observations) which were likely data entry errors (for instance, one participant noted 486 trips walked in a week). Next, walking was dichotomised into “low” and “high” levels of walking by first splitting the data into tertiles and retaining the first and third tertiles. The first tertile corresponds to 0 trips walked in the previous week (n=1343, 39% of the sample), while the third tertile corresponds to five or more walking trips in the previous week (n=1223, 35%). This split was chosen to maximise the heterogeneity between groups: those who didn’t walk, and those who walk on most days of the week. This meant that 3,456 of the initial 4,114 participants were included in the analysis.

First, pairwise associations among perceptions, motivations, individual characteristics, and walking behaviour were examined using a series of Chi-squared tests. All 41 candidate variables were examined after having been dichotomised (variables measured on a 1–10 Likert were dichotomised as either “poor” (below 4/10) or “high” (above 6/10). The middle values (4–6) were excluded to highlight differences between lower or higher characteristics.

Secondly, machine learning was used to predict “low” or “high” walking behaviour from the variables related to perceptions, motivations, and individual characteristics. Machine learning is seen as a promising tool to address the inherent complexity of walking, related namely to a multiplicity of dimensions and variables having associations with each other [208], but also to the uncertainty around their relative importance [21, 54].

From the 41 variables identified as conceptually related to our question, a subset of 33 were chosen to (a) avoid redundancy or replication of information (e.g. the number of trips walked and the declared frequency of walking were seen as redundant, and declared frequency was therefore removed), and (b) omit variables that had large numbers of missing values. A gradient-boosting machine (GBM) algorithm was selected given its ability to identify patterns from a large array of variables, selecting those that are most relevant for improving prediction accuracy [209]. These characteristics set GBM apart from traditional methods such as logistic regression, generally incompatible with a high number of independent variables, particularly those with a high level of internal association (see results of pairwise associations below). A GBM consists of multiple decision trees which are fit sequentially, each aiming to explain the error resulting from the previous tree [209].

Prior to training the model, the observations were randomly assigned to a training set for model development and a test set for model evaluation (80% / 20% of the data). Using the training set, the optimal model hyperparameters were identified. Firstly, several tree depths (1 to 5) were evaluated using the area under the receiver operating characteristic curve (AUC) metric. A depth of 2 was selected as it maximised the AUC (0.80). To avoid overfitting the model, the number of iterations (i.e., the number of trees) was dictated by a stopping criterion, found using 20-fold cross-validation [209, 210]. This method automatically selects the inflection point where performance on the validation data starts to decrease while performance on the training data continues to improve. The predictive accuracy of the optimal model was then evaluated by using the model to predict walking behaviour using the 20% of data reserved for testing.

The relative importance of each variable for predicting walking behaviour was also computed during the model training process. This metric is based on the reduction in error every time a given variable is included in a tree [209]. The importance of all variables sums to 100%. A variable with a relative importance of 30% can be interpreted as accounting for 30% of the reduction in model error, given this set of variables. Given the high observed importance of PT, separate models were trained for users (n = 822) and non-users (n = 1,744) of PT. As a last step, two further models were fit, stratified by the availability of alternative travel modes (i.e., those who answered “Yes” and “No” to the question “I walk because there is no other way for me to get around”). All analyses were performed using the R software [211] and the *gbm* package was used to fit the GBM models [212]. To aid reproducibility, the analysis code is provided in the Appendix 4B, while the results of the tree depth optimisation for all five models (all participants, users and non-users of public transport, availability and non-availability of walking alternatives) are presented in Appendix 4C.

3 RESULTS

3.1 Pairwise associations

Multiple pairwise associations were noted between perceptions, motivations, individual characteristics, and walking behaviour. Each of the 41 variables were significantly associated with 12 to 33 other variables. Walking levels and safety at night as a barrier were both associated with 33 other variables. The chi-squared test results are presented in the Table 13 below.

Table 13: Variables examined and number of variables associated at p<.05 (full questions: Appendix 4A)

Question	Variable examined - explanation	Number of variables associated, p<.05
Q2 Travel behaviour	Levels of walking: tertile 1 or 3	33
	Did use the car in the previous week (driver or passenger)	22
Q11 Key barriers to walking in Auckland; list of items with answers y/n	Safety, night time	33
	Too much stuff to carry	28
	Boring routes	28
	Safety, day time	27
	Hills	26
	Weather	26
	Live too far	24
	Doesn't know how long it would take	24
	Other reason	24
	Need transport others	22
	Walking adds too much time to the journey	22
	Walking is not quick	21
	Footpaths condition	21
	Walking is too much effort	20
Q10 Key reasons for choosing to walk; list of items with answers y/n	Save money	27
	Fitness	26
	No other choice	26
	To reduce traffic congestion	26
	Walking is “me time”	26
	Contributes to address environmental concerns	25
	Allows to enjoy the weather	26
	Travel time is more consistent, when walking	24
	Less parking hassle	24
	Better walking paths are now available	22
	Save time	22
	Fun	19
	Other	15
B15 Perceived safety in relation to traffic, crime, or tripping and falling, by night time	Traffic; rated "low" or "high"*	26
	Crime; rated "low" or "high"*	27
	Tripping/falling; rated "low" or "high"*	16
S2 Age	Age 65 and over, true/false	26
B14 Perceived safety in relation to traffic, crime, or tripping and falling, by day time	Traffic; rated "low" or "high"*	20
	Crime; rated "low" or "high"*	18
	Tripping/falling; rated "low" or "high"*	12
D1 Employment	Working, studying, house duties or retired, vs not employed currently	20
D4 Level of income	Income <50,000 $ per year before tax, y/n	17

* low: <4/10; high: >6/10

The identified multicollinearity confirmed the strategy of using machine learning for modelling walking as an outcome based on diverse perceptions. The results of the test for pairwise associations were not used to select variables to be held out. As noted above, a selection of variables to be used was however performed based on redundancy of information (e.g. number of trips walked and self-declared frequency of walking) and on availability of data (excluding variables that were in large part empty because related to questions that had not been asked at every edition of the survey). The variables used for analysis are reminded in Appendix 4A.

3.2 Predicting walking behaviour

The best model for predicting walking behaviour was formed using 59 trees with a maximum tree depth of 2 (AUC = 0.80). When stratified by public transport use, the performance of the models decreased for both non-users of public transport (AUC = 0.69; tree depth = 2, n trees = 45), and users of public transport (AUC = 0.61; tree depth = 1, n trees = 51). Accuracy testing is presented in more detail in Appendix 4d.

For each of these three models, the relative importance of each variable for predicting walking behaviour is presented in Appendix 4e, and an overview is shown in Figure 8 below.

3.2.1 All respondents

The use of public transport in the previous week was the most important variable by far, with 44% of the total influence. Of the people who walked 5 or more trips per week, 33% were non-users of public transport, while 77% were public transport users. The other important variables were motivation to walk because it saves money or avoids parking hassles (both 9%), age group, the motivations to help reduce traffic (both 5%) and walk because it saves time (4%), the overall satisfaction with the conditions for walking (3.5%), and the perceived safety regarding traffic (3.5%). The importance of perceptions of the qualities of WE was below 2.5%.

3.2.2 Users and non-users of public transport

The relative importance of variables varied between users and non-users of PT to each other, but also between both groups and the overall population. These variable importance of the variables must be interpreted keeping in mind the relatively low accuracy of the models.

For the non-users of PT, to the important variables implicitly compared walking to driving. Motivation regarding avoiding parking hassles had the highest comparative importance (22%), followed by saving money or saving time (both 12%), seeing walking as fun (10%), the perceived barrier of a less attractive travel time (7%) and the motivation to protect the environment (2%).

For PT users, the most important variables were the motivation to walk because it saves money (21%), the age group (18%), and the lack of choice (10%). Perceived barriers played a more important role in this group, namely too much effort (9%), safety by night (6%), the need to transport others (5%), or living too far for walking to be practical (4%).

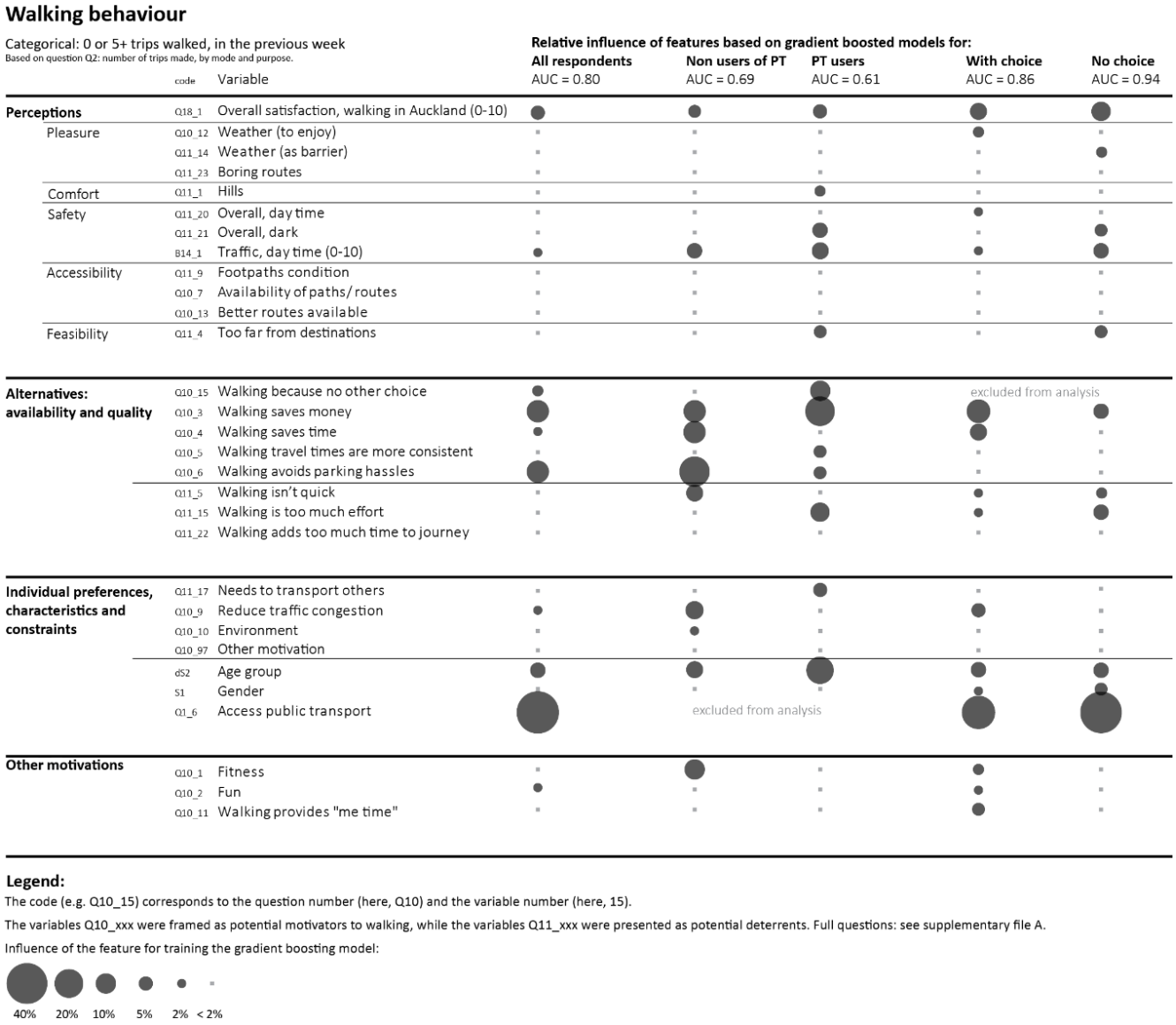


Figure 8: Relative influences of features for the whole population and the specific models for: users / non-users of public transport, and those with / without alternative modes of transport available

3.2.3 Users with and without alternative travel mode options

A surprising finding was that although there were comparatively few respondents declaring not having the choice (n=337, 13% of the total sample), the model had a high accuracy (AUC=0.94) compared to the other tested models. Some notable differences were observed between the models for respondents with and without choice: public transport use had a larger importance for those "without choice" (42% vs. 26%). Further, interesting differences were noted in the relative importance of variables, when comparing those with choice and those without: motivation of

reducing congestion (5% vs 0%); saving money (14% vs 6%); living too far from destinations (1% vs 4%); fun, fitness and "me time" (2 to 4% vs 0%); or perceived safety at night time (0% vs 4%). The detailed results are presented in Appendix 4D.

4 DISCUSSION

This chapter assessed the relative importance of users' perceptions, motivations, and individual characteristics in relation to walking levels. Walking levels were predominantly explained by perceived qualities of walking within the transport system. Surprisingly, the importance of the perception of living too far for walking to be practical was marginal for predicting the walking levels (3.6% for PT users, 1% for non-users and 0.6% for the total population). A multiplicity of variables were associated with walking behaviour. This is consistent with the theoretical model, associating walking both to perceptions and to individual, social, and trip-related characteristics. The number of associations between perceptions is also consistent with the concept of walking environments as complex systems, encompassing interactions between different components (e.g., traffic, carriageway width, and type of traffic controls are all related to difficulty crossing [124, 126]).

The strongest association with walking behaviour was the use of PT, which aligns with the growing awareness of the synergies between the two modes, internationally [22, 126, 213–215] and in Auckland [201]. Delivering efficient travel solutions is also crucial for populations relying on PT and accessible environments, such as disabled people [13, 205, 206, 216]. Disabled people were not included in this sample and understanding their barriers of access is a key research direction. People with temporary or permanent disabilities are likely to perceive and experience more barriers in their environment [16, 24, 40, 57, 217, 218].

Developing separate models for users and non-users of PT suggested differences regarding what matters for walking and how much. Non-users of PT implicitly compare walking to driving, putting importance on variables such as parking hassles or traffic congestion. Interestingly, the PT users put a higher importance on saving money than the non-users. This could relate to a difference of sensitivity to paying a ticket now as opposed to incurring sunken costs of owning a car [219], but also to a difference of socio-economic status between the two groups.

Further, important differences were noted between those declaring having/not having alternatives to walking. Those who declare having the choice implicitly compared walking with driving (e.g. noting parking hassles or putting emphasis on fitness). For those without choice, walking behaviour was closely associated with the use of PT, suggesting walking as a "first/last mile" solution and an alternative to PT. In the model for those without the choice, to the importance of perceived barriers was higher than in other models, while the importance of fitness and well-being factors disappeared, suggesting trips foregone if PT is not available and walking environment not supportive. These considerations raise the question of equity: populations living in areas with lower quality of walking environments and a poorer PT service (e.g. car-dominated sprawl) are at risk of being car-dependent or excluded, if they cannot drive or afford to own or run a car [220]. Saving money or avoiding parking hassles had considerable importance in the specific models, while environmental characteristics such as footpath quality and – surprisingly - the availability of destinations (i.e., declaring not having destinations within walkable distance) did not. This last element appears as a challenge to commonly used walkability assessment tools revolving around destinations and street connectivity (e.g. Walkscore™ [118]).

Overall, the results suggest that walking is assessed in the light of the availability of alternatives, their comparable qualities and probably the familiarity with them. This is significant as it implies that the absolute qualities of the walking environment are not sufficient to predict behaviour.

These findings align with past research. They support the draft Social Model of Walkability (previous chapters) and are consistent with the existing literature outlining the role of PT [126, 213, 215, 217, 221] and other alternatives [144, 222, 223] in the assessment of walkability. However, aspects such as the use of PT or the availability of alternatives were noted as inconsistently considered in walkability assessments and are formally absent from "3D" models considering density, diversity of destinations, and street connectivity (Chapter 2).

The significance of findings is threefold:

- **The draft Social Model of Walkability is supported** in its claim that perceptions, motivations, and individual characteristics are key explanatory factors of walking (previous chapters);
- **The low relative importance of the availability of destinations challenges commonly used methodologies** such as WalkScore™ [118] (based on the availability of destinations within a certain perimeter), at least in a car-dominated realm; and
- **The identified importance of a broader transport system (i.e. alternatives available and their qualities) prompts to develop the draft Social Model of Walkability**, adding explicitly this dimension. This is at odds with common walkability models that put emphasis on the contributions of the walking environment and often ignore the "competition" of other modes [43, 53, 54, 100].

The finding prompted revisiting the draft Social Model of Walkability, proposing four important new changes:

1. **The wider transport system**, encompassing the PT service and provision for driving as an alternative, is now explicitly included, within the objective environmental attributes;
2. **Two new levels are integrated in the hierarchy of needs: convenience and ethics** – convenience relates to the ease of use, and had already been identified in ITDP's recommendation for walkable cities [224], while ethics regroups attributes such as "helps reduce traffic congestion" or "environment";
3. **Two new dimensions are added to the hierarchy of walking needs:** (a) the relative qualities of walking, as compared with the alternatives at hand, and (b) the qualities of walking in combination with another mode – typically public transport.
4. **The availability of other modes of transport** has been re-positioned between the transport system and the hierarchy of walking needs. This is linked to the two new dimensions added to the hierarchy: only if an alternative exists, walking might be compared with this mode (e.g. to walk or to drive?) or assessed in combination (e.g., walk + bus).

Arguably, the relative importance of different dimensions could vary in different contexts (e.g., car-dominated or not) and demographics. More research is needed to better understand the importance of individual characteristics, namely disability and constraints, as well as to clarify the role of motivations and habits, possibly influencing choices [152, 180, 181, 225]. It would be interesting to examine for instance if individuals concerned about the environment consider the "ethics" level differently than others. This aspect should be particularly important considering societal changes, such as for instance a higher importance given to the environment and readiness to change for the younger populations [226].

The findings are also important for the planning practice. For the retrofit of the WE, the results can help identify priorities for retrofit. Identified barriers that could qualify for the "first fixes" included traffic safety, overall safety at night, and the comparative quality of driving. Second, the findings encourage developing holistic strategies and interventions, considering walking within the transport system and the built environment, improving integration, and building positive synergies (e.g., strategic walking network considering PT stops and their importance, based on patronage).

4.1 Strengths and limitations

The study described in this chapter has five main strengths. Firstly, it considered the associations between perceptions and walking behaviour, which are generally overlooked in studies associating directly WE attributes to walking. Second, the analysed data included travel behaviour and a broad range of motivations and perceptions, enabling the exploration of the relative importance of diverse constructs. Third, the analysis of the relative importance of explanatory variables on the levels of walking with machine learning allowed for the simultaneous examination of all the potential dimensions of interest, despite their association, so to identify which combination worked best for predicting walking levels. Arguably, the association of any one of the variables with walking would be trivial, because they all have conceptual relationships to walking as a behaviour. However, the novelty in this analysis was the holistic approach undertaken that highlighted strong effects of some variables and absence of signal for others. Fourth, the findings provided input for the further development of the Social Model of Walkability. Lastly, it illustrated an application of machine learning for dealing with complex data, including a multiplicity of associations between explanatory variables. Machine learning remains underutilised when examining the associations between WE and walking (Scopus retuned only seven results for the search for "machine learning" AND "built environment" AND walking [227–233]. Three of those results, all published after 2005, analysed the associations between built environment and walking behaviour [228, 232, 233]).

This study also has four important limitations. Firstly, the available data did not include people having difficulties walking or using a wheelchair. The study could therefore not examine the associations for a population known to be diverse and have higher barriers to access [16, 24, 40, 47, 57, 217]. Second, the inputs are relative to Auckland New Zealand, requiring caution before extrapolation to other environments, particularly those with different driving, public transport and built environments. Third, the format of the available data (respondents offered only yes/no answers to questions about motivations and barriers) may have prevented a more nuanced understanding of how people perceive barriers. Fourth, the distance to and quality of destinations were not considered, although they are known to affect the choice to walk and access public transport [213, 234]. Lastly, the participants declaring not walking have not been included. This was a methodological choice aimed at considering those people who are regularly exposed to their walking environment and whose perceptions of the satisfaction of their walking needs are based on a recent experience. However, considering the reasons why some people cannot or choose not to walk remains an important research topic.

5 CONCLUSION

The findings provide four main take-aways for both research and the practice. First, people's perceptions of their environments need to be better understood and linked to objective aspects of the walking environment. Second, walking needs to be considered within the transport system – as a complement to public transport or an alternative to other modes. Third, it is crucial to embrace the diversity of users, examining how different constraints (e.g., having difficulties walking, seeing or hearing) might moderate the perceptions of the environment. Fourth, assessing walkability should have a lower the emphasis on the pure availability of destinations, giving more room to the quality of the experience. Beyond the surveys of those who were found walking, the study of severance is key to understand what are those characteristics that can act as "deal-breakers" and prevent someone from taking a trip on foot in the first place.

CHAPTER 5: STUDY 2 – HOW STREET QUALITY INFLUENCES THE WALKING EXPERIENCE

PREFACE

This chapter is based on the paper ***How street quality influences the walking experience: a naturalistic inquiry into the perceptions of adults with diverse ages and disabilities***, submitted for publication in the Journal of Urbanism: International Research on Placemaking and Urban Sustainability. The text presented here has undergone minor edits to improve readability (e.g., shortening the contextual elements presented in the introduction as well as findings described in the previous chapters). An illustrative example was also added (Jeremy's and Freddie's modal choice, Figure 9).

The chapter seeks to understand what diverse people perceive as barriers to walking or difficulties, in a car-oriented environment, further testing the drafted Social Model of Walkability (previous chapters). While Chapter 4 examined the second sequence of the model, between perceived walkability and walking quantitatively, using data that did not include disabled people, the present chapter takes a qualitative approach, including both disabled and non-disabled people and examining what features of the WE they associate with difficulty or unpleasantness. Following Forsyth's idea that an ideally walkable environment might not exist [21], and considering the fact that even if it did, current car-oriented environments would be extremely far from it, this chapter reverses the question and asks: what is *not* walkable? To answer this question, barriers to walking as perceived by 56 Aucklanders are explored.

1 INTRODUCTION

Modernistic approaches to urban design have focused on motorised vehicle flows and infrastructure, creating a reliance on cars for everyday mobility [235, 236] with further negative effects on public health [37, 39, 237], degradation of the natural environment [149, 238], and climate change. Within the required "rapid, far-reaching and unprecedented changes in all aspects of society" [239], cities and urban transportation can, and should, play a crucial role [3, 106, 240].

It is now well understood that leveraging walking, or walking combined with PT, aligns with efforts towards less greenhouse gas emissions, better public health, increased equity, and more liveable places. Achieving that modal shift requires a better understanding of how walking is chosen, and what aspects of the urban environment might encourage or discourage walking [13, 19, 106].

As seen in Chapters 2 and 3, research on walkability has made significant progress and reached aspects of consensus on the availability of destinations within walkable distance [22, 55, 56], a certain absence of barriers [27, 57], and safety [21, 22, 58]. There is however no consensus regarding the nature of WE features that people might perceive as difficult or unsafe, and ways it might vary across people [21, 22, 100, 213]. Challenges described in previous chapters relate namely to (a) measuring the quality of the WE in a way that reflects people's experiences; (b) considering how individual characteristics such as disability moderate perceptions and behaviours; and (c) assessing the quality of the WE in a systemic way, considering the available transport alternatives which are known to influence walking levels. The previous chapter identified the importance of considering perceived satisfaction of walking needs *in comparison with* alternatives one might have, or *together with* a companion mode such as PT.

The inquiry is located in Auckland. As seen previously (Study context and setting, p. 36), Auckland is a spread out city [241] with car-centric infrastructure [241] and mobility patterns [81]. Negative outcomes include important safety issues for pedestrians [85] and inequities of access due in part to systemic barriers [76]. Auckland aims to become a city where walking and public transport are attractive choices, one where equity and health are promoted through genuine travel choices, and where safety and environmental protection are maximised [76]. Transitioning from a car-dominated environment and car reliance to walking as a choice implies a systemic approach to change. This approach in turn calls for a better understanding of the decisions to walk.

This chapter examines how perceptions of the WE are related to the choice and experience of walking[9] across a diverse range of adults, considering namely:

- What characteristics of the WE are seen by users as difficult, unpleasant, or appealing?
- Why trips within a walkable distance might be foregone?
- How do WE features perceived as barriers vary between people who have some difficulty with one or more of the following: walking, seeing, hearing, remembering, or concentrating; and those who don't report any of these difficulties?

2 METHODS

2.1 Design

The chapter draws on a naturalistic inquiry, method used for examining perceptions of diverse people of their environments, understood as a "multiple, intangible, divergent, holistic" reality [97]. It is assumed that the phenomena depend on the context and multiple interacting factors, and that inquiry is influenced by the inquirer and by the methods used [97]. The design is broad but not exhaustive, based on 1-1 structured face-to-face interviews. Data and analysis were both quantitative (collection of categorical items and numeric ratings, analysis of distributions and frequencies of mentions), and qualitative (open-ended questions and their content coding).

The drafted Social Model of Walkability (Chapters 2, 3, and 4) is used as theoretical framework. The methods are drawn from the enactive view of perceptions (considering that perceptions are gathered through a recursive process involving sensorimotor knowledge, bodily skills and past experiences) [153] and the circumplex model of affect (understanding perceived emotions as unique combinations of valence – a pleasure–displeasure continuum – and alertness [242]). The circumplex model of affect is supported by vast and growing evidence, and helpful in its recognition of emotions as "ambiguous and overlapping experiences" [242], and not clearly defined categories.

Ethical approval was obtained from Auckland University of Technology Ethics Committee (ref. 18 431, 12.12.18). All names appearing in this document are pseudonyms to protect participant identity.

[9] As in the rest of the thesis, walking includes the use of any mobility device a person might need

2.2 Participants

Participants were a convenience sample of adults living in Auckland. The sample was selected so that half of the participants experienced at least some difficulty with one or more of the following: walking, seeing, hearing, remembering, or concentrating (further noted as disabled participants – see "A note on language", p. 36, in the general introduction). Other inclusion criteria were being aged 18 and over, and self-declaring walking "at least sometimes for transport". The availability of destinations was controlled for by selecting participants living in areas with a pre-determined Walkscore® [118]. Walkscore® ranges from 0 (non-walkable) to 100 ("walkers' paradise" [118]). Participants in this study lived in neighbourhoods with a score between 70 and 90, a range chosen for two reasons: firstly, as the aim was to talk about usual trips, this score meant that participants would have a high chance of perceiving destinations as being within walkable distance; second, working within a given walkability range related to the aim of examining the quality of the walking environments, leaving the availability of destinations as an almost fixed parameter. Participants were recruited via three methods: information posters displayed in public spaces with an invitation to information sessions; information sessions organised at local venues, presenting the research and providing additional information (answers to question, information sheet available to those potentially interested); and researchers' networks (sharing the invite via email and social media). The recruitment methods are detailed in Appendix 5A.

2.3 Measures/Interview design

The interviews covered three aspects. **Firstly, participant and overall insights:** demographic information (age, gender, living and employment situation, time of residence in the neighbourhood), possible impairments (Washington Group Short Set questions [243]), usual travel behaviour, satisfaction with own levels of walking, and perceptions of (a) the proportion of destinations that are easy to reach, by any mode, (b) the ease and pleasantness of walking in their own neighbourhood by day time and night time and (c) improvements noticed in their walking environment. **Second, three usual trips**: mode and reasons for choosing, availability of travel alternatives, purpose(s), destination(s) accessed and their importance, overall perceptions of ease, pleasantness and safety, route chosen (drawn on a paper map), reasons to choose that route, aspects that might make the trip difficult, unpleasant or both (mapped and scored regarding difficulty/unpleasantness) and appealing aspects (mapped); if the trip hadn't been walked, the participants were asked to estimate if the distance would have been walkable and how easy and pleasant walking would be, if done. **Third, destinations desired but less accessed**: destination type, why they are difficult to get to, is the distance walkable and if walked, how would the ease, pleasantness and safety be rated.

The notion of "usual" was intentionally not strictly defined. The objective was to focus on trips participants feel familiar with, acknowledging and accepting that the absolute frequencies of exposure might vary. Therefore, participants were invited to talk about whatever trip they consider usual, for their standards. The questions (Appendix 5B) were worded identically to those of the Household Travel Survey [244] and the Auckland Active Modes Survey [83] wherever possible. The participants were encouraged to develop the issues raised (e.g., when something was rated as difficult or unpleasant, they were invited to specify what aspects were causing them issues). Before the start of the interview, the participants were briefly reminded of the nature of the project – better understanding possible barriers to walking or wheelchair use. It was also specified that the words "walk" or "walking" always included any mobility aid the person might use.

2.4 Procedures

I realised the individual interviews between December 2019 and March 2020, before the lockdown period (Alert Levels 3 and 4 - stay at home, schools and businesses closed with the exception of essential services) due to the COVID-19 pandemic. Participants were interviewed at a place of their choice, which could be their homes or a local public space. Interviews were recorded and categorical answers were noted on a record sheet, on the spot, along with brief remarks (e.g., "crossing" and "complex traffic movements, fast speed" to describe the type of feature and the reason this feature is perceived as difficult). Interview data were revisited as needed, to complement the notes and/or transcribe specific quotes (e.g., explanation regarding why a certain feature is perceived as difficult), but not transcribed verbatim. This method allowed for a more efficient data treatment [245].

2.5 Data analysis

Deductive content analysis was chosen given that this technique is adapted to testing a theoretical framework [99] - in this case, the draft Social Model of Walkability. Different empirical inputs were used to analyse a same phenomenon (data triangulation). The reported barriers to walking were coded using participants' descriptions of what the barriers are, but also their ratings of relative difficulty and unpleasantness. To achieve consistency, a coding protocol was established (Appendix 5C), drawing on the dimensions of the draft Social Model of Walkability (previous chapters). The WE features used as categories build on the general umbrella review (Chapter 2). The WE categories and the rationale for including them are presented in Appendix 5C2. Spreadsheets were used for data capture and content analysis. Associations between difficulty and unpleasantness on the one hand, and trip characteristics on the other (purpose, availability of alternatives and type of barrier noted) were examined through Chi-squared tests using R software [211].

3 RESULTS

Fifty-six participants consented to participate and were interviewed. The study response rate could not be determined given the variety of techniques employed for the recruitment (e.g., posters). The characteristics of participants and reported trips are presented in Table 14 below.

Table 14: Characteristics of the participants and reported trips

			Non-disabled		Disabled[10]		Total	p[11]
			N	%	N	%	N	
Participants		**Total**	**29**		**27**		**56**	
	Age	18-29	8	28%	3	11%	11	ns
		30-44	14	48%	4	15%	18	*
		45-64	2	7%	7	26%	9	^
		65-79	2	7%	7	26%	9	^
		80+	3	10%	6	22%	9	ns
	Socio-demographic data							
		Sex: women	18	62%	13	48%	31	ns
		With drivers licence	28	97%	14	52%	42	^
		With car usually available	21	72%	6	22%	27	**
		With income <20'000 NZ$/y	9	31%	17	63%	26	^
	Difficulties experienced with							
		Seeing, even when wearing glasses	0	0%	19	70%	19	**
		Hearing	0	0%	10	37%	10	**
		Walking 500m unaccompanied	0	0%	8	30%	8	**
		Remembering or concentrating	0	0%	12	44%	12	**
		Two or more impairments	0	0%	19	70%	19	**
Trips		**Total**	**105**		**84**		**189**	
	Modes	Walking only	73	70%	52	62%	125	ns
		Walking and PT	12	11%	18	21%	30	^
		Running	3	3%	0	0%	3	ns
		Walking and/or running	88	84%	70	83%	158	ns
	Importance: high		69	66%	75	89%	144	^
	Purpose	Shopping	29	28%	26	31%	55	ns
		Exercise and recreation	23	22%	11	13%	34	ns
		Work or education	25	24%	8	10%	33	*
		Social	14	13%	11	13%	25	ns
		Other	14	13%	28	33%	42	**
	Ease	High (>6/10)	85	81%	62	74%	147	ns
		Low (<4/10)	2	2%	5	6%	7	ns
	Pleasantness							
		High (>6/10)	75	71%	59	70%	134	ns
		Low (<4/10)	4	4%	8	10%	12	ns

[10] See definitions above

[11] Chi2 test of independence comparing disabled and non-disabled participants: **: <0.01; *: <0.05; ^: <0.1; ns: ≥0.1

Disabled participants were older, had lower availability of driver's licenses/cars, and were more likely to have a low income. For non-disabled participants, the proportion of people satisfied with their own levels of walking or wanting to walk more were not significantly different (p =0.468) from that observed by Auckland Transport (45% and 41%, respectively) [192].

The results are presented below against four questions of interest:

1. When and why is walking chosen?
2. What makes a walking trip appealing?
3. What do deterrents to walking look like?
4. What is perceived as unpleasant and/or difficult when walking?

For each question, the relative role of the quality of the WE is examined more in detail. The overall motivations, deterrents and barriers were coded against the dimensions and (sub)categories of the draft Social Model of Walkability. The results are presented in Figure 11, p. 126 and Appendix 5D.

3.1 When and why is walking chosen?

When speaking about walking in general ("What motivates you to walk?"), participants noted three aspects. **Firstly, internal-motivations** (34 participants, 61%) such as exercise and fitness, health, mindfulness or "me time". For instance, Barbara, 30, walks "when it feels like winning", and Glenn, 64, enjoys the slow pace and thinks that "walking is one of life's big blessings". **Second, convenience as compared to other modes of transport** – for instance, walking being quicker than taking the bus or avoiding parking hassle. **Thirdly, the quality of the walking environment**, explicitly noted by 13 participants speaking of street trees, greenery and views of the nature, presence of other people and architectural quality. Lower levels of the hierarchy of needs [43, 100] (i.e., feasibility, accessibility, and safety) were not mentioned, with the exception of one participant noting accessibility issues. Disabled and non-disabled participants referred to the same environmental categories (for instance street design aspects were mentioned by three disabled and four non-disabled participants). Habit was noted by only one participant, non-disabled.

When speaking about specific trips usually made, almost 2/3 of the reasons to choose walking related to the broader transport system or walking as compared to other alternatives. Convenience played a major role, often in comparison to other modes – bus (18 trips), car (17 trips), or bicycle (8 trips) – and related to the proximity of destinations. The internal motivations (41 trips) all related to fitness, exercise, and health. The social dimension of walking (walking with friends or family, or just amongst strangers), was another important aspect, noted by 16 participants. Disability appeared

as an important lens: non-disabled participants were more likely to note pleasure-related aspects, such as walking with friends (23 vs. 9, $p < 0.05$) and were less likely to walk because of a lack of choice (3 non-disabled versus 22 disabled participants reported this barrier, $p < 0.05$). The results are presented in Figure 11 and Appendix 5D. Participants also described 25 usual trips for which they chose not to walk; most of these trips (19) were considered as being within a walkable distance. An alternative mode to walking was chosen most often because it was perceived as more convenient, faster, or because it allowed the avoidance of obstacles (e.g., steep hill, absence of footpaths, a path that feels unsafe at night).

The choice of walking seemed largely individual. The difference is illustrated by the Jeremy's and Freddie's trips to the supermarket: both are aged 28, are non-disabled, live in the same area, have a car available, shop in the same supermarket and access it using a similar route (see Figure 9 below). Having "stuff to carry" is however presented by Jeremy as the reason for usually walking (instead of taking the skateboard), while Freddie drives for the same reason.

Figure 9: Modal choice, comparison between Jeremy's and Freddie's decisions; the places of residence are indicated approximately, for privacy reasons, and not centred exactly on home addresses

3.2 What makes a walking trip appealing?

Three aspects were noted as appealing or pleasant: **design and greenery** – for instance, streets with quiet traffic that can be “very pretty”, pleasant public spaces and good quality footpaths; **activity on the street**, relating to the pleasure of being with other people, even without interacting; and, to a lesser extent, **efficient combination of walking and public transport:** for Glenn, 64, buses “sailing past the traffic” contributed for instance to a usual trip being perceived as pleasant. Some participants noted topography (e.g., flat or downhill, although some appreciated an uphill as a form of exercise) or the fact that the route they were taking did not involve crossing streets.

Trips noted as appealing because of street design features represented 58% of trips reported by disabled participants (43 trips) versus 88% of those reported by non-disabled participants (78 trips). Disabled participants were more likely not to name any appealing aspect relative to trips walked (21 vs. 8, $p < 0.01$). For instance, Sam, 41, blind, seemed almost surprised by the idea of appealing aspects - "No, because I'm concentrating!".

Eight participants also spontaneously noted aspects that decrease the ranking of appeal. All those aspects related to street design, and referred mostly to busy streets: Phoenix, 27, enjoys arriving in Ponsonby "but the motorway is pretty ugly"; Kit, 79, enjoys "everything apart crossing Dominion Road"; Dennis, 44, notes that "once you're there, it's pleasant, but Dominion Road is in the way!”.

3.3 What do deterrents to walking look like?

When speaking in general about deterrents to walking, participants noted internal barriers (health issues/pain/fatigue), and external aspects related to accessibility, safety, comfort, and pleasure. Traffic, and traffic-oriented environments were noted 10 times, implicitly or explicitly. Examining why specific trips to desired destinations are perceived as being within walkable distance but not walked, provided rich insights into ways the quality of the walking environment can deter walking. Participants reported 27 instances of barriers of access, some being systemic (e.g., inconsistencies of design that caused blind participants to avoid any route that they have not learned previously, by fear of being exposed to dangerous situations).

The noted barriers of access fall under five categories:

- **Traffic, and traffic-oriented environments**: non-signalised crossings, environments designed for traffic;
- **Footpaths design and quality**: insufficient width and obstructions, permanent or temporary;
- **Lighting**: absence or poor quality, at night;
- **People**, relating either to the discomfort of walking when "there is no one around" or else the presence of people perceived as potentially threatening (stranger danger); and
- **Broader transport system**: inefficient bus services that mean longer distance trips cannot be done by a combination of walking and public transport. Most of the reported barriers (24 out of 27) correspond to the first four categories and relate to the quality of the walking environment.

While disabled and non-disabled participants spoke about hills, indirectness of the walking network at similar rates ($p>0.05$), some differences were also noted:

- **Non-disabled people** spoke more often ($p<0.05$) about destinations not being within reach and reported unpleasant street designs (car-oriented, grey) and too high traffic volumes.

- **Disabled people** spoke of barriers to access such as difficult crossings, poor maintenance causing tripping hazards, or a lack of toilets and benches.

The most frequently noted aspects were non-signalised crossings (seven mentions) and environments designed for traffic (six mentions). They are illustrated through participants' quotes and in a short video: https://bit.ly/walking_AKL.

3.3.1 Non-signalised crossings

Nora, who is aged 85, struggles to cross the road to access the bus stop. In theory, she could catch a bus every 15 minutes to go to the city centre, but "If you want to get your bus, you take your life in your hands. It puts you off to getting to town because you have to cross that road. You gotta be careful, you stand in the middle [on a narrow refuge], but the trucks are wider than you think". She raised the issue with the Council but "they said they couldn't stop the flow of traffic or didn't want to." Dwight, 41, is active and athletic, but he noted that the restaurants and shops on Dominion road (very close to home) are inaccessible if they involve crossing the road with his two children. Hollie, an active 75-year old wheelchair user spoke of micro-level design features - abrupt gutters and kerb cuts, saying: "I can come to a crossing and think "I'm not even going to try!".

3.3.2 Environments designed for traffic

Participants reported avoiding environments that they perceive as grey or difficult to navigate. Wren (48) spoke of “hostile environments”, Dover (20) of “bad intersections, places where it’s not fun to walk, that are not easy”. For Kamaal, 28, any destination that involves going over the motorway overbridge "feels like a bit of a project; a very prominent divider for anyone who would want to cross on foot. You don't see a lot of people walking that street".

> *Have you seen the Khyber Pass? [laughs] A lot of cars and parkings, motorway on/offramp, no trees, there isn't anything happening, people there walk from A to B. – Phoenix, 27*

Dev, 77, is legally blind and described important difficulties right outside his house: traffic, speeds, narrow footpaths - it's a hostile environment. He defines himself as "basically home-bound" - "for his own safety", adds his wife. Systemic barriers could also mean that whole areas are inaccessible.

3.4 What is perceived as unpleasant and/or difficult when walking?

Participants were what they perceive as difficult and/or unpleasant on the trips they usually walk (alone, or in combination with public transport). After filtering those inputs to include only features having ratings of >6/10 for difficulty and/or unpleasantness, 134 barriers were identified (60 noted by disabled participants, 74 by non-disabled participants).

Features noted as difficult (80 mentions, of which 40 were noted by disabled participants) relate to four categories: **traffic, and traffic-oriented environments**: non-signalised intersections difficult to navigate, traffic, signalised intersections with long waiting times or a short time available to cross, or traffic infringing on the footpaths to access parking lots; **footpaths design and quality**: footpaths design, maintenance or quality of execution; **hills**; and **availability of toilets.** The last two categories were noted only two and one time each, respectively. Interestingly, the environmental features perceived as difficult are the same as those that had been noted as barriers to walking (general deterrents), the only exception being the absence of people (no one around, or stranger danger, noted as general deterrent but not difficulty).

Disabled and non-disabled participants reported similar numbers of barriers per trip, both overall (respectively 0.84 and 0.87 barriers per trip) and when examining trips perceived as difficult and unpleasant (0.94 and 0.95). However, disabled participants rated the difficulty of their trips higher (median difficulty out of 10 (SD) respectively: 6.8 (2.1) for disabled people, 5.9 (2.4) for non-disabled people, $p < 0.05$).

The frequencies of mentions of different environmental categories were not significantly different between the two groups at $p < 0.05$, except for the availability of destinations (mentioned by 10 non-disabled participants (37%) and three disabled participants (10%), and traffic along the path (five non-disabled participants (19%), not mentioned by disabled participants). Within the WE features, some were mentioned by both disabled and non-disabled participants, while some were specific to those groups. Within the trips considered as difficult and unpleasant, non-signalised crossings, footpaths (materials, execution, and maintenance), and traffic across footpaths were mentioned by everyone; non-disabled participants only spoke of waiting time at signalised crossings and holistic design quality (streets designed for cars); while disabled participants mentioned the width and obstructions of footpaths, the traffic volume and speeds, and the use of footpaths by e-scooters. Detailed results data for this topic is provided in Appendix 5F.

Non-signalised crossing facilities were the most prominent feature causing difficulties to walking (29 mentions). The participants noted the difficulties caused by complex/fast traffic movements and infrastructure layout, often very wide.

> *[Newton overpass on/off ramp] is the motorway onramp and offramp, and there's a lot of traffic going really fast, trying to figure itself out. Being a pedestrian around there is pretty dangerous. I really… I hate getting out of the city. Once I get on Dominion Road it's ok, but getting out of the city - there's traffic, noise, car exhausts, bad smells, buses, all that kind of gross car stuff. And that bit is particularly bad" - Morgan (40)*

> *Church road [Mangere Bridge] is a bugger to cross, it's really busy. […] So on a bad day, it can take 10 minutes to cross. […] There are crossing points, where there are tactiles, but you know […] Auckland Transport seems to be a lot into what they call *refuges* in the middle of crossings, where you're meant to stand and go forward again. They don't work for blind people. A, you don't know if you're right in the middle, B, it's difficult to delineate each side by sound, so I have to wait till both sides are clear, really. So I would favour a controlled or at least a zebra crossing, where the traffic will stop. I would prefer controlled, I always prefer controlled, you know, where you press the button and you get the sounds, but a zebra would at least be helpful. - Lenny (49), blind*

The results for these comparisons are included in Appendix 5E. An overview of the frequency of apparition of different barriers for disabled and non-disabled participants is presented in Appendix 5F.

3.5 Roles of the walking environment in the perceptions of walking and the walking behaviours

Participants were free to indicate any aspect participating to their choice of walking or the perceived difficulties of accessing destinations. The walking environment (destinations, walking network and quality of the street environment) was an important topic. Interestingly, features were often associated with different outcomes (e.g., perceived as a "cannot do" barrier by some participants, and difficulty by others). An overview of these associations is provided in Figure 10, below. Figure 11, on next page, provides more detail on the causes of severance, difficulty, and unpleasantness.

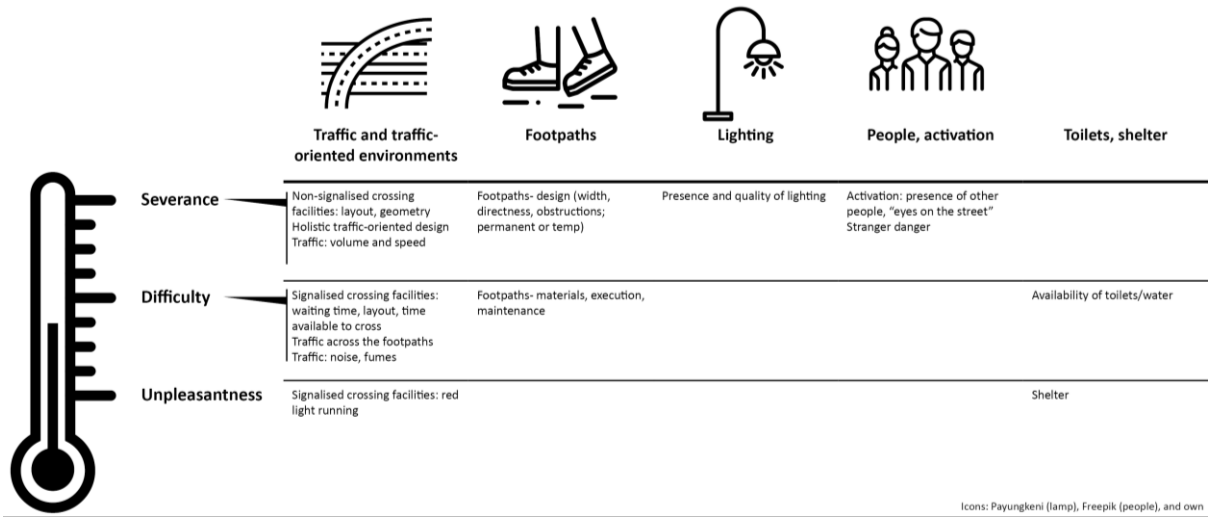
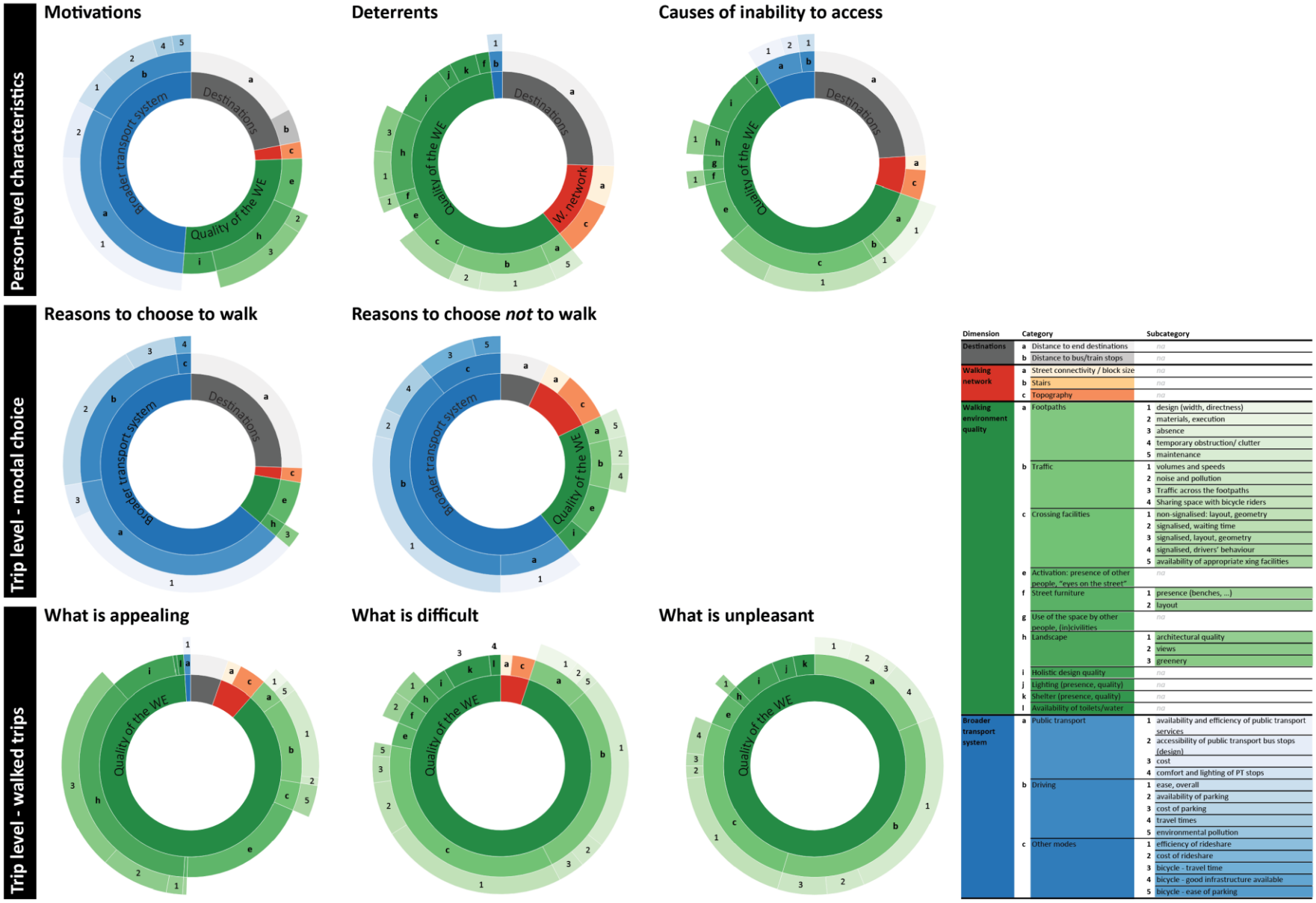


Figure 10: Features of the walking environment reported as causing barriers of access and/or being detrimental to the quality of the walking experience



Dimension	Category	Subcategory
Destinations	a Distance to end destinations	na
	b Distance to bus/train stops	na
Walking network	a Street connectivity / block size	na
	b Stairs	na
	c Topography	na
Walking environment quality	a Footpaths	1 design (width, directness)
		2 materials, execution
		3 absence
		4 temporary obstruction/ clutter
		5 maintenance
	b Traffic	1 volumes and speeds
		2 noise and pollution
		3 Traffic across the footpaths
		4 Sharing space with bicycle riders
	c Crossing facilities	1 non-signalised: layout, geometry
		2 signalised, waiting time
		3 signalised, layout, geometry
		4 signalised, drivers' behaviour
		5 availability of appropriate xing facilities
	e Activation: presence of other people, "eyes on the street"	na
	f Street furniture	1 presence (benches, ...)
		2 layout
	g Use of the space by other people, (in)civilities	na
	h Landscape	1 architectural quality
		2 views
		3 greenery
	i Holistic design quality	na
	j Lighting (presence, quality)	na
	k Shelter (presence, quality)	na
	l Availability of toilets/water	na
Broader transport system	a Public transport	1 availability and efficiency of public transport services
		2 accessibility of public transport bus stops (design)
		3 cost
		4 comfort and lighting of PT stops
	b Driving	1 ease, overall
		2 availability of parking
		3 cost of parking
		4 travel times
		5 environmental pollution
	c Other modes	1 efficiency of rideshare
		2 cost of rideshare
		3 bicycle - travel time
		4 bicycle - good infrastructure available
		5 bicycle - ease of parking

Figure 11: Occurrence of citations of the characteristics of the walking environment in relation to person-level views (motivations, deterrents, difficulties) and trip-level characteristics (reasons to choose a mode, and contributors to appeal, difficulty or unpleasantness). For each "donut", the dimensions (e.g. quality of the walking environment) ore on the inner circle, and further split across categories (middle circle) and subcategories (outer circle).

3.6 Consequences of experienced barriers

The barriers experienced had a series of consequences:

- **Consequences on the way people travel** (e.g. leaving home early to allow 10 minutes or more to cross a single street, for Lenny and Sam, both blind; taking the bus for part of a trip that would take about 10 minutes on foot, specifically to avoid having to cross a certain road (Sam) or leaving home 45 minutes earlier so to cross the road before the traffic peak – Morgan);
- **Increased stress**: Aiko, 28, said "I almost need to plan in advance how I get around it [roundabout with heavy traffic]". The blind participants seemed especially impacted by the difficulties encountered, and reported big efforts put into learning the necessary routes and planning their trips. For instance, Jacqui, 65, plans all her routes to use the safest crossings, making important detours. Older participants seemed particularly inclined to take responsibility of their own safety – for instance, Leigh, 83, feels safe because she is "always on alert", and Amareki, 72, because she is "well aware" and "won't cross where it's unsafe". Lee, 85, thinks it's crucial to watch the traffic because "the road belongs to the cars, doesn't it?".;
- **Trips foregone**, for those lacking alternatives: Nora, 85, goes less into town because of reported difficulties accessing the bus. She described this as a loss, given that she would like to visit the library or the theatre;
- **Risk-taking:** complex non-signalised intersections or long waiting times at signalised intersections might provoke people to take risks. Non-disabled participants reported that they often weighed safety against convenience, and potentially put themselves in danger:
  You know, when you try to get into St Luke's from that side and you just have to walk around like, every single crossing, to get in, or you just have to run across the road and hope that you don't die [laughs]. I absolutely hate that entrance to St Luke's, it's a nightmare. [...] There's signs now, to say "please don't cross if there's no crossing" and I'm like "well, you don't really give people much of an opportunity!" - Robin, 38

  There's nowhere to cross the road here. So you just have to walk out into the middle - because it's so busy, you can't wait for there to be no cars - so you just have to walk out into the middle and stand in the middle hoping that no one hits you [laughs]. So in daytime it's not too bad (!) but in the night time I'm really worried that I'm not visible enough. I always thing that - how would someone with limited mobility, how would an old person who walks really slowly or whatever it might be, how would they - because I don't even know where the next crossing is, how far you would have to walk to find a crossing. – Robin, 38

4 DISCUSSION

This study examined individuals' experiences of walking in a car-dominated environment. Specifically, it considered the ways people's perceptions relate to their choice and experience of walking, using the draft Social Model of Walkability (Chapter 2) as a theoretical framework. Features of the walking environment and transport system were a key focus, as these aspects can be modified through planning and design. The results provided rich insights relative to the choice of walking and the three research questions:

- What characteristics of the WE are seen by users as difficult, unpleasant, or appealing?
- Why trips within a walkable distance might be foregone?
- How do WE features perceived as barriers vary between people who have some difficulty with one or more of the following: walking, seeing, hearing, remembering, or concentrating; and those who don't report any of these difficulties?

4.1 The choice of walking

The mentioned motivators for walking had previously been identified (namely: internal motivations [54, 246, 247]; the qualities of the walking environment [53, 54, 65, 248]; the broader transport system, considering the comparative convenience of walking relative to other modes [110, 222, 223] or the lack of choice). It should however be noted that the current evidence base is somewhat heterogeneous. For instance, Barnett and colleagues' systematic literature review, examining older people's walking levels, found a large proportion of non-significant findings for greenery and aesthetically pleasing environments (19 out of 29) [65]. As examined in chapters 2 and 3, the moderating effects of health status and functionality are usually poorly captured, which could lead to aggregating results across demographic groups or trip purposes even though these might have different requirements, expectations, or priorities.

The literature also tends to give less importance to the broader transport system, examining the walking environment (e.g., distance to destinations or quality of footpaths) but not necessarily the attractiveness of walking as compared to alternatives available. Barnett and colleagues noted for instance the lack of consideration for the participants' driving status / car ownership (2/100); or examined the availability of public transport, as measured (8) or perceived (10) [65].

The availability of destinations was not a major theme in the responses and appeared mostly implicitly, with participants noting the convenience of walking as compared to other modes of transport. This result could seem at odds with the importance of the destinations in the walkability literature - for instance as reported by Frank and colleagues or Cervero and Kockelman [60, 249]. The study design targeted participants having a relatively high measured availability of destinations: therefore, the findings do not question the overall importance of the availability of destinations within walkable distance but it is possible that this topic was not the first priority for this group of participants.

Interestingly also, habits, that had been associated with modal choice [152, 247], were almost absent from both the general and specific motivations to walking. This absence could be explained by the status quo bias, or the not necessarily conscious way of preferring usual ways [152, 181, 250]. Pooley and colleagues even posited that walking might not be recognised as a choice or a mode of transport because it is such an ubiquitous aspect of everyday life [251]. Participants who have alternative transport modes appeared to compare the options available and choose the most convenient one regarding their needs.

4.2 Question 1: features seen as difficult, unpleasant, or appealing

The ease and pleasantness of the walking experience were good conversation starters, readily understood by participants of all ages and backgrounds. Participants' inputs provided further detail that (in most cases) allowed their perceptions to be matched with the hierarchy of needs (some coding challenges and recommendations are discussed below). For the walked trips, there was a palpable sense of stress related to interactions with traffic. While practitioners might perceive pedestrian distraction as a safety issue [252], my participants showed high levels of vigilance and displayed strategies to deal with complicated environments and avoid or mitigate danger.

The quality of the WE was more important than the high-level attributes (destinations, walking network connectivity and transport system), in terms of walking experience. Traffic and traffic-oriented infrastructure were difficult and/or unpleasant for the participants, regardless their age or impairment. These findings align with previous evidence that associated people's walking experience with the qualities of the WE, namely the traffic volume [131, 253, 254], the ease and safety of crossing [62, 122, 255] or the availability and condition of footpaths, especially for older people [122, 217, 256]. Pooley and colleagues note that the enjoyment of walking can be counter-balanced by difficulties due to a non-supportive environment (e.g., difficulties to cross; traffic noise and pollution; multi-lane roads seen as grey and unappealing; or poor quality footpaths) [251]. Walking was described as "simply something that you did to carry out the tasks necessary for everyday life" and

"most people were very accepting of the constraints imposed by the environment through which they passed" [251]. As this study focused only on usual trips, it is possible that the perception of difficulty might be lessened. This suggests that the barriers reported are significant: firstly, because participants remembered them, despite the familiarity of the trips and the possibility to walk them "on auto-pilot" [18], and second because encountering similar barriers in less familiar contexts might cause a greater difficulty.

4.3 Question 2: characteristics of trips foregone

Barriers to walking were defined as features associated with the inability to walk to a desired destination. Barriers to walking were both specific (e.g., an obstacle encountered on a certain trip) and systemic (e.g., knowing that the design is inconsistent prompted blind participants not to walk anywhere without having previously learned the route and its obstacles). Systemic barriers are understood to have a higher impact on a person's mobility, as they can deter them from undertaking several potential trips. For instance, it has previously been shown that people who report difficulties crossing the street were 8.25 times more likely to leave the home less than once per month than people of the same age group not reporting difficulties [257]. Barriers related to safety, comfort, and pleasantness, consistently with recent findings based on virtual exposure and photo-elicited interviews [258]. However, this study allowed interesting insights into comparing preferences of disabled and non-disabled people and noting differences: disabled participants reported mainly on critical issues, related to the most fundamental walking needs, and not on those related to pleasurability for instance. Bornioli and colleagues had noted that including disabled people could have produced a different set of findings [258].

The definition of "barrier" considered in this relates to trips not being walked. Interestingly, Barnett and colleagues did not associate the absence of physical barriers with older people's walking levels ($p = 0.38$) [65]. This result could be due to the definition of "barrier" or, as mentioned earlier, to the noted lack of controlling for functional limitations [65] or specific needs. Thus, studies could assume the nature of barriers and relate them to walking levels, "averaging" the results relative to mostly non-disabled participants with those of people with diverse types and levels of disability, using diverse mobility devices, and therefore potentially losing track of what might constitute barriers for some people. Barnett and colleagues noted also a wide variety of geographical areas considered, with the risk that those areas would not necessarily correspond to the users' "playgrounds" [65]. This study dealt with those difficulties by asking people what they perceive as difficult, and focusing on people's usual trips, ensuring therefore that each participant was talking about the area familiar to them, no matter how large or distant to home it was.

4.4 Question 3: disability as a moderating factor

While the disabled participants rated the overall trip difficulty higher as the non-disabled participants, it can seem surprising that both groups reported similar rates of numbers of WE features making walking difficult. Two hypotheses could explain comparable rates of difficulties. Firstly, disabled participants described numerous strategies for accessing their destinations and avoiding specific barriers – an aspect noted in previous studies and associated with a mental burden of travel [20, 41]. Blind participants reported for instance memorising routes and specific attention points or even using buses for parts of short trips to avoid certain obstacles while wheelchair users paid special attention to the geometry of kerb drops and steepness of inclines. Therefore, disabled participants' usual routes could be considered as carefully curated, which might not be possible for non-habitual trips. Similar rates of barriers reported could also be due to under-reporting. Oliver noted for instance that disabled people could feel not represented and listened to [47], which could suggest a weariness in participating in engagement unlikely to trigger change on the ground [259].

When considering those trips that were both difficult and unpleasant, the disabled participants reported certain types of features that had not been noticed by the non-disabled participants (e.g., footpath obstructions). This finding aligns with results from Moura and colleagues, having shown that same environments can be perceived differently across age groups, physical ability, and trip purpose [122]. The barriers reported by disabled people tended to be real challenges to overcome, while non-disabled people sometimes reported barriers rather linked to convenience (long waiting times at signalised intersections) or enjoyment of the route (lessened by roads designed for cars). As noted above, disabled participants put significant time and effort into strategies to alleviate obstacles but experienced more and severe potential consequences related to the encountered difficulties (e.g., having to alter routes, use other modes of transport or avoid altogether).

In 2018 the New Zealand Transport Agency reported that 75% of interviewed disabled people had not been able to make a journey that would have been beneficial, in the previous week, as compared to 23% for the overall population [207]. As the interview reported in this chapter investigated up to three trips by participant, the total volume of travel was not assessed, and it is therefore possible that the disabled participants made less trips altogether than the non-disabled ones. As mentioned earlier, non-disabled participants were also impacted by the traffic-oriented environments, although the result could lead to an unpleasant experience that is not necessarily a major difficulty. Trips involving unpleasant or unsafe environments were walked because of higher-order motivations but could sometimes lead non-disabled participants to avoid journeys as well. For instance, avoiding crossing certain roads with children and therefore not accessing an array of local destinations.

4.5 Methodological considerations

In 2010, Middleton and colleagues reported that while pedestrian behaviours were sometimes counted and captured, important gaps persisted in experiential data [18]. Eleven years later, studies have progressed the understanding using diverse techniques such as walk-along interviews [256, 260]; participatory action research [261, 262]; rating of pre-defined environments, in situ [17, 122] or virtually [258]; a combination of different types of interviews and ethnographies [251]; measures of behaviour used as experiential proxies (e.g., head movements and fixation points [263, 264]; or physiological responses, an approach recently reviewed by Zanwar and colleagues [265]). There does not seem to be consensus on how to capture experience, and it is possible that methods will complement each other. The approach taken in this study (sit-down interview) does not allow to observe participants in their milieu or measure their reactions. However, it presents some significant advantages: firstly, instead of assuming a psychological response from a physiological measure (e.g., gait), it asks participants to name it; second, instead of measuring the responses or reactions of people present in a certain environment, it interrogates participants about those destinations that are too hard to reach, and therefore captures perceptions of those who are absent; and third, instead of taking the visual input as a proxy for the overall experience (as done in studies considering eye tracking for instance), it encompasses all senses and captures the insights of participants who do not rely on sight for orientation.

4.6 Significance for transport planning and urban design

Identifying aspects of the built environment that are problematic is important as a decision-support tool for improving built environments. Certain aspects of the walking environment (e.g., intersection layout, traffic-oriented environments) were prominent among the interviews. These are related to severance, difficulty and unpleasantness, for all ages and disabilities. Any given city will have many occurrences of these problematic features (such as non-signalised intersections). Targeted retrofit will require specifying the characteristics that should be altered, to facilitate systemic assessments of walking networks. This work should relate experiences of diverse users (for instance aspects perceived as difficult or features discouraging a local walk) to objective measures on the ground. Given the diversity of potential perceptions of similar environments, noted here and previously, it will be important to examine specific user groups separately, identifying what might be an obstacle for at least some people (e.g., blind, long cane users).

4.7 Strengths

This study has five major strengths. Firstly, it examined trips that are usually walked vs. potentially walkable and addressed dimensions of lived experience, controlling for familiarity and habits, which can potentially influence the choice and experience of walking [152, 247, 251]. Second, it included adult participants with a wide range of ages and physical abilities, responding to the need for better understanding particular needs of people with different types and levels of disabilities [16, 57]. Third, it included trips combined with public transport, an area that is under-researched [213]. Fourth, this research contributes to addressing the emotional experience of walking, an aspect studied less than the practicality and often through proxies and not direct insights [213]. Fifth, practical insights were provided into what aspects of the walking environment can discourage walking.

4.8 Limitations

This study also has four major limitations. First, all participants reside in urban or suburban areas of Auckland. Therefore, while findings can be helpful for other car-dominated environments (e.g., US, Canada, Australia), they cannot necessarily be generalised to areas with radically different street design and transport system characteristics (ease of driving, efficiency of public transport). Second, while half of the participants are disabled, the numbers of participants when split by disability, assistance used, and age are low (for instance, only one participant is blind and uses a service dog, and no deaf participants were recruited). This is an issue considering disabled people as a heterogenous group. Third, the interviews were structured and may have lacked depth in some

respects. The interviews sought to understand what matters, but answering this question fully confronts the problem of identifying and verbalising one's feelings [242]. Fourth, basic dimensions of experiential quality (ease/difficulty and pleasantness/unpleasantness) were tentatively mapped across the dimension of the hierarchy of walking needs, using a structured coding framework, but there is inherent difficulty categorising perceptions [242].

5 CONCLUSIONS

This study outlined the importance of three major dimensions in research examining walking environments and users' perceptions. Firstly, the quality of the street environment (including traffic speed, volumes and infrastructure) played a major part in perceived barriers to walking across all ages and disability status. Second, the broader transport system was related to the choice of walking, particularly when perceived as more convenient than other options. Thirdly, disabled participants deployed a range of strategies to overcome obstacles they encountered. Despite this, they were more likely to experience severance, and inconsistency of design, making most spontaneous trips unfeasible. Future research should characterise the features of the walking environment that impede the ability to access destinations (e.g., non-signalised intersections). This will enable planners to systematically examine cities' networks and identify instances of those features that should be redesigned.

CHAPTER 6: STUDY 3 – RELATING WALKERS' EXPERIENCES TO MEASURABLE BUILT ENVIRONMENT CHARACTERISTICS

PREFACE

This chapter is based on a paper submitted for publication in the Journal of Urban Design. The text was slightly edited here, shortening elements of context presented earlier in the thesis.

The chapter reports on an analysis of the barriers to walking identified through the interviews of 56 Aucklanders (chapter 6). Six types of environmental features (critical features) resulted in at least some people not accessing desired destinations. The present study sought to quantify the barriers as perceived by the participants by measuring them and characterising them objectively.

1 INTRODUCTION

In an increasingly urbanised world, cities appear as major actors regarding climate action, particularly through more sustainable travel patterns [3, 5, 6]. A modal shift towards low carbon mobility also presents major and now well understood benefits in terms of public health, well-being, equity of access and liveability.

As examined in the general literature review (chapter 2), WE and the transport system are associated with walking through the important filters of individual perceptions and individual, social, and trip-related characteristics. These associations form part of the draft Social Model of Walkability, developed throughout this thesis.

Despite the growing conceptual understanding and the accumulation of evidence, the lack of consensus on what is "walkable" or "non-walkable" perpetuates discrimination in terms of ease of movement and contributes to uncertainties regarding how to measure WE quality in a way that reflects people's experiences (chapters 2 and 3). The ways how individual characteristics moderate the relationships between environmental quality, perceptions and walking behaviour needs to be better understood [16, 24, 57]. It is therefore important to triangulate objective measures, user perceptions and guidelines to help develop recommendations on the priorities of retrofit, and "reality-checking" the recommendations and objective measures against lived experiences.

This chapter examines what is ***not* walkable** for adults of varying ages and abilities**.** The problem of the WE is inverted: instead of considering the ideal, **features of the WE that are seen by the users as difficult, unpleasant or non-traversable, in a car-oriented environment** are examined and characterised**.** This chapter builds on data previously collected through interviews (chapter 5), focusing on the types of features of the WE that discouraged participants from accessing destinations perceived as both desirable and within walkable distance (***critical features***).

The aims of this study were to:

1. **Characterise objectively the critical features of the WE**, providing insight for retrofit; and
2. **Examine the appropriateness of best practice design recommendations and local guidelines for identifying the deterrents to walking observed by people**.

This analysis sought to specify what "critical" means, identifying relevant indicators and thresholds can (a) help specify what is particular about the instances that participants indicated as difficult or non-walkable; and (b) help identify other instances that can be difficult or impossible, across Auckland or other cities.

2 METHODS

This is a descriptive study examining features of the WE perceived as barriers to access and builds on previously gathered insights from participant interviews (chapter 5). Briefly, participants were a group of diverse ages (20 to 89), living in Auckland, with half of the participants having at least some difficulty with one or more of the following: walking, seeing, hearing, or remembering or concentrating. Participants reported what made walking trips in Auckland difficult and/or unpleasant, and what discouraged them from taking walking trips altogether (barriers to access). Each reported barrier included a description (e.g. “difficult to cross”), a location, and the reference of the participant who mentioned it.

Individual barriers (secondary data) reported by interview participants, were assigned to one of six critical features: non-signalised crossing facilities, footpath design and obstructions, traffic, street lighting, holistic design and activation. The critical features were defined as at least one participant declaring not being able to access destinations because of that feature. In this chapter, the critical features are characterised and compared with recommendations found in international best practice and two local guidelines.

Data relative to the reported barriers (chapter 5) were first filtered, eliminating (a) duplicates (e.g. a single non-signalised crossing identified by several participants); (b) instances not related to specific locations; (c) instances that could not be measured because they related to a past or evolving situations (e.g. a worksite with changing layout and vehicle flows); and (d) instances that could not be measured because the perceived barrier was a personal assessment (e.g. presence of people perceived as threatening). Table 15 provides an overview of the filtering and included numbers, for each type of barrier to access.

Table 15: Barriers to access related to the quality of the walking environment: reported cases and filtering

Critical features	Barriers				
	N reported (interviews)	N duplicates[12], excluded	N other excluded	Reasons for exclusion (other)	N included
Non-signalised crossing facilities – layout and geometry	46	9	6	Not relating to specific situations, or relating to an evolving situation	31
Footpaths design & obstructions (width, directness, obstructions)	24	0	8	Not relating to specific situations, or relating to an evolving situation	16
Holistic design quality – car-dominated environments	16	2	3	Not relating to specific situations	11
Traffic along the path - volumes and speeds	11	0	3	Not relating to specific situations, or relating to an evolving situation	8
Lighting (presence, quality)	7	0	1	Not relating to specific situations	6
Activation: presence of other people, "eyes on the street"	5	0	1	Barrier associated to a participant's personal assessment related to the threatening aspect of some people that could be seen in a location.	4

2.1 Data collection

Data collected in this chapter are measures informing each barrier reported by the participants. A set of metrics were chosen for each critical feature, and all the reported barriers were measured against those metrics. The choice of metrics was informed by:

- **Participants' insights**, explaining what they find difficult or non-feasible;
- **Previous research**, building on findings of the previous chapters;
- **The Healthy Streets framework**, considered best practice and laying out the important dimensions to consider [95]; and
- **Applicable local guidelines**: NZ Transport Agency's Pedestrian Design guideline [93] and Auckland's Transport Design Manual (TDM) - Urban Street and Road Design Guide [94].

The full list of metrics chosen, the rationale for their selection, and the data sources are presented in appendix 6A. Wherever possible, the measures chosen consider metrics that cities routinely collect

[12] Duplicates refer to a same barrier reported by different participants.

(for instance, peak hour traffic volumes), with the idea of developing an assessment that answers the research questions while being pragmatic and easy to implement.

Data relative to the chosen metrics were gathered in July and August 2020. I visited all locations of the reported barriers. Wherever possible, existing data were used (identified through online search and direct contact with Auckland Transport). I gathered in situ those metrics that were not readily available. It is interesting to note that pedestrian counts were not available except for the core of the city centre, where they are automatically gathered via cameras and video recognition [266]. A brief overview of the methods used to collect data is provided in Appendix 6A. Detailed information about data collection methods and approaches used to describe the data are provided in Appendix 6B.

2.2 Data analysis

Each of the six critical features was described across the chosen metrics. Four aspects are considered for each metric:

- **The recommendations and identified thresholds from the Healthy Streets approach** [95];
- **The indications and identified thresholds from the local guidelines**;
- **The measures gathered for each instance belonging to that critical feature**; and
- **A rapid assessment of the measures in Auckland's context** (are they "exceptional" or common?).

Given the relatively small number of examined instances of each critical feature, the analysis is mainly descriptive, based on the chosen metrics (e.g. median, interquartile range (IQR), minimum and maximum, within the given metric). Patterns, or absence thereof, were identified.

3 RESULTS

The results are presented in sections, one for each of the six critical features, presenting an overview of the findings and a minimal definition. The full results (information for the four dimensions above, for each of the examined metrics and each barrier reported) are presented as appendices.

3.1 Non-signalised crossings - layout and geometry

The non-signalised crossings examined were mostly informal (not marked across the carriageway but only indicated to the pedestrian through lowered kerbs and tactile pavers, in most cases). The crossing distances and speed limits, although higher than the recommendations, did not appear exceptional for Auckland's context. Traffic volumes were also not a good indicator of "problematic" crossings. Ten of the instances have peak hour traffic below 500 vehicles per day, which would award them the highest score for the metric #1 (traffic), in the Healthy Streets approach [95]. Eight of the cases (26%) had peak hour traffic lower than 200 vehicles per hour corresponding to the highest score regarding suitability of non-signalised crossings, in the Healthy Streets approach [95].

The instances with "low" peak hour traffic appeared as particularly interesting: as mentioned, an assessment using the Healthy Streets approach [95] would rate them as appropriate in their context. Yet, participants pointed them out as difficult or impossible to cross, indicating the presence of serious issues. The presence or absence of crossing aids, to which both Healthy Streets and the local guidelines relate, was not an obvious explanation: five of the instances with "low" peak hour traffic (under 200 vehicles per hour) also have pedestrian refuges, four of them with a STOP sign.

Two aspects help however explain the difficulty and are presented below: **(a) turning radii** and **(b) the complexity of the crossing**, measured by the number of traffic movements that the person needs to watch before crossing.

Turning radii appear to be an important parameter, acknowledged but not strictly prescribed in the guidelines or the best practice. All of the problematic crossings situated at intersections have turning radii above 8 m, for the direct left hook, suggesting relatively high cornering speeds. It was not possible to inform the association between turning radii and cornering speeds through local measures or results from published empirical studies. Therefore, measures were taken on the ground for a sample of locations presenting a range of radii corresponding to those indicated by the participants. A total of 966 measures were examined. Each additional meter of cornering radius was associated with 0.8 km/h higher cornering speed. The detailed findings are presented in Appendices 6C (metrics, best practice and measures) and 6D (detailed findings regarding traffic, turning radii, and cornering speeds).

Including the number of traffic movements in conflict with the pedestrian crossing allowed the refinement of the definition of problematic crossings. Two of the crossings considered problematic presented only one lane to cross and zebra crossings, but the turning radii were high in both cases (18 and 26 m).

Problematic crossings identified correspond to one of the following categories: (1) Peak hour traffic > 500 vehicles/h; (2) peak hour traffic < 500 vehicles/h, three or more traffic movements in conflict and left hook radius >= 8m; or (3) peak hour traffic < 500 vehicles/h and left hook radius >= 18m. Guidelines and best practice focus on traffic volume and physical crossing aids, failing to identify instances noted as difficult or non-walkable by people.

3.2 Footpaths design

Participants spoke of footpaths being difficult to navigate because they were too narrow or obstructed. Measuring footpaths widths and pedestrian flows presents methodological difficulties due to the variability of those measures (respectively in space and in time) and sometimes their interaction (e.g. temporary presence of people waiting to cross the lights and obstructing the footpath). The results are presented in Appendix 6F.

Three types of barriers were identified: **(a) crowding**: footpaths having a width that is not small in absolute terms but too narrow for the present pedestrian flows; **(b) footpaths that are perceived as narrow in the context of the adjacent heavy traffic**: the edge near the traffic being de facto not usable, but also, the traffic means that the other side of the street (having possibly a wider footpath) is not necessarily accessible; and **(c) footpaths where obstructions force people to change directions frequently** or "slalom". The obstructions could be for instance signs, electric boxes, parked cars, bins, chairs, or scooters.

Footpaths perceived as crowded had minimal widths between 1.3 and 2.3 m (median 1.7 m, IQR 0.4m; six of the seven measures ≤1.8 m, i.e. the lower limit defined by the Auckland Transport Design Manual [94]). The estimated flows through the narrowest section ranged between 10 and 390 people/h/m width (median: 130, IQR 210). The seven examined situations displayed a combination of widths and flows, without obvious pattern relative to the combinations between pedestrian flows and geometry (narrowest width, proportion of the street length between 1.5 and 2 m).

Footpaths perceived as narrow and close to traffic were not necessarily narrow, in absolute terms: for instance, the footpath on New North Road is 2.9 m wide and with low pedestrian traffic. Of the three cases, two presented high traffic volumes: 28,300 and 23,000 vehicles per day; and 2,300 and 2,000 vehicles/peak hour [267]. The traffic was relatively low in one case (Mountain Rd, ADT 1,520 vehicles per day, below the threshold of 2,000 recommended for the local paths [268]). The three reported cases all had footpaths directly adjacent to traffic, without buffer.

Obstructed footpaths were raised by several participants who were either blind and forced to figure out ways around, or non-disabled but bothered by the lack of consideration of other people. Observations on the ground highlighted the presence of a variety of obstructions, both built-in and temporary. The remaining usable walking surfaces were not narrower than 1.2 m but it was noted that the obstacles could force pedestrians to slalom. Walking routes that are direct, wide enough and unobstructed, as recommended by the best practice and the guidelines, were seldom observed. It is to be noted that the assessment of footpaths width presented significant difficulties (see discussion).

Overall, the perceptions of narrowness could not be informed by a simple width/usage rule. It is possible that dimensions such as proximity to heavy traffic or disposition of obstacles might participate in those perceptions. The guidelines focus on the width of the clear path, providing limited input regarding how the width should vary with pedestrian flows. The measurement of width is further complicated by the fact that on the ground there is no separation between the theoretical clear path and other footpath areas (e.g. furniture area).

3.3 Holistic design quality – car-dominated environments

The examined streets and roads were defined by five main characteristics: (a) traffic volumes markedly higher than the threshold of 450 vehicles/h above which the score regarding noise is null, in the Healthy Streets approach [95]**; (b) a very low availability of safe crossings, indicating that most desire lines are not catered for, especially in the light of high traffic volumes; (c) wide streets and roads, typically above 27 m, with little enclosure; (d) speed environments of 50 km/h or higher, with speed distribution expected to be mostly under 50 km/h; and (e) a low façade transparency, typically under 20%.**

The large widths and low façade transparency typically meant a limited oversight from the nearby buildings. The “eyes on the street” were also limited by a low or intermittent pedestrian activity. When a reasonable tree canopy was present (Nelson and Hobson Street), it was possibly offset by carriageways of 15 m and wider, and generally “grey” facades, with little transparency and activity. The detailed findings are presented in Appendix 6G.

3.4 Traffic along the path

Traffic along the path was associated with volume, speed, or a combination of both by participants. Eight specific locations were noted as difficult or unpleasant and examined here.

The measures showed traffic volumes above 1,400 vehicles/h and 14,300 vehicles/d, largely higher than the thresholds as defined by the Healthy Streets methodology and corresponding also to the higher range of the measures available across Auckland (see Appendix 6E). The indicated sections with two lanes of traffic had the highest traffic volumes per lane (around 750 vehicles/h/lane). The locations with five or six lanes had between 300 and 460 vehicle/h/lane. The examined locations are presented in the Figure 12 with their measures of traffic, carriageway width and lanes. The detailed findings are presented in Appendix 6H.

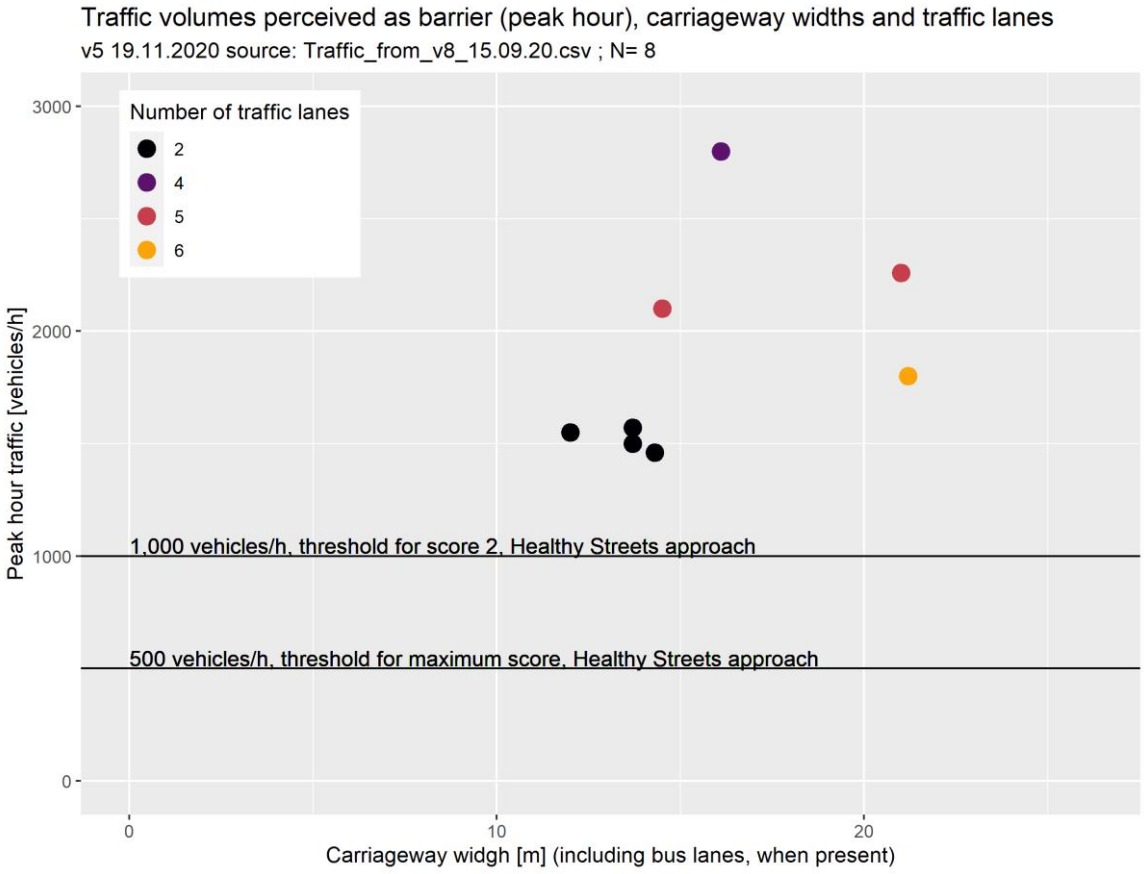


Figure 12: Traffic volumes as barrier - peak hour volume, carriageway width and number of lanes

3.5 Absence of people

Four locations were noted as being unpleasant because of a lack of human presence. All cases lacked passive surveillance both because of a low footpath activity and façade transparency. The pedestrian traffic was below 15 people in 20 minutes, corresponding to long periods of time without any presence directly on the street. The façade transparency was low (13%) in one case (Mt Eden Road) and almost null in the other three cases.

The four locations indicated as lacking human presence combined low pedestrian activity and low oversight from nearby buildings. Detailed results are presented in Appendix 6I.

3.6 Lighting – presence and quality

In three of the four cases reported, the average horizontal illuminance was between 0.2 and 1.6 lx, markedly lower by the 5 lx recommended in Healthy Streets for the lowest hierarchic level of footpath (local, residential street). In addition, the averages mask the fact that the three low values include vast lengths without light punctuated by a few isolated and relatively bright lamps. In two cases, a pedestrian walkway connecting two streets was illuminated by one lamp at each side, but the length (70 and 280 m, respectively) was entirely dark. The fourth case is a railway overbridge (Onslow road to Kingsland) and although it cannot be described as dark (8.1 lx), it presents an experience of aloneness and isolation, with few if any people walking and no oversight from buildings. For all four instances, the lighting was strictly functional, with high luminaires (above 4 m), often set far apart. The assessment of lighting is made challenging by recommendations and guidelines presenting an array of values for illuminance, depending on pedestrian activity and/or fear of crime, both being typically unknown.

Amongst the four locations indicated as dark, three were either located in residential areas, with non-illuminated sections. In the fourth case, the perception of low lighting was not explained by the illuminance (relatively high, at 8.1 lx). Guidelines do not directly allow to identify problematic sections given that they prescribe lighting levels based on the categorisation of each street, which could not be identified here. Full results are provided in Appendix 6J.

4 DISCUSSION

Objective measures of the WE, users' perceptions of feasibility or difficulty and guidelines' recommendations were triangulated. This chapter contributed characterise previously identified barriers (chapter 5) and explored the appropriateness of guidelines against users' perspectives of utility and difficulty. The results provided a real-world perspective on local guidelines and the Healthy Streets framework [95]. Instances that would have been characterised as "good enough" from the technical standpoint but were highlighted by participants as causing major difficulties were particularly interesting. Analysis sought to identify what parameters might not have been considered in the recommendations.

The findings are discussed below in the light of previous research. Further, the usefulness of the findings for the urban retrofit and future research are recommended.

4.1 Findings in the light of previous research

Orstad and colleagues' systematic literature review (examined also in chapter 3) showed low levels of agreement between measures of environmental features and users' perceptions of those same features [50]. Primary studies tended to pre-define measures, often in non-comparable ways, and examined the associations with users' perceptions captured in diverse ways. For instance, Michael and colleagues examined footpath obstruction as an environmental attribute, comparing (a) the presence or not of obstructions, as observed by trained surveyors; and (b) users' agreement or not with the statement that the footpaths are unsafe to walk, finding a poor level of agreement [269]. Analysing the evidence, the review authors noted that "[t]he perceived neighborhood environment and objectively measured neighborhood environment are related but distinct constructs […]" [50].

The present study took a different approach, starting from users' inputs (e.g., footpath perceived as obstructed) and striving to find what measures could help explain the perceptions. The methodology allowed suggesting metrics and thresholds for assessing critical environmental features. In terms used by Orstad and colleagues (2017), this study took users' perceptions as the baseline construct and considered only those metrics that can help characterise those perceptions and therefore identify further instances on the ground. Informing barriers reported by people of diverse ages, abilities, and backgrounds, walking for different purposes, also provided an interesting insight into the diversity of associated measures. For instance, "high" traffic along the path corresponded to situations with median peak hour traffic of 1,700 vehicles/hour, with an IQR of 600. The diversity can be related to individual differences but also to the interplay of different metrics.

Possible interplays between metrics were considered here, and indications of associations were observed, conceptually aligning with previous findings. For instance, one situation considered as having insufficient lighting had a level of light of 8 lx, relatively close to Fotios' recommendation of 10 lx [161], but was also noted to be a lonely area. Isolation and aloneness had already been suggested by Fotios and colleagues as influencing negatively the relation between lighting and reassurance [161]. These interplays stress the importance of considering walkability as a complex, multi-dimensional phenomenon [21, 22]. The characterisation also enabled a reality-check of the Healthy Streets approach and the local guidelines, discussed below.

It is important to recall that the barriers characterised in this study represent a subset of the possible barriers to walking experienced by people. For instance, although a step-free access and the presence of cues for blind and low vision people are essential [16, 24, 57], these aspects were not raised by interview participants in relationship to specific locations. They are therefore not included in this assessment.

4.2 Findings and the Healthy Streets approach

The findings generally supported the existing quantitative thresholds set within the Healthy Streets approach [95] or aligned conceptually with the dimensions prescribed qualitatively in Healthy Streets, providing specific measures. Two disagreements were also noted.

4.2.1 Measures aligned with thresholds

The findings aligned with the thresholds for (a) traffic volumes along the street; (b) traffic speed; and (c) the levels of lighting. In each case, observed levels were markedly worse than the thresholds defined by the guideline (e.g., traffic volumes 50% or more higher than the threshold yielding the lowest score for traffic (metric #1).

Although the comparison between the results and the Healthy Streets approach are consistent, it is important to keep in mind that the Healthy Streets approach presents the "ideal case scenario" or at least a threshold considered a sufficient, while the findings relate to situations that in this research were deemed "not walkable". This difference of approach could explain why some of the results can be far even from the threshold defined in Healthy Streets as the minimum.

4.2.2 Conceptual alignment, in the absence of thresholds in the guideline

Measures were provided to inform metrics for which the Healthy Streets approach provides a qualitative assessment (namely measure #10: availability of appropriate crossings for all/some/none of the desire lines; measure #20, natural surveillance: permanent, intermittent or absent [95]).

Low availability of pedestrian crossings was measured for streets noted as "car-dominated" (200 m to over 1 km between safe crossing points). These measures were also put in the context of generally high traffic speeds, volumes, and carriageway widths. Together, these aspects contribute to a poor provision of connections across the street. While pedestrian connectivity is known to be an important aspect of the ease of access to destinations [91, 249], it usually isn't possible to quickly assess how many of the desired connections are not catered for. It is therefore suggested to indicate maximum distances between safe pedestrian crossings while accounting for traffic volume, speed, and carriageway width.

Natural surveillance was examined through measures of façade transparency and pedestrian activity. The "best" of the areas described as worrying because lacking activity had 13% of transparent facades and approximately 50 pedestrians per hour. The importance of the street width can be assumed (wider streets allowing less surveillance from the opposite side). These measures should be developed through more cases, reported by diverse people in diverse contexts, to inform thresholds corresponding to perceptions of isolation or conversely a comfortable level of human presence.

4.2.3 Disagreements

Two main disagreements were identified between the measures and the Healthy Streets framework: (a) **footpaths reported as too narrow** would be considered in some cases as wide enough for the pedestrian flows in presence, according to the framework; and (b) some of the **non-signalised crossings** difficult to navigate would be considered as appropriate.

The **footpaths** for which the disagreements were noted were either directly adjacent to heavy traffic or designed or obstructed in ways that forced interview participants to dodge obstacles or other people (for instance standing at the lights or at a bus stop). Although the initial question seems very simple and technical ("how wide should a footpath be?"), the user experience proves more complex. Even if physically able to pass, adjacent heavy traffic reduces the usability of part of the footpath and having to zigzag increases the difficulty of the walk, especially for blind people. The findings hint once again towards walkability as a complex system with a variety of dimensions such as traffic, street furniture, overgrown vegetation or other obstacles.

Eight of the reported **non-signalised crossings** (26%) had peak hour traffic volumes below 200 vehicles per day, corresponding to the highest score regarding the appropriateness. The assessment of those instances and others show the **interplay of traffic speed and complexity**. The importance of the number of traffic movements the pedestrians are exposed to and of turning radii was suggested. These two metrics are not discussed in Healthy Streets approach. It is to be noted that the

movement complexity as assessed did not consider pedestrian refuges, that can in theory reduce the complexity by allowing pedestrians to split the crossing in a sequence. This is an intentional choice, prompted by the indications given by the participants: blind people not knowing if a pedestrian refuge will be available in the middle of the street and participants, blind or not, avoiding using the refuges because their design (typically too narrow) made them feel exposed to the traffic.

The **turning radii** appeared to be an important feature because related to traffic speed and therefore to the time available to decide whether to cross, and the time available for crossing. Further, open radii also mean traffic trajectories that are not orthogonal to the pedestrian crossing, and therefore a lesser mutual visibility between the pedestrian and the driver. Pedestrians can expect traffic to arrive at them almost from behind. Even if the traffic volume across the considered crossing is low, an open radius on a side street means the possibility for any driver using the main stretch to turn left almost without having to alter their driving speed. Both the non-orthogonal impact and the speed at which it can happen can be assumed to add to the stress of crossing.

4.2.4 Comment on metrics

The Healthy Streets approach makes a notable and needed effort to promote a holistic assessment of environments. The approach also provides simple metrics often with quantified thresholds. The risk, as seen above in relation to the footpath width and the appropriateness of non-signalised crossings is that a specific metric is used by itself in the practice to assess a footpath or a crossing as “adequate”, not considering factors that could influence this assessment.

Healthy Streets helps assess environments in a straightforward way, through clear indicators and scoring rules. Recent publications recognise that Healthy Streets provides pragmatic decision support for delivering complex policy goals such as health and sustainability [270, 271]. The findings from this chapter suggest three directions for future developments. Firstly, as noted above, thresholds should be identified regarding natural surveillance (pedestrian traffic and façade transparency), distances between safe crossings, and cornering radii (as a proxy for cornering speeds). Second, the measures for footpath widths should be further developed. Thirdly, guidance should be provided regarding pedestrian counts. Recommendations regarding the last two points are presented in Appendix 6K.

4.3 Findings and local guidelines

Two local guidelines were considered: the national pedestrian design guide [93], that is understood to be under review at the time of the writing, and the Auckland Transport Design Manual [94]. The available guidelines mostly focus on best practice, naming all the aspects that should ideally be in place for a "walkable" environment, with the caveat of not necessarily identifying those aspects that could be perceived as barriers. In the case of inherited, car-dominated environments, the gap between what is on the ground and what is ideal could seem overwhelming, and the difficulty of knowing what should be improved first is real.

Identifying barriers to walking using existing guidelines is challenging in three ways: firstly, advice given regarding identifying issues often requires data that is not available (e.g., pedestrian desire lines and suppressed demand, to assess if the network completeness (p. 4-1 and 6-8); perceptions of poor safety, for determining the appropriate levels of lighting (p. 17); or simply the use of footpaths by people walking or sojourning, to help determine the right dimensions (p. 14-3). Second, recommendations tend to be qualitative. For instance, while motorised traffic is described in broad terms as deterrent to walking, the recommendations do not provide explicit thresholds regarding traffic volumes and speeds and their roles regarding the levels of service of paths or crossings. Third, thresholds that are available or embedded into assessment tools relate mainly to vehicle and pedestrians flows, crossing distances, or footpaths widths. This set of measures gives a form of "hydraulic" vision of walking, mirroring the vehicular traffic modelling by emphasising the throughput and waiting times. While being aligned with the qualitative recommendations, the findings were at odds with the guidelines regarding non-signalised crossings, discussed below.

4.3.1 Disagreement: non-signalised crossings

For pedestrian crossings, a sophisticated tool estimates levels of service based on traffic, crossing distances, physical crossing aids (e.g. refuge) and the vehicle speed [272]. While the tool is helpful in estimating a level of service and comparing variants, it assesses intersections one at a time requiring data that is often not available (e.g. traffic speed as measured or pedestrian flows). Conceptually, the idea of producing a single output, or level of service, can also be problematic, as it arguably does not reflect the diversity of users' needs. Namely, as seen above, blind users do not rely on pedestrian refuges, and therefore, their effect on the calculation of the level of service is debatable.

The national guideline provides one illustrative threshold, stating that “On busier roads, kerb extensions and a raised median or pedestrian island can provide excellent safety benefits and a satisfactory level of service at flows above 1500 vehicles per hour.” [93]. The eight cases with built crossing aids and traffic below 1500 vehicles per hour were at odds with this statement. As seen above, participants reported that pedestrian refuges were at best not satisfying and at worst not usable at all (blind participants, not knowing if a refuge will be available and feeling exposed while standing in the middle of fast-moving traffic). All the problematic crossings at intersections had radii higher than 8m, over two times higher than the recommended “tight radius” of 3.5m (from AT’s Transport Design Manual [94].

The findings of this study suggest assessing the appropriateness of non-signalised crossings based on traffic volume, complexity, and speeds, considered simultaneously (low complexity can be an issue if high speed, and vice versa).

4.3.2 Comments on metrics

The comparison of the findings with the guidelines provided two insights regarding the ways how footpaths and holistic street environments are assessed. The recommendations regarding footpath widths relate to pedestrian through routes and other areas of the footpath (for instance buffers to walls and kerbs, or furniture areas). In real life, those different surfaces are not distinguishable. Therefore, while recommendations are made regarding footpath widths, the usability of these proves challenging. Appendix 6L illustrates the difficulty to compare guidelines and observations.

The guidelines did not provide specific rules or thresholds for assessing of environments described as car-centric and perceived as barriers to walking. The findings suggested an interplay between street width, lack of transparency, lack of pedestrian activity (low surveillance), and absence of crossings (difficult to use the other side). The observed cases typically had two or more lanes per direction and/or high traffic volumes and speeds, but a notable lack of signalised intersections. All measures indicate the potential for re-thinking the street as a public space, and namely (a) the relative space given to traffic and people; (b) the traffic volumes and speeds as major contributors to severance [62, 273]; and (c) possible additional metrics relative to aesthetics and emblematic factors, for which current evidence base is poor [175]. Guidelines should evolve to encourage and facilitate this type of assessment.

4.4 Usefulness of the findings for urban design and transport planning

The findings from this study can first help characterise the most non-walkable features of Auckland. Combining the information of the non-walkable features and the expected local traffic (for instance using tools like Space Syntax [190]), could provide a draft prioritisation for retrofit. The findings could also be useful for other New Zealand's towns and cities, having been designed based on the same national design standards as Auckland and likely to display similar systemic issues.

Two key aspects of this study can also be relevant beyond Auckland and New Zealand: firstly, the methodology of informing the non-walkable could be replicated, through users' inputs, metrics and measures. Second the findings can be interesting for urban areas having been developed in patterns similar to Auckland, around a car-dominated infrastructure and single-use low density suburbia. United States, Canada or Australia (with whom New Zealand shares design standards and for which similarity in users' behaviours are noted [274]), are the most obvious examples.

The identified metrics and thresholds should *not* be used directly for design, given that their purpose is to characterise what is *not* walkable. For instance, it is suggested that some users will not cross at non-signalised intersections with cornering radii above 18 m. A cornering radius below 18 m should therefore not be seen as a "good" radius, because although possibly crossable, it might still correspond to a high level of difficulty and stress for users. It is however suggested the findings be integrated in design guidelines. The guidelines should provide indications on **(a) what are the critical features**, having the potential of preventing people from accessing their destinations on foot or by wheelchair; this chapter provides an indication of what those features could be, in a car-dominated environment, but the findings should be adapted to the area of application of the guidelines; and **(b) what metrics should be examined**, for each critical feature; in this study, traffic volume, cornering radii and number of traffic movements in conflict with the crossing were for instance suggested as key metrics for assessing non-signalised crossings, and indicative thresholds were provided. Most benefit would be gained from metrics that can be operationalised in a systemic way, for instance using an algorithm through an entire urban network, to identify the a priori hot spots.

4.5 Strengths and limitations

This chapter has two major strengths. Firstly, it contributes to understanding the environments perceived as non-walkable by examining which metrics and thresholds characterise barriers as reported by users (chapter 5). As the inputs stemmed from interviews with people aged 20 to 89, half of whom were disabled, the identified characteristics help understand the lowest common denominators of environmental barriers. By doing so, the study provides a support for systemically assessing walking networks in a way that considers the diversity of users and helps better consider disabled people and their diverse needs [16, 24, 57]. The approach taken responds to the often noted difficulty of measuring environments in a way that is consistent with people's perceived walkability [50].

Second, this chapter examined the findings against the Healthy Streets approach and the local design guidelines, allowing to identify important metrics that had not been directly considered (e.g. cornering radii as a proxy for cornering traffic speed) and thresholds for some of the existing metrics (e.g. natural surveillance). The findings can complement the best practice and local design guidelines because contrary to those documents, they do not describe what is "ideally walkable" but rather the most non-walkable features.

This study also has three main limitations. Firstly, only those critical features identified from previously realised interviews and corresponding to the inclusion criteria (for instance, specific location indicated) were characterised. It is understood that people might experience barriers other than the six critical features identified here. Second, the characterisation of critical features relied on relatively low numbers of instances, especially for the places described as lonely (low presence of other people) or poorly illuminated. Third, given that the pedestrian count data was largely absent, counts were based on estimated peak hours and collected through one survey, for logistical reasons. Knowing in addition (a) the expected daily variability of the pedestrian flows; and (b) the fact that part of the counts had to be realised after the first NZ lockdown, thresholds related to pedestrian flows are estimates.

Future research should develop characterisation based on more identified barriers, from more people of diverse ages and abilities, residing in different car-dominated cities. Thresholds relative to pedestrian flows should in particular be further developed, basing on more locations, with ideally 7-day counts over 24 h, so to capture the diverse uses of the streets and volumes of pedestrian traffic.

5 CONCLUSION

Walking for transport and walkability are becoming more common in urban development agendas but face two major difficulties: the lack of consensus around what causes the highest barriers to walking, and the need to prioritise retrofit, especially in car-dominated realms that might be "inherently non-walkable".

A pragmatic approach is needed, and this study offers a possible way forward by triangulating users' inputs (specific barriers to walking indicated), objective measures, and technical recommendations and guidelines. Grounding the research into lived experiences (features discouraging the access to destinations both desired and perceived as being within walkable distance), barriers to walking were characterised and examined against technical guidelines.

The results provide both a minimum definition of non-walkable features, and a critical assessment of the walkability guidelines. The characterisation relies on multiple metrics, wherever needed, emphasising the systemic aspect of walking. Findings highlight the most important (groups of) metrics and suggest improvements to routinely used guidelines. The suggested improvements relate to a more nuanced approach to barriers (systemic aspect), but also to a need for guidelines helping professionals in charge of walkability identify the most critical non-walkable features. Future research should develop the drafted characterisation through more interviews and measures, considering people with different ages and abilities, living in different car-dominated cities.

CHAPTER 7: STUDY 4 - STREET ENVIRONMENTS' BARRIERS TO WALKING IN AUCKLAND – HOW PRACTICIONERS PERCEIVE THE NEEDS AND CHALLENGES

PREFACE

This thesis built on the premise of the importance of the street environments for walking. The previous chapters examined how environments might influence perceptions and behaviours. This study was designed as a way of closing the loop, focusing on how current low levels of walking in Auckland are understood and addressed by the professionals involved in the (re)design of streets and public health. The study examines the agreements and disagreements between professionals active in five different disciplines, providing insight into the operationalisation of more walkable environments.

This chapter is based on the paper ***How to improve the walking realm in a car-oriented city? (Dis)agreements between professional disciplines***, accepted for publication in Transportation Research Part A: Policy and Practice [275]. The paper (see Appendices, from page 125) was slightly edited for the thesis (contextual aspects presented in the general introduction were shortened here).

1 INTRODUCTION

Urban areas are facing the challenge of transforming and integrating their land use, infrastructure, and services to enable and encourage low-carbon mobility [2, 23]. This challenge requires addressing systemic barriers to, or risks for, walking [62, 276, 277]. Barriers experienced by people of greatest need should be prioritised [11, 278].

Chapter 2 outlined the complexity of walkability and suggested a lack of consensus on the relative importance of different dimensions of the walking environment. A focus on professionals is crucial because of their conjoint roles in delivering better environments for walking but also because of noted disagreements between disciplines (e.g. relative to the quality of same built environments [45] or the causes of negative outcomes such as pedestrian causalities [252]). Achieving more streamlined multidisciplinary collaboration is urgent as major integrated urban transformations are required to achieve carbon neutrality [5].Different professional disciplines can however base their practice on different perspectives and assumptions [22, 91], and it is not clear if professionals in charge of street design share views regarding what these barriers are and who suffers from them [13, 18, 279].

1.1 Assumptions

This study builds on two assumptions: firstly, that the delivery of walkable environments is a complex socio-technical system (CSTS); second, that the delivery of walkable environments is hindered by a lack of quality data regarding users' experience (UX), and therefore a lack of consensus among professionals relative to needs and priorities; and third, disagreements regarding priorities and challenges exist amongst professionals. These three assumptions are explored briefly below, with a focus on Auckland, used as a case study.

1.2 Walking as a complex socio-technical system

In this study, the planning and delivery of walkable environments are understood as part of a CSTS. The concept refers to systems that are evolving, dynamic, and open to external forces [280]. CSTS approaches were developed in an effort to understand and manage relationships between people, technologies, infrastructure, processes and goals [280]. Cities had previously been characterised as CSTS, with Davis and colleagues [280], and Adelt and colleagues using systems approaches to analyse modal choice [281].

Complexity is framed and described by Righi and Saurin's research [282]: complexity is real and measurable, but cannot be described objectively (i.e., the description is limited by the biases of those trying to describe it). The authors showed that complexity can be examined through an assessment of four dimensions [283]: a multitude of components interacting dynamically with each other; an important diversity of those components; unexpected variability; and resilience, including redundancies and the possibility for outcomes to be generated in different ways. The key aspects of each dimension and an application to the walking environment are presented in appendix 7A. The complexity of delivering more walking environments is amplified given that diverse components of walking environments are managed and/or altered by professionals from different disciplines.

1.3 Lack of consensus between professionals

Previous research has suggested that professionals who deliver urban environments (e.g., planners, policy-makers) and those who deal with their outcomes (e.g., health researchers) do not necessarily share a common vision regarding needs and priorities [90, 284, 285]. It is suggested that transport planning and public health have been disconnected from each other, resulting in transport systems having adverse health outcomes [14, 23]. Further, a lack of integration between land use and transport planning appears to be a barrier to modal shift away from personal vehicles towards active modes [14, 23].

In New Zealand, a disconnect between disciplines can be observed at different decision-making levels. Ministerial portfolios delivering infrastructure, or portfolios impacted by it, can lack coordination and operate within legislation that can be conflicting [89]. This situation can result in negative interactions between domains, namely transport, housing, economy, and productivity [89]. Further, investment decision-making is based on benefit-cost ratios that overlook pedestrian accessibility [286], suggesting a difficulty in delivering optimal walkable environments. At the local level, past evidence indicates a certain misalignment between stated policy objectives and the infrastructure delivery [80]. An example of this situation is special housing areas that can be car-dependent and therefore not meet the objective of reducing greenhouse gas emissions [80].

Professionals' views also appear to align poorly with the diverse needs of diverse users. For instance, in New Zealand, gaps were recently outlined between priorities seen by professionals involved in the design of transport systems, and users [279]. Previously, fewer than 20% of 238 interviewed transport professionals declared that walking realm retrofit was prioritised according to the needs of people who use it [13]. Paucity of data regarding users' needs appears to be an important element. Only 6.7% of the interviewed transport professionals thought that good data was available about people using the footpaths [13]. While access to jobs, leisure and recreation, green spaces, and social

networks is instrumental to people's well-being, the ease of access remains poorly captured in New Zealand [287]. This is important, as neglect from policy and practice had been linked to difficulties of access and decreased wellbeing [20, 41, 286]. The New Zealand Transport Agency commissioned an investigation into the barriers to participation experienced by disabled people, to be delivered early 2022 [288].

Given the dispersion of professionals' views and the fact that they don't necessarily align with the users' needs and behaviours [114, 252, 279], users' insights and experience can provide a helpful form of "reality check". Citizen Science (CS) [261, 262] is a methodology involving the civil society in research projects, from data gathering to recommendations. CS can improve the understanding and consideration of people's experiences in decision-making [289]. This thesis applied CS to better understand the barriers to walking, as experienced by diverse people (chapter 8). The present study builds on this information and uses the inputs of Citizen Scientists (CS) that had been recruited amongst the interview participants (chapter 5).

1.4 Aims and questions

The aims of this study are to: **(a) gain the views of professionals from five different disciplines**, with a focus on priorities, challenges, and evidence gaps for delivering quality walking environments in a car-oriented city. The targeted disciplines are urban design, road safety, transport planning, public health, urban development and strategy. The reference to "the practitioners" relates to participating professionals active in one or more of the five disciplines identified; and **(b) examine from the professionals' perspective the assumption that planning and delivery of walking environments is a CSTS**. The study is located in Auckland and moves beyond the observation of disagreements to provide insights regarding how professional practices could evolve towards a more integrated approach.

The research questions are:

1. **How is "walkability" understood?** What are elements of consensus and divergence regarding the nature of a "walkable" city? How are users' walking needs understood, and what data do professionals use to back their understanding of walking needs?
2. **How do professionals perceive facilitators of and barriers to walking in Auckland**? What are aspects of consensus or disagreement, and how do the ideas compare with the insights gained from users? What elements of consensus or divergence can be outlined?
3. **How is pedestrian accessibility implemented?** How do professionals perceive the priorities for retrofit in Auckland and the challenges relative to the improvement of the walking environment, and how is "improvement" understood? What elements of consensus or divergence can be outlined?
4. **How do practitioners rate the four dimensions of systemic complexity of planning and delivery of the WE** considered as a complex socio-technical system? To what extent to the ratings support the claim of the walking environment being a complex socio-technical system?

2 METHODS

Data were collected via an online survey completed over September and October 2020 and a focus group (November 2020). While this study targets professionals, users were included in the process in two ways: CS (recruitment and involvement described in chapter 8) were invited to prepare the questions to be submitted to the professionals in the focus group, and to delegate up to three representatives who would participate in the focus group. The methods are presented below.

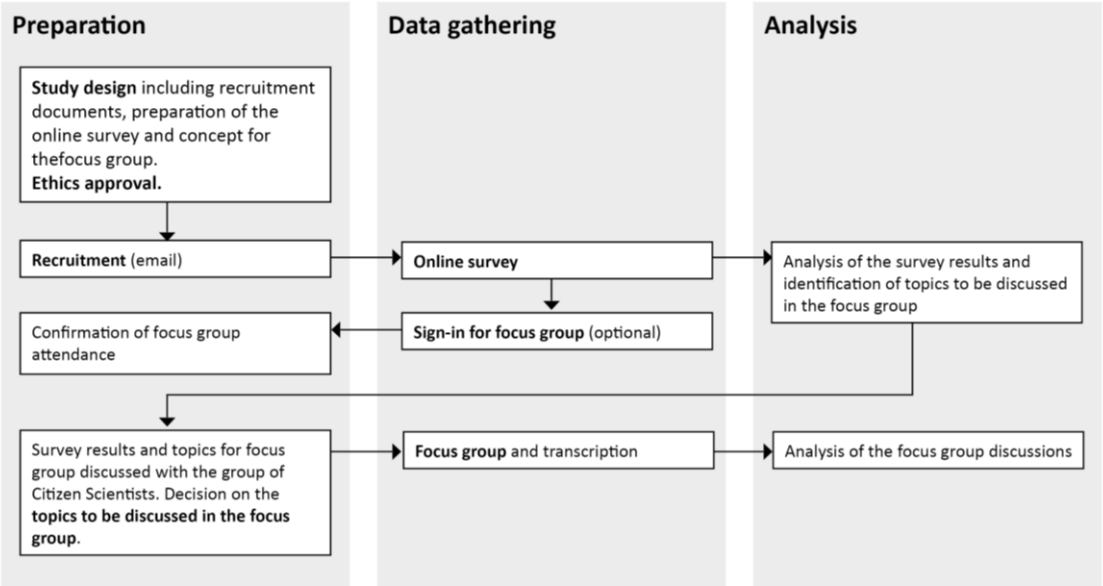


Figure 13: Investigating professionals' views - overview of the methods

2.1 Participants

The survey participants were professionals (n=28) from fields relative to design and delivery of walking environments and public health, working in Auckland or at the national level. Professionals were identified by the research team through their networks and online searching of organisation websites. The participants were selected based on three criteria:

- **Primary activity** in one of the designated areas;
- **Expertise**: senior role and over 5 years of experience in that field; and
- **Focus on walking**: primary employment activity has a focus on walking - through planning and design of the urban environment, urban strategy, or public health interventions and strategies to promote walking as contributor to physical and mental health.

All survey participants were invited via email to participate in an online survey (Appendix 8b1). At the end of the survey, participants could opt in for being re-contacted for the focus group. The focus group included professionals by order of expression of interest, ensuring that each area of expertise was represented; and one of the users who had previously participated in the project as a CS [261].

Measures were taken to minimise the risk of associating specific survey responses to individual participants. Namely: only one wave of invites was sent; the participants opted in by accessing the provided link and did not need to contact the research team; and expressions of interest for the focus group were gathered in a way that did not allow association to the responses provided (the last ("thank you") screen is de facto a separate survey with a sign in option for the focus group). The focus group was transcribed without participants' identity but only a letter (unrelated to their name) and an indication of their profession.

2.2 Online survey

The survey questions are presented in appendix 7B2. Briefly, the survey covered five topics, presented in Table 16.

Table 16: Survey topics, inputs given to participants and response types (full survey: Appendix 7B2)

	Survey topic	Further framing / indications	Response type
1	An accessible city: signs of success	Cite three aspects	Open
2	Priorities of intervention regarding accessibility on foot/by wheelchair	For the next 3 and 10 years.	Open
3	How well the users' needs are understood	n/a	4-point Likert scale, from "not at all" to "extremely well"
4	The single biggest challenge regarding retrofit of built environments	n/a	Open
5	Levels of complexity, within the activity of planning and delivering walkable environments	Agreement with four statements (brief version below): There are many dynamically interacting elements There is a wide diversity of elements There is unexpected variability There is resilience	Sliding scale from 0 ("disagree entirely") to 100 ("entirely agree"), for each statement

2.3 Focus group

The purpose of the focus group was to discuss and further explore the results of the survey. The topics to discuss with the professionals were first discussed and reworked with the group of CS. The CS received a summary of the survey findings ahead of the meeting, with a focus on questions for which the professionals' responses showed either a lack of consensus or an agreed evidence gap. The purpose of the meeting with the CS was to collect their views regarding what topics should be further explored, in the focus group.

The CS group prioritised two topics: the lack of consensus regarding users' needs and the lack of prioritisation of walking. Prior to the focus group, the professionals received an information pack (Appendix 7C) presenting the two topics to be discussed and potential questions to help the discussion. I facilitated the focus group, with the presence and support of Dr Moushumi Chaudhury. The discussions were audio-taped and transcribed verbatim.

2.4 Data analysis

Survey data were both qualitative (open-ended questions regarding the priorities and challenges relative to the improvement of the walking realm, and open-ended focus group questions) and quantitative (scoring of aspects of complexity relative to different dimensions of the professional practices dealing with the walking environments). Two forms of data analysis were used: (1) inductive and deductive content analysis [99], for the inputs to open-ended survey questions and focus group questions; and (2) descriptive statistics and quantitative analysis of the associations between the scores.

Content analysis is a flexible approach to exploring qualitative content [99]. The content analysis examined individual responses to different questions as units of meaning [99]. Topics were examined separately for different types of questions (perceived motivations and deterrents to walking, perceived priorities, sources of data, data gaps, and challenges relative to implementing walkable environments). For each type of question, the process followed the three steps described by Elo and Kyngäs: open coding, creating categories, and abstraction [99].

Content analysis can be inductive or deductive. **Deductive content analysis** was used for testing a previously established model [99], the draft Social Model of Walkability (Chapter 2). Responses regarding incentives and deterrents were associated to pre-established categories and sub-categories, covering (a) the availability of destinations and the higher-level walking network; (b) the qualities of the walking environment; (c) the broader transport system; and (d) personal characteristics and preferences. The categories are presented in Appendix 7D. The codes relative to the walking environment previously used to test the theoretical model through users' interviews (Chapter 5) were re-applied here. Further, the frequency of mentions of environmental characteristics was compared between the professionals (primary data of this paper) and the users previously interviewed [290], using a chi-square test. **Inductive content analysis** was used to code survey questions relative to priorities, challenges and data used, as well as the focus group transcriptions. The technique was chosen due to the explorative nature of those questions, and allowed categories to be extracted from the data [99]. For the responses relative to the characteristics of a walkable city, the priorities and the challenges, the open coding stage (annotating text with draft categories) led to defining categories under four types, presented in Table 17. Each response could be coded in several categories. For instance, a characteristic relative to pedestrian connectedness due to intentional implementation of pedestrian priority was coded across all four categories (environment: holistic design; perceptions: accessibility; practice: pedestrian priority through design; policy: prioritisation of walking).

Table 17: Types of categories for the content coding analysis of the characteristics of the "walkable city"

Type of category	Explanation
Built environment and transport system	Every time an environmental aspect is mentioned, e.g. footpaths or crossings
Perceptions	Implicit or explicit mention of perceptions, e.g. "safe"
Practice	Implicit or explicit mention of design or management, e.g. Healthy Streets approach embedded in design
Policy	Implicit or explicit mention of policy, e.g. reference to parking management or speed management

The ratings of the levels of complexity were analysed in a descriptive way, reporting means, interquartile range (IQR), minimum, maximum, and number of ratings above 70, retained as an arbitrary "high" threshold, roughly corresponding to the highest tertile. Distributions were generated for the four dimensions of complexity, and a composite index was created and used to compare responses from professionals associated to different disciplines. The composite index is the average, by participant, of the ratings provided. For each dimension, the number of ratings above 70 was determined, and compared using chi-square tests.

3 RESULTS

3.1 Overview of the survey responses

Twenty-eight practitioners responded (37% response rate). Half of the respondents self-associated with several disciplines, for instance, seven mentioned urban design, urban development, and transport planning together. A clustering was performed, grouping together professionals working in similar fields. The frequency of mentions of disciplines and the suggested clustering are presented in Table 18 below.

Table 18: Professional disciplines selected by respondents and clustering

Cluster	N	Self-selected disciplines	N
UD_PH Urban design with a public health perspective	**8**	Urban design	5
		Urban design, Public health	2
		Urban design, Public health, Urban development	1
UD_TP Urban design and transport planning	**7**	Urban design, Road safety, Transport planning, Urban development	4
		Urban design, Transport planning, Urban development	2
		Transport planning, Public health, Urban development	1
TP_RS Transport and safety	**8**	Transport planning	3
		Road safety	3
		Road safety, Transport planning	2
PH_RS Public health	**4**	Public health	3
		Road safety, Public health	1
NA	**1**	Urban design, Road safety, Transport planning, Public health, Urban development	1
	28	**Total**	**28**

Most participants self-defined as technical specialists (19 mentions), but the cohort also included nine decision-makers and three researchers. Five participants self-associated with roles not listed (e.g., advocacy). The following paragraphs examine the results relative to specific questions, after which the focus group inputs are reported.

3.2 The understanding of walkability

The notion of walkability was examined through the attributes of a walkable city, the level of understanding of the barriers to walking, and the evidence used regarding barriers and motivations to walking, in Auckland. The results for each dimension are presented below.

3.2.1 The attributes of a walkable city

Participants were asked to name three characteristics of "a city supportive of walking". The 84 inputs related mostly to the built environment and the transport system but included also references to implementation and experiential qualities. Three major topics were identified: **quality street environments; implementation of pedestrian amenity; and walking being perceived as a positive experience by the users**.

WE quality was described as a range of features detailed in Table 19. The biggest cluster of responses related to holistic environments. A few participants provided some detail about the environmental characteristics of those holistic walkable environments (e.g., "human scaled infrastructure and architecture", "people scale", or "high-quality public spaces"). The majority mentioned the broad outcomes that these environments deliver (e.g., "the ability to permeate the city on foot", "attractive", or "designed to genuinely put pedestrian at the top of the modal hierarchy"). Participants took a user-centric approach, stressing that the environment needs to be adapted to the users' needs as a minimum, some indicating that beyond being accessible, the environment needs to be perceived as inviting or "delightful". Universal design was mentioned and could be understood as a specific dimension of holistic design quality, participants stressing the need for streets to consistently provide for all, regardless of their age and ability.

Table 19: Walkable city – aspects relative to the built environment and the transport system mentioned by professionals

Dimension	Category	Mentions			% participants
Street environment - quality	Holistic design quality	16	**52**	70%	57%
	Universal design	8			29%
	Footpaths design	7			25%
	Crossings and traffic conditions	6			21%
	Traffic intensity	5			18%
	Footpaths maintenance	2			7%
	Presence of other people	2			7%
	Signalised crossings - waiting time	2			7%
	Greenery	3			11%
	Lighting (presence, quality)	1			4%
Destinations	Distance to destinations	10	**10**	14%	36%
Walking network	Pedestrian connectedness	5	**6**	8%	18%
	Connectivity	1			4%
Broader transport system	Efficiency of public transport	3	**4**	5%	11%
	Parking management	1			4%
Pedestrian priority when crossing side streets		2	**2**	3%	7%
Total built environment and transport system		**74**	**74**	**100%**	
Total general, including perceptions and delivery		**84**			

Implementation of pedestrian amenity (33 mentions, 39%) related mostly to a higher focus on walking in the delivery of streets and spaces. Twenty of the responses (61%) spoke about design of walking environments, fourteen focusing on the streets design, six mentioning land use (compact, connected to public transport). Features relative to the pedestrian amenity were either explicit (e.g., "Priority at intersections for people" or "intersection designed around ped delay and not vehicle delay" delivering "the ability to permeate the city on foot") or implicit (e.g., "A city that values streets and connectivity, space to walk" or "Designed to genuinely put pedestrian at the top of the modal hierarchy"). Nine of the comments specified that best practice should be embedded in the design process (e.g., "A commitment to a healthy streets approach at mayoral level and embedded throughout planning policy and urban design https://healthystreets.com/home/about/ ").

The perceptual quality of walking as a positive experience (22 mentions, 26%) related to comments describing the kind of feelings that a walkable city would foster. The comments referred to dimensions of safety (nine mentions), pleasant walking experience (eight) and accessibility (five). Safety was not always explicitly related to traffic and/or stranger danger, some participants noting just "safe". Traffic was however explicitly mentioned four times. The perceived pleasantness was described through characteristics such as "Attractive", "Interesting - things to look at, things to do" or "Designed not just to make walking accessible, but to make it delightful". Accessibility was framed through the ideas of ability to easily cross the streets or "permeate the city on foot". One participant specified that accessibility involved an environment that is "inclusive, culturally safe, disability friendly", but overall, the answers did not provide much detail on what accessibility implied in terms of environmental features, design, or traffic. In most comments, it was not necessarily clear if the participant was speaking of their own experience or imagining themselves in users' shoes (e.g., "Easy to cross the street […]"). Three inputs related perceptions to features of the walking environment (well-maintained footpaths, safe crossings and walkways separate from traffic) and eighteen did not.

The clusters of professional disciplines were compared regarding the frequencies of mentions of quality of street environments, broader transport system, and perceptions of safety, accessibility or pleasant walking experience. The differences of frequencies were not significant at Chi2 $p<0.10$, and the only difference being in the range 0.1–0.2 related to the frequencies of mention of quality (lower for public health and road safety specialists, higher for urban designers).

3.2.2 Understanding of barriers and motivations to walking

The professionals were asked: *How well do we understand what might cause people not to choose to walk/wheel, or to struggle by doing so?* The views were diverse: 10 respondents considered that the barriers are well/extremely well understood, while 18 thought that they were not well understood. The answers were also mixed when examining the professional clusters, with some interesting differences: a majority of public health professionals (3/4) considered that barriers and motivations were very well understood, while this was the case for a minority of transport planners and urban designers (2/8 and 5/15, respectively). The differences of frequencies were not significant at $p < 0.1$.

3.2.3 Evidence used

The practitioners were asked: If you had to present evidence about motivations or barriers to walking, for Aucklanders, what source(s) of data would you use? Twenty-six of the 28 participants responded to this question, providing 63 inputs (2.4 per participant who answered). Most of the inputs (51, 81%) provided some detail about what type of evidence they would use. Overall, the noted sources were quite disparate: no consensus was observed about "go to" evidence base, and variety of types of documents was noted.

Eleven participants noted using specific documents or data sets and the participants collectively mentioned 13 documents: three international publications and ten local documents or data sets (WalkScoreTM scores was considered as local data, in this study). Four documents had two mentions each (National Census [291] and Disability Survey [77], the Healthy Streets guideline [95] and WalkScore ™ [118]), while the other documents were mentioned only once.

Empiric evidence was predominantly noted (23 mentions to qualitative insights and 16 to quantitative findings), but the participants also noted a variety of other sources such as guidelines, expert advice, or even own experience. Three participants spoke about the difficulty to source appropriate evidence (e.g., "I would probably struggle to find data to support claims about motivations or barriers to walking or I wouldn't know where to turn to first. […] I'd probably turn to international research and try to apply it to the Auckland context.").

Differences were noted between the professional clusters: **transport and safety professionals** were more likely to indicate quantitative evidence and statistics (11 mentions, $p<0.05$), and less likely to refer to research documents (1 mention, $p<0.05$). **Urban designers** contributed most of the mentions to guidelines (5 out of 6, 83%) while transport planners did not report using guidelines. **Urban designers with a transport planning perspective** were more likely to cite research documents (6 mentions, $p=0.05$). There were however no significant differences in the frequencies of use of qualitative data, expert advice or audits ($p>0.1$).

3.3 Incentives and deterrents to walking

Responses suggested five main types of incentives and deterrents to walking:

1 **The quality of the WE** (major potential deterrent and a potential incentive);
2 **The broader transport system** (incentive to walking and to a lesser extent as deterrent);
3 **The availability of destinations** (potential incentive or deterrent); users' perceptions of their environments (potential deterrent);
4 **Health and fitness** (as incentives).

The frequencies of mentions are presented in Table 20 and detail (including subcategories and professional disciplines of respondents) is reported in Appendix 7E.

Table 20: Incentives and deterrents to walking - professionals' inputs coded against dimensions and ordered by highest percentage of mentions, either as incentive or as deterrent

	Incentives		Deterrents	
Dimension	**N**	**% mentions**	**N**	**% mentions**
Street environment - quality	15	24%	23	44%
Broader transport system	17	27%	7	13%
Destinations	15	24%	15	29%
Perceptions	8	13%	14	27%
Internal motivations/deterrents	17	27%	2	4%
External motivations/deterrents	4	6%	12	23%
Walking network	1	2%	2	4%
Other	0	0%	0	0%
Total mentions	**62**	**100%**	**52**	**100%**

Public health experts spoke only of deterrents relative to the street environment, objective or perceived, while other disciplines mentioned other aspects, such as weather. Health and fitness were mentioned 16 times as incentives for walking, 14 of which from practitioners who associated with urban design and/or transport planning. The topic was not noted as a deterrent and was mostly noted without further indications. The other topics referred to a range of aspects, examined below.

The quality of the WE was noted as incentive or deterrent and was the biggest cluster of mentions. When examining the aspects cited within the broader umbrella of quality, the answers were diverse. Holistic design was noted both as a possible incentive and deterrent (eight and ten mentions, respectively).

- **Quality when noted as an incentive** mostly related to holistic design (e.g., "Urban amenity" or "Nice environments"). Other characteristics were noted each by one participant only (footpaths design, presence of other people, greenery, shelter, traffic intensity or priority at crossings).
- **Quality when noted as a deterrent** related to traffic and the associated noise and pollution or traffic-oriented infrastructure (e.g. "hostile road environment", or crossing facilities - their availability, layout, waiting time or the interactions with traffic).

Some polarisation was observed across professional clusters: those associating with urban design/strategy and/or transport planning contributed the bulk of the mentions to WE quality (11 out of 14 as incentives; and 19 out of 23 as deterrent), while the transport planners were the only ones who spoke of the crossings (7 mentions as deterrents).

The broader transport system was a label applied to answers comparing walking to other modes or speaking of walking as the companion mode of public transport. Professionals considered that walking was chosen when more convenient, faster, cheaper, or more sustainable than other modes or convenient when combined with public transport. The transport system was also noted as a potential deterrent, mainly in relation to the ease of driving (e.g., "why walk or PT/walk when you can drive", or "Driving is too easy"). The different professional disciplines mentioned the topic at similar rates ($p>0.1$).

The availability of destinations was either explicit (e.g., "A mix of land uses meaning key things to walk to are in walking distance", "Distance to useful destinations is not walkable") or implicit, participants mentioning for instance "distance" or "(in)convenience", without further indications. There were no significant differences in the frequencies of mentions of destinations across professional groups ($p>0.1$).

People's perceptions of their environments noted as incentives related to pleasantness, comfort and safety. While some responses were loosely associated to the environment (e.g., "Traffic danger from motor vehicles"), the responses did not provide much detail overall on the environmental aspects that could incentivise or deter from walking. Perceptions noted as deterrents related mostly to a lack of safety (12 out of 15 mentions, 80%). Public health professionals spoke of perceived safety more often than other disciplines ($p<0.05$).

The frequencies of mentions to broad environmental dimensions (transport system, availability of destinations, quality of WE and walking network) were examined and compared with those previously collected from users (Chapter 5). Some significant differences were found. The professionals were less likely to mention the broader transport system as incentive ($p<0.05$) but more likely to mention it as a deterrent ($p < 0.01$). Professionals were also more likely to indicate the availability of destinations as an incentive ($p < 0.1$) but less likely to mention the walking network (connectivity, topography) as a deterrent ($p < 0.1$). The frequencies of mentions of WE quality as incentives or deterrents were not significantly different from those given by the users, at $p < 0.1$. The comparison is displayed in appendix 7E. The professionals' views on the incentives and deterrents to walking being both dispersed and somewhat misaligned with the users' views, this topic was further discussed in the focus group (results reported below).

3.4 Priorities

Each participant indicated their main priorities relative to improving accessibility on foot/by wheelchair (three-year and ten-year horizons). Three main topics were identified from the 56 responses: the WE quality, design and delivery, and the systemic nature of the walking realm. An overview of the topics is presented below, and detail findings are in supplementary file E.

The quality of the WE was noted 42 times (75% of the mentions), without significant differences in frequencies across professional groups ($p>0.1$). The participants most often associated WE quality with a holistic vision of design: eleven spoke of better streetscapes in general (e.g., "Improved walking infrastructure, wider streets, sep[a]ration from traffic, improved crossings. Walking is given greater priority"), while five specified that this design needs to provide a good walking experience to users regardless their age or ability. Nine of the 42 mentions (21%) related specifically to traffic, participants noting the importance of streets with low traffic, low speeds, or no traffic at all. The idea of quality was mostly associated to design and delivery (36 of the mentions, 86%), however some participants also mentioned the importance of policy (e.g., "Change design standards and road rules so that pedestrians have genuine priority in a fully accessible way."); footpath maintenance; planning (requiring accessibility considerations early on, in projects development) and data (one participant

noting the need to access current levels of accessibility). Professionals who associated with both urban design and transport planning spoke less often in proportion of the quality of the walking environment than the other groups ($p<0.01$). The priorities mentioned by group covered a wide range of aspects, such as maintenance, better planning, or policy.

Design and delivery were noted 44 times (78% of all the mentions). Inputs related to the "how" (e.g., "universal [design] approach mandatory for new and existing streets and spaces", "LQC [light, quick, cheap] opportunities - where small moves could add up to a bigger whole") or the "what" (e.g., safer crossings, or low traffic neighbourhoods). Four mentions (10%) did not relate directly to the quality of the walking environment but mentioned urban density (three references) or good quality public transport (one reference). Again, this topic was less mentioned by those who associated with both urban design and transport planning ($p<0.05$).

The systemic nature of the walking realm was sometimes noted directly, referring to holistic pedestrian-friendly environments and their multiple facets (11 mentions, 20%), but mainly suggested by the diversity of types of actions noted: the priorities noted by the professionals included design and delivery (new build, retrofit, or both), policy and regulation, maintenance, data collection, education, and planning. The responses included diverse features of the walking environments: a range of built features but also traffic, urban density, activation, pedestrian network connectedness and public transport service. Among the clusters of professional disciplines, those participants who associated with both urban design and transport planning seemed to have the broadest view in terms of system-related priorities.

3.5 Challenges

The professionals were asked to name "the single biggest challenge regarding the improvement of street environments". Three main topics were identified: the lack of prioritisation of walking (15 mentions, 54%); an inherited car-dominated environment (14 mentions, 40%); and the inability to implement change (11 mentions, 39%). Eleven responses referred to two or three topics each.

The lack of priority given to walking was described as both technical and political, as illustrated in the following quote:

> *Aside from budget, I think there is an underlying car-centric mindset amongst designers and policy makers which reflects on the streetscape.[...] The language is still car centric; for example, highway and intersection design levels of service are centred around vehicle delay and travel time. Even though pedestrians use the same intersection, their time is valueless and is not captured in the design."*

The participants' emphasis on this theme as well as its importance for delivering more walkable environments prompted to further discuss it in the focus group (below).

The mentions to car-dominated environments suggested a need for re-allocating space and/or priority, or were simply stated as the challenge, implying the extent of the inherited inadequate infrastructure. One participant described the issues as:

> *[...] roadside parking, long crossing times and intimidating signalised crossings, vehicle priority at minor roads, roads maintained whilst footpaths are not etc.*

The car-oriented environment was implicitly associated to a lower pedestrian amenity and often mentioned together with the challenge of delivering change and retrofitting the urban environment. One participant noted that the challenge was the "reallocation of priority from other uses, esp. space from traffic/parking lanes, time/delay at crossings".

The inability to deliver change was associated to design and delivery, policy, and a combination of both. The challenge regarding design and delivery related to understanding users' needs, having the appropriate tools and knowledge, bureaucracy, and inadequate everyday practices, as illustrated by the quote below:

> *Traffic modelling (belief in). There are many people in senior roles New Zealand who believe that the traffic model, with all its simplifications, assumptions and parameters, must be 'solved' for streets to be successful. Erroneous assumptions (e.g. that traffic is "a liquid that always flows somewhere") are stated by people who should know better. This attitude, when it excludes user-centred design, rarely leads to improvements in street environments. Actually, it never leads to improvements in street environments.*

References to policy mentioned investment allocation, political courage and inertia, e.g.:

> *Political/social inertia which continues the dominance of car-oriented thinking above all else. Reluctance to implement any real change for fear of inconveniencing/upsetting drivers (voting public). Design and planning for walking is not technically difficult, but implementing it appears to be almost beyond us.*

One participant noted that "this is a system challenge, there is no biggest challenge". The idea of system was very present through this section, either explicitly as before, or through the references to the way the city has been designed, the professional practice, the policies and the governance. All the dimensions noted need to change, and this change either involves large scale retrofit, or a reconsideration of everyday practices.

The three topics have been mentioned by participants of all four professional groups, without differences significant at $p < 0.1$. It is however interesting to note that urban designers contributed nine of the 14 mentions to car-dominated environments (64%).

3.6 Assessment of the delivery of walking environments as a complex socio-technical system

The participants were asked to indicate their level of agreement with four statements relative to the complexity of the delivery of WE. The ratings for the four aspects had median values higher than 60/100, the dynamic interactions and diversity of elements being highest (91; see Table 21).

Table 21: Levels of agreement with the four dimensions of complexity characterising the planning and delivery of walking environment

	Level of agreement with the dimension of complexity (0 to 100, n=28)				
Dimension of complexity	**median**	**IQR**	**min**	**max**	**% scores >= 70**
Dynamic interactions	82.5	29.3	39	100	79%
Diversity	91.0	32.3	50	100	75%
Variability	71.0	41.5	30	100	61%
Resilience	60.5	34.0	19	100	39%
Total	**73.8**	**25.3**	**50**	**99**	**63%**

The aggregate rating of complexity (average of the ratings provided for the four dimensions considered) was most consistent amongst public health specialists and urban designers with a public health perspective (IQR 13 for both). Across participants, 63% of all ratings were ≥70/100. This ratio was lower for public health specialists (31%, p<0.01) and higher for transport planners (78%, p<0.1). The distributions are presented in Figure 14 below, and the complete results are presented in Appendix 7E.

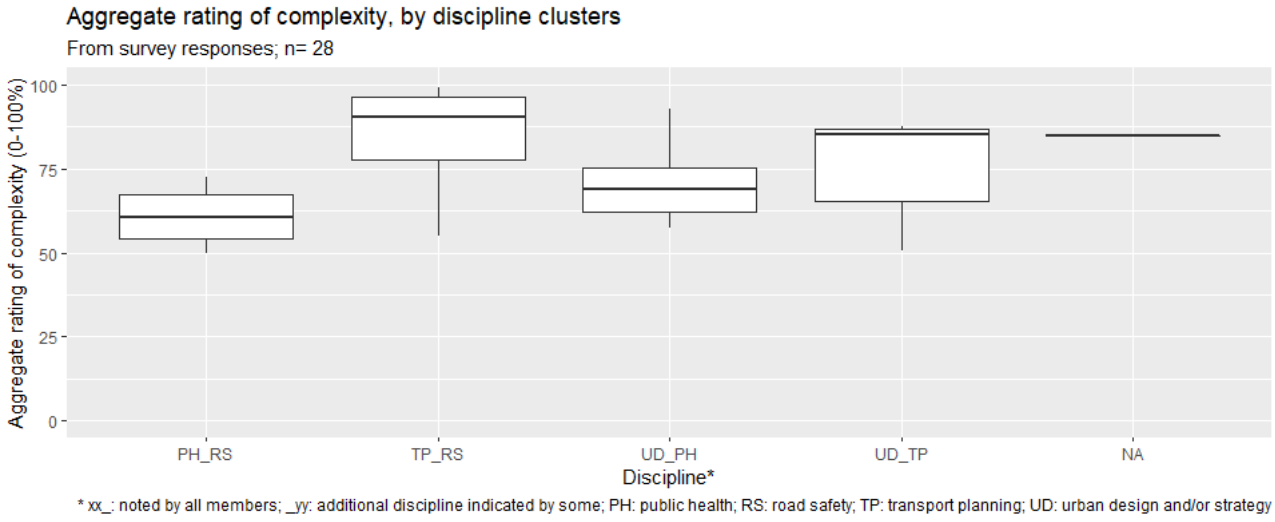


Figure 14: Rating of complexity: distribution of the average rating by dimension and professional discipline

3.7 Focus group inputs

The focus group took place on 17.11.2020, from 5 to 6 pm. The participants included four professionals (one of each discipline, by order of expressions of interest; none of the public health experts who had participated to the survey volunteered also for the focus group, therefore the discipline was not represented) and one CS. One of the professionals had not been able to participate in the focus group due to an emergency having occurred immediately prior. They were however keen to be involved in the process and this was achieved through a separate face-to-face interview. At this extra meeting, the professional gave their thoughts on the two topics and reacted to my report of other participants' views.

The two sessions examined two prioritised topics: **the lack of consensus regarding users' experiences and needs**, and the reasons why this lack of consensus does not appear as a challenge to implementation; and **the lack of prioritisation for walking in the policy and the practice**, discussing the reasons for it and the apparent disconnect with the vision for Auckland as a liveable, accessible and carbon-neutral city [76, 292].

A content analysis of the focus group's inputs helped understand the components of the two topics and their relationships, illustrated in Figure 15. Links between the two topics were identified, in the form of a vicious circle: the lack of prioritisation of walking can explain why walking levels and experience are neither monitored nor used as indicators in decision-making; as user experience (UX) is not an indicator of success nor a decision-making input, it is not routinely considered in design and planning; transport planning either doesn't consider walking or uses proxies that assimilate pedestrians to "little cars", through models that consider their numbers, speeds and delay, but not the experience; there is therefore no overview of the difficulties faced by those who walk, participation (ability of diverse people to access their destinations on foot, and therefore presence of people of all ages and abilities in the streets) or suppressed walking trips; this lack of overview can explain the lack of consensus regarding UX, but also perpetuate a system where walking is not given much political priority.

The lack of UX, both in decision-making and project development, was a recurrent idea and also a key aspect of the noted vicious cycle. The participants provided rich insights relative to its reasons and consequences, explored below.

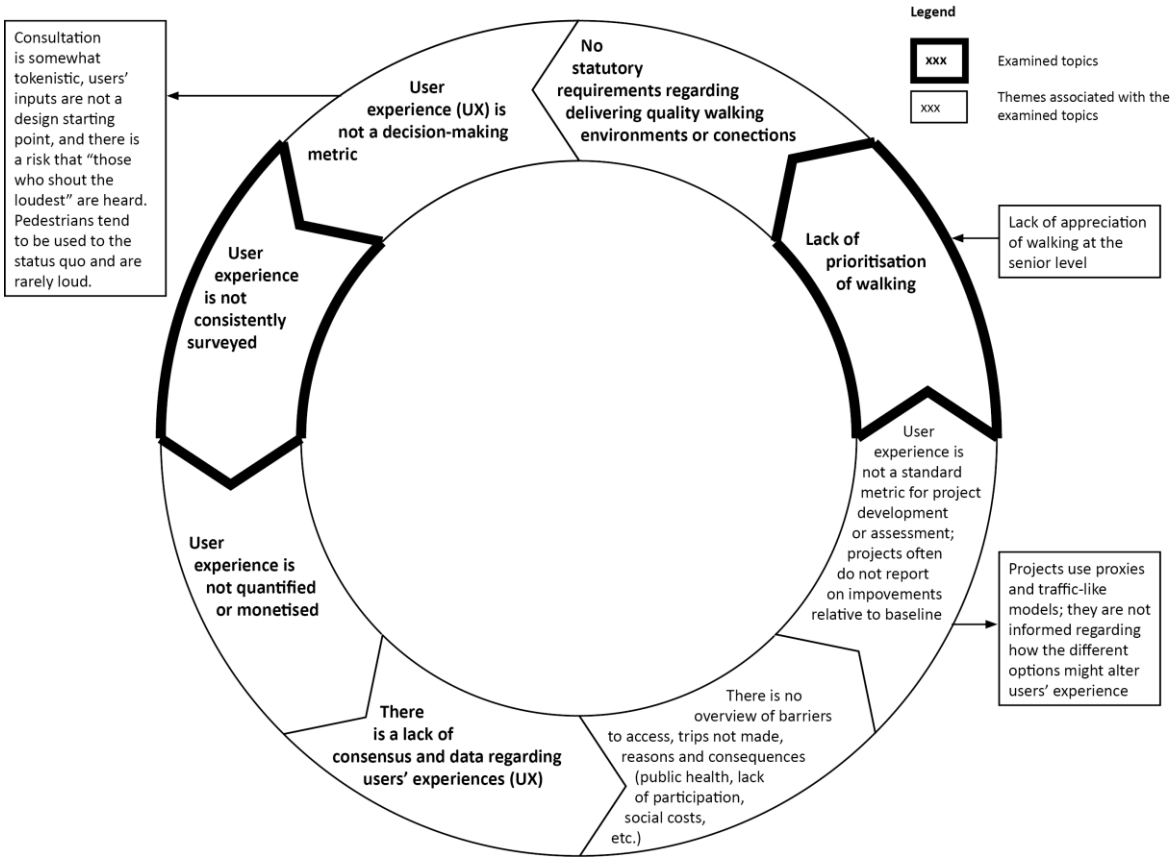


Figure 15: Topics identified from the focus group and relationships

The lack of UX was often associated by the participants to a traffic-oriented "business-as-usual" practice. Two key ideas were discussed. Firstly, participants noted **traffic-oriented decision-making metrics**, stressing that if some projects examine UX, it is not a metric required for decision-making.

> *The decision-making that we mostly deal with is about numbers and volumes and speeds and time, and safety risk. Nowhere in there is experience captured and so if your decision-making metrics exclude it, it's excluded from the process. [...] we are dealing with people like we are dealing with vehicles – so we are counting them, looking at direction of travel maybe, A was talking about mass and force, regarding collisions and then you have visibility issues and he gave a kind of engineering solution of a potential risk between a pedestrian and a car, and it was very much not a human-focused solution. [...] I've never been asked "did you include diverse groups of people in your project planning?". It's always "what's the benefit-cost ratio", in the end. "Oh, it's a good value project – we will do it". So all these things about policy and having more people included are fantastic, but if you can't include it in a value judgment, in the end it will just get excluded. And I experience that every day, so I know! - B, transport planner*

> *If you cut AT [Auckland Transport] open it's not a cake, it's a traffic model – Q, urban designer*

Professionals also described commonly used monetary indicators (benefit-cost ratio) that are less appropriate for assessing projects related to walkability or liveability because dimensions such as inclusion, accessibility or severance are difficult to monetise and routinely not monetised. One participant spoke with conviction about the needed monetisation of those benefits (quote above). Another, however, noted that the monetisation is both difficult and potentially unnecessary, arguing that if decision-making metrics included participation or accessibility, those aspects could be considered without the need of transforming them into dollar values.

Participants noted a **lack of focus on walkability, liveability and carbon emissions at the governance level** of local authorities. One of the participants explained this lack of focus by a certain lack of awareness of the members of transport authorities' Boards:

> *No one there knows much about transport. They know lots about governance – they are lawyers, or accountants. I mean, the main thing with governance is that you are doing everything you are meant to do legally and that you are financially competent. So you need good accountants and good lawyers for that. It means that decision-making doesn't have anything to do with transport. It is about good governance. Which leads to a real reversion to conservatism and path dependency and you don't rock the boat or the tanker – you stick with what you know and it's very difficult to bring meaningful change [...]. If in your twelve Board members you had someone from Living Streets, someone who has had a 20-year career in transport analysis, a land use planner, and so on – you would have very different questions, and very different outcomes. – Q, urban designer*

Given that UX is not required for project evaluation, the experience is not routinely monitored and planning does not consider how it might be altered. When walking is assessed traffic-like models are used. In those models, pedestrians are not more than moving units, and results assess a form of hydraulic feasibility of footpaths, as explained by one participant:

> *I think that our processes are very much set up in an engineering sense to deal with metal boxes moving around, and that people are treated as a small metal box. So there is nothing about experience and how they might feel, and what might make them walk, not walk, or feel more comfortable walking – none of that is there. It's simply how many were there, where were they going, is there enough room for them, and maybe is it safe? – B, transport planner*

The participants abundantly spoke about the issues caused by both the absence of a shared view of users' needs and the lack of prioritisation. They noted the need to better understand why certain trips are not walked and to capture the diverse needs:

> *I think also that when we talk about "the user", we need to further break it down. We need to gather more information – whether it's just talking to people with different life experiences or conditions, or research and bring it all together. People find urban spaces hostile for different reasons. – O, urban development strategy expert*

The issue of the lack of prioritisation was both related to its influence on practice but also to the idea that a systemic change was needed:

> *I think that you need a statutory change because – the point is, you can't do it one piece at a time because it requires too much effort. It needs to be something fundamental. I think that a legal requirement to use every opportunity to enhance pedestrian amenity would be fundamental. – Q, urban design specialist*

4 DISCUSSION

This study engaged with 28 professionals involved in the design of street environments and public health, in Auckland or at the national level. Through an anonymous online survey, professionals provided insights regarding what matters (what is a walkable city, what incites or deters from walking, and how well we understand users' needs) and how walkability is delivered (evidence used, priorities and challenges). They also indicated their level of agreement with four statements framing the delivery of WE as a complex socio-technical system.

Answers about incentives and deterrents were analysed through deductive content analysis [99] and associated with topics drawn from the draft Social Model of Walkability (Chapter 2). As a reminder, the model's *inputs* were the walking environment and the transport system. The inputs were linked to walking behaviour through the moderating effects of people's perceptions of walkability (hierarchy of walking needs) and their personal characteristics (Chapter 2). The open answers regarding what makes a walkable city, priorities, challenges, and evidence available were coded using inductive content analysis [99], the codes being developed from the data. A focus group further aimed to clarify the reasons why users' experience (UX) is not agreed upon and the reasons for the observed lack of priority given to walking.

The findings are discussed below. First, I examine the findings to each research question separately. Second, I discuss the case of dimensions of the walking environment and transport system for which inconsistencies in feedback were noted across the questions.

4.1 Question 1: How is "walkability" understood?

Participants' responses regarding how a city could support walking were overall consistent with the draft Social Model of Walkability. The participants predominantly noted the importance of holistic quality of street environments but also people's perceptions: feeling safe, having enjoyable walking experiences, and perceiving the environment as accessible.

This emphasis on quality and people's perceptions can seem surprising given that transport engineers have historically had a more functional approach to walking, modelling pedestrian flows as they model vehicles' movements [22]. For instance, D'Arcy analysed in depth the understanding of walkability across professional disciplines, finding some consensus around functional aspects and safety, but a lack of agreement relative to aesthetics and comfort [293]. Further, D'Arcy's analysis also indicated engineers' tendency to value functional aspects [293], in line with the historical trend noted by Lo [22]. In the focus group, the participants had spoken of habitual transport planning processes treating pedestrians like "little cars" and ignoring experience. The fact that participants valued the quality of walking realms and people's perceptions could be explained by the recruitment method, through my networks and my supervisors': given that I focus on walkability and have a history of collaborations with urban designers and landscape architects, it is possible that the professionals recruited represent a more progressive fringe of transport planning. Another possible explanation could be that the transport planning field has progressed towards a more humanist approach.

The three types of perceptions noted (safety, accessibility, pleasure) are part of the hierarchy of pedestrian needs, a key moderator between the environment and the walking behaviour, in the model. The professionals' views align therefore with the posited model. Interestingly, the dimension of feasibility, or: having destinations in a reachable distance, was not directly noted, despite being the core component of most commonly used walkability indices such as WalkScore ™ [118]. Implicitly, professionals saw walkability from the angle of the walking *experience*, rather than the mere physical possibility of reaching destinations. The broader transport system, including the provision for transport alternatives, was mentioned, although much less than the physical WE. This aspect is examined below (Overview: walking environment and transport system across dimensions).

Interestingly, the responses to the question how well the barriers to walking are understood were very diverse, ranging from “not well at all” to “extremely well”. While knowledge gaps have often been identified in the literature (e.g. [21, 22, 62]), it can be surprising that a good understanding would be noted for Auckland, especially in the absence of shared evidence regarding the barriers (nature, location) and the numbers of people affected by them. A previous survey of 238 New Zealand transport planners had shown that a small percentage (6.7%) thought that good data was available about pedestrians [13].

The participants quoted a variety of sources of evidence, when asked what would help them make a case for barriers experienced by Aucklanders. There was no clear consensus or “go to” source of information, and no document was cited more than two times. Gathering of evidence appeared to be mostly ad hoc. When mentioning specific data sources, two thirds of the mentions referred to data other than users’ insights (for instance street quality audits or even international guidelines), which could be related to Andrews’ view that much is assumed, regarding what matters [63].

No participant mentioned the people’s insights on walking commissioned annually by Auckland Transport [83], although some respondents noted “Auckland Transport resources” without more detail. This ongoing research, now replicated at the national level, questions users about walking (agreement/disagreement with statements such as “I don’t feel safe”). The published overview reports present adult Aucklanders’ views of their environments (e.g., barriers and motivations to walking) but with two major caveats: these data are collected only from people who declare not having difficulties walking, and the perceived barriers are not further related to objective environmental characteristics. These gaps might contribute to a lower usability, especially from the part of professionals focusing on infrastructure and its features. To my knowledge, Auckland does not have a form of inventory of barriers to walking, that could be a start for a prioritised action plan.

Data gaps had also recently been noted in a study examining professionals’ views on the barriers to integrating public health evidence in spatial planning, in the UK [90]. The 162 respondents were asked to rate their agreement with potential challenges. A majority agreed with a lack of local evidence ready to be translated into practice (91% agreement) and lack of monitoring and evaluation of the planning decisions (81%) [90]. Surprisingly, the absence of data was not noted as a major challenge to retrofit, in the present study, although this aspect was largely discussed in the focus group and linked to a lack of interest in pedestrian experiences. Both aspects suggest the need for data that could be used as practical and pragmatic decision-support. Differences noted between professional disciplines indicate a need for building a common understanding of urban complexity and its critical links, for instance transport – public health, or land use – urban design – travel patterns. This need has been stressed by previous research (e.g., [14, 90, 91]).

4.2 Question 2: How are facilitators of and barriers to walking described?

The disparity of the responses and the inputs from the focus group revealed an important gap in the understanding of users' experiences and attributes that could be perceived as incentives or barriers. This finding aligns with previous results gathered in New Zealand: Burdett had identified that only a small minority of transport planners considers that pedestrians' needs are well understood [13], while Park and colleagues found differences between barriers to access to transit as perceived by professionals (transport planners, urban designers, and policy-makers) and users [279]. The finding is however at odds with a piece of work commissioned by the New Zealand Transport Agency, stating that "The overall drivers and barriers to walking and cycling are well understood; they remain constant over time." [294]. The commissioned research captured general perceptions of walkability (e.g., safety or convenience), not examining however what features of the WE might influence them and how these associations might vary across demographic groups.

Under the New Zealand Transport Outcomes Framework, having inclusive access as one of its five pillars [295], the Ministry of Transport is leading an initiative aiming to inform people's perceptions of transport and experienced barriers [296]. The existence of this initiative seems to support the need to better understand people's perceptions and how they relate to their environments. However, the way this topic was addressed indicates a rather shallow approach, not addressing the causes of difficulties and ways they might vary across people (i.e., not relating perceptions to objective features of the WE and not considering the diversity of disabled people).

The barriers and incentives stated by the professionals were based on disparate elements of evidence but also often on personal experience and assumptions. This observation seems to support the idea of a lack of quality data on people's experiences, shared across professional disciplines. The participants' emphasis on convenience/availability of destinations and perceived safety both reflect declared barriers to walking from the Auckland Transport active modes survey [83]. Interestingly, the ease of driving did not come up as a major deterrent to walking, in contradiction with evidence suggesting the importance of both ease of driving and public transport services respectively as barriers to or facilitators of walking [192, 297, 298]. This point is examined below (Overview: walking environment and transport system across dimensions).

Future research should examine what WE characteristics are associated to people's perceptions, namely those relative to the experienced difficulties, targeting in priority populations most likely to be excluded. An example of such an approach is given by Transport for London: at risk users group are defined (including disabled people or people with a low income), the barriers they face are analysed in detail, and an effort is made to address those barriers and incorporate inclusive design in all processes [278]. While Transport for London stresses that understanding and addressing barriers is "integral to success" [278], it was found here that the improvement of people's experience is not considered as an indicator of success, in Auckland, and is not part of decision-making metrics. A change is required at policy level: projects should be assessed not only on a benefit-cost scale but also in terms of their contributions to the visions regarding ease of walking or modal shift – a recommendation already made globally [14, 91] or for instance specifically for the UK [90].

4.4 Question 3: How is pedestrian accessibility implemented?

For the professionals, the priority relative to improvements to pedestrian accessibility related mostly to the quality of street environments, which participants associated to both traffic (especially reduction of vehicle flows and/or speeds and safer crossings) and physical infrastructure providing for all ages and abilities (design and maintenance). Availability of destinations and improved public transport were mentioned only by a small minority of responses (3/56 and 1/56, respectively). In a sprawling, low density city like Auckland [241], it could be quite surprising not to see a greater role given to intensification.

The challenges relative to improving street environments related to retrofitting a whole inherited car-oriented infrastructure, but also to transport planning practice geared towards delivering more of the same. One participant noted that "this is a system challenge, there is no biggest challenge", and the focus group stressed the lack of political priority, further linked to inadequate data and processes. Governance of transport agencies was described as broadly lacking awareness of the issues and potentials associated to walkability, liveability or public health. This aspect is a major challenge in delivering future visions and aligns with the findings of Carron Blom's thesis, having noted a disconnect between strategies and infrastructure, and "inability to fully deliver appropriate and relevant infrastructure outcomes over the long term" [299]. Sectorial differences in priorities had also been noted even by New Zealand's Infrastructure Commission, warning the new Minister of the array of negative outcomes they can have [89].

Participants stressed that the improvement of quality of the walking environments or improvements of users' experiences (UX) are not captured in the metrics used to assess projects and take investment decisions. The lack of UX in the evidence available and the processes reflects recent findings from the UK [18, 90]. Middleton and colleagues posited that examining walkers' experiences could even seem unnecessary, noting that "much of this policy-commissioned research assumes walking is a homogeneous and largely self-evident means of getting from one place to another. As such, the very practice of walking is positioned as a functional, easily understandable mode of transport people 'just do' and to this end the ways in which walking is understood and engaged with is essentialised as a self-evident activity." [18]. This lack of interest in UX appears at odds with the widespread use of this approach in other sectors, such as product development: a quick search for "ux" yields almost 550 million entries from Google, and 6,302 results from Scopus [300], three quarters of them published in 2017 and later. In a paper from 2006, cited by over 1,300 publications, Hassenzahl and Traktinsky noted that the term had become a buzzword in the area of human-computer interaction design and offered a proposal for future research [301].

Improvement of the WE would require a strategic shift, including a progressive retrofit of current environments, with appropriate budgets and focus; the requirement to deliver benefits regarding access, inclusion, participation, and climate change; adequate monitoring of users' perceptions (user experience), behaviours, and the infrastructure; and expertise at the governance level (Boards of the national and local transport agencies).

4.5 Question 4: How do professionals perceive the complexity of delivering walkable environments?

The rapid assessment of four dimensions of complexity suggests that professionals consider the delivery of walkable environments as a complex socio-technical system (CSTS): an evolving, multi-dimensional entity [280]. UCL's Lancet Commission had grounded its analysis of the delivery of healthier cities in the notion of complexity [302].The potentials of CSTS had previously been outlined: Adelt and colleagues outlined for instance the appropriateness of the approach to governance and took the urban transport system as a practical example for implementation [281]. The team also noted being surprised by the lack of discussion on how to apply system approaches to governance, in an era where multitude of complex systems need to be influenced or re-directed [281]. Importantly, complexity implies that incremental improvements need to be tested and monitored, within an iterative learning process [302].

An example of application of socio-technical systems approach was shown by Hoffmann and colleagues, examining how existing European “automobility regimes” could be shifted towards sustainable mobility [303]. They outlined structural issues relative to the large number of actors and dimensions (e.g., behaviours, technology, infrastructure, funding, regulation), their interactions, as well as established social norms and models, and suggested that a shift to a sustainable mobility cannot be achieved simply through the offer of new alternatives [303]. The systemic challenges relative to delivering more walkable environments encourage further research aiming to identify levers of intervention.

Our results suggest however different perceptions of complexity across disciplines: higher complexity for transport planners (based on ratings) and urban designers (based on the higher variety of aspects mentioned by this group as potential deterrents to walking) and lower complexity for public health specialists. This finding could be due to the differences in understanding of walkability noted above. Authors have also noted past tendencies to segmented approaches, failing to fully acknowledge and address the repercussions they might have on other sectors [91, 285]. Our findings support previous calls for a greater awareness of sectorial interdependencies, at the policy and implementation levels [11, 90, 302].

4.6 Overview: walking environment and transport system across dimensions

The quality of WE was generally agreed upon as key characteristic of a walkable city, a potential incentive and deterrent to walking, but also a priority for retrofit and a challenge (delivering change in a car-centric environment). The responses did not provide however a clear picture of the "what" should be addressed: firstly, numerous features of the WE were indicated (e.g., destinations, crossings, quality of street environments noted in general). Second, the participants also took the users' perspective, talking about perceptual qualities of the WE (e.g., "that INVITES you to walk"), raising the question what it is, that prompts the desired perceptions of pleasantness, convenience, comfort, or safety? Thirdly, the challenges cited had a strong focus on transforming a car-oriented environment, which again calls for an agreement regarding what should be done and how the expected long "to-do list" should be prioritised. While all the professional groups considered mentioned quality, as incentive or deterrent to walking, or characteristic of the walkable city, it is possible that quality can be conceptualised differently: for instance, public health specialists' mentions of feeling safe and transport planners' references to crossings could both to relate to environments where a pedestrian does not feel threatened by traffic.

The broader transport system, including the provision for driving and PT, was seen in diverse ways by the professionals, when examining different topics of this survey. The comparative quality of walking as compared to the alternatives available was suggested as incentive to walking, and both potentials and challenges spoke about a system geared towards the comfort of driving. However, although some participants noting that driving is "too easy" in Auckland and that the city is "car-centric", the ease of driving and the poor quality of PT were not major topics within the potential deterrents to walking. Previous research had however suggested the importance of considering walking within the broader transport system, noting that (a) walking levels can be influenced by the perceived ease [110, 192, 222, 297], or difficulty [192] of driving; and (b) an efficient PT as the natural enabler of walking [126, 213, 224]. The importance of the broader transport system supports the idea of cities as systems, where outcomes such as the choice of walking cannot be understood by examining the WE in a vacuum [21]. It could also help explain the high ratings given by the participants to the dimensions of complexity, possibly influenced by chain reactions linking different modes (e.g., it is easy to drive, therefore people drive which can incite them to choose neighbourhoods accessible primarily by car, meaning in turn low density, low potentials for public transport and low attractiveness to walking, further inciting to drive).

Park and colleagues had noticed that policy-makers in the transport field tended to focus more on built, tangible characteristics, rather than on perceptions or "soft" characteristics [279]. This explanation could help understand the apparent disconnect between on the one hand the car-oriented *environment* identified by the participants of this study as a priority for improvement, a challenge and a barrier, and on the other hand a lesser consideration of the *ease of* driving.

The findings suggest the need to examine conditions of walking *within the broader system* and communicate the importance of the qualities of walking *as compared to* other options available, both the practice and the research.

4.7 Significance and contributions

Following the numerous previous calls for more walkable cities, this work examined the *how* and the potential hurdles in retrofitting an inherited car-centric environment. The findings suggest actions regarding both policy and delivery.

4.7.1 Policy level suggestions

- **Vision to action**. Ensure linkages between high level objectives (e.g., accessibility for all) and practical implementation – namely: delivery of WE and prioritised retrofit of barriers. This requires revisiting the funding decision mechanisms, including data and indicators; coordination between different sectors delivering infrastructure or dealing with its outcomes (transport, urban design, health, road safety, economy); and appropriate funding.
- **Addressing the needs of those who need it most**. Identify populations of greatest need, regarding accessibility on foot/wheelchair to destinations or PT, investigate their needs and current barriers, and confirm budgets and time frames for addressing those barriers.
- **Prioritised retrofit**. Tools and processes should consider people's experience and deliver against it. Benefit-cost ratios, currently applied in New Zealand but poorly adapted to pedestrian improvements [11, 286], should be replaced by an assessment of the values delivered against higher policy objectives such as accessibility, well-being, or climate change mitigation.
- **Awareness and education**. A sound understanding of the systemic complexity of cities is necessary. Decision-makers need to be aware of the important interactions between land use, transport planning, health, well-being, participation, and local economies, namely. This understanding should be strengthened through training, inter-sectorial collaboration (e.g., health and urban design experts on the Boards of transport authorities), and resource allocation towards shared evidence bases.

4.7.2 Suggestions for planning and delivery

- **Vision-based action plans.** The action plans should be crafted towards delivering on the vision, specific enough about targets and interventions, and based on data such as barriers to walking, their magnitude and the populations they affect.
- **Addressing the needs of those who need it most.** Data on barriers to walking should be improved so to better understand who experiences barriers to walking and what these are. This understanding will require substantial user engagement and collaboration with academia. Data gathered should be used to prioritise interventions.
- **Prioritised retrofit.** Practice should take ownership on delivering higher visions such as access, climate change mitigation, public health or participation. This will mean changing some planning standards – instead of a predominant reliance on traffic models and benefit-cost ratios, retrofit should be prioritised acknowledging user experience and broader benefits. Sound monitoring and evaluation should be in place so to learn from the improvements made and the projects underway (for instance: implementations under the Innovating Streets initiative [304], in New Zealand).
- **Awareness and education.** Professionals need to be aware of the important interactions between land use, transport planning, health, well-being, participation, and local economies. This understanding should be strengthened through training (both at graduate levels and throughout the career) and more integrated approaches (for instance, collaborations between transport planners, urban designers and public health experts should become more common).

4.8 Strengths and limitations

This work has four major strengths. First for the first time in New Zealand, it targeted a range of disciplines involved in the design of streets and public health, to better understand the breadth of views regarding needs, priorities and challenges associated to walkability. Second, after having analysed survey data through content analysis, questions requiring more detail were examined in a focus group. Thirdly, insights were triangulated, examining the roles of the quality of the walking environment and the broader transport system from different perspectives (attributes of walkability, incentives, and deterrents to walking, priorities and challenges). Fourth, practical recommendations based on the findings were made for both policy and practice.

Several limitations are to be noted. Firstly, a small sample size (n=28) and the clustering into groups that might have some heterogeneity. Second, recruitment through researchers' networks including a risk of "echo chamber". Third, while all results provide useful insights for New Zealand, they might not be directly transposable to environments presenting strong differences (e.g.: environments that are not car-centric). Future research should investigate perspectives between professionals involved in the design and retrofit of WE elsewhere, identify patterns (e.g.: are there commonalities across car-dominated cities?), and inform best practice (what is done differently in cities where professionals' views are consistent and aligned with people' needs – for instance, is there a culture of UX and interdisciplinary exchange?).

5 CONCLUSION

Improving urban environments to support walking aligns with the current urgency of delivering drastically better outcomes in terms of greenhouse gas emissions, public health and inclusion. Considering Auckland, New Zealand, this study examined how professionals of different disciplines understood the needs, challenges and priorities relative to delivering walkable environments. The findings indicate (a) a general agreement on the priorities and challenges (car-dominated realm and practices, and the need of transforming them in a consistent and systemic way), and on the complexity associated with delivering good walking environments; (b) a lack of consensus and shared evidence on user experience (UX), namely regarding features of the walking environments that might now cause barriers; and (c) a tendency of not considering the comparative convenience of driving as a barrier to walking. Underlying issues included a lack of prioritisation of walking linked to the lack of UX evidence through a negative chain reaction and possible communication gaps between professional disciplines. Through the in-depth analysis realised, this study identified complexities of and barriers to improving walkability. Findings were further used for crafting recommendations to policy and practice. Further research should investigate other cities, identify common patterns, develop the recommendations suggested here, and inform best practice in terms of multidisciplinary collaboration based on UX.

6 ACKNOWLEDGMENT

I would like to acknowledge Dr Moushumi Chaudhury for her inestimable help with the focus group and the workshop with Citizen Scientists.

CHAPTER 8: INQUIRY INTO MOTIVATORS AND BARRIERS TO WALKING AS REPORTED SPONTANEOUSLY BY DISABLED AND NON-DISABLED PARTICIPANTS

PREFACE

This chapter was not submitted for publication to date. Within this thesis, a group of participants were involved as Citizen Scientists (CS). The CS participated to:

- Data gathering, collecting insights from their environments using a specialised app
- Data analysis, providing feedback to the draft analysis of the interview data collected previously (Chapter 5) and on the practitioners' survey (Chapter 7); and
- A focus group involving professionals (Chapter 7).

Data gathering constituted the largest volume of the CS activity and provided extremely rich insights. It is the topic of the present chapter.

1 INTRODUCTION

Within this thesis, the Social Model of Walkability initially drafted by other authors (chapter 2) was developed through literature reviews and empirical data derived from multiple research methods. First, an umbrella review examined how walkability is understood in the literature (Chapter 2). Second, associations between objective features of the walking environment and perceived walkability were determined from international literature (Chapter 3). Third, associations between perceptions and walking behaviour were examined quantitatively (Chapter 4). Fourth, Aucklanders were interviewed about walking and barriers they might encounter (Chapter 5). Fifth, WE features reported as causing difficulties were objectively characterised (Chapter 6). These studies delved into WE and perceived walkability, and provided rich insights, both as individual lines of enquiry and as a cohesive whole. However, as each of these studies used structured approaches for data collection, the findings may have failed to capture nuances.

The Citizen Science (CS) approach can provide a different lens by *"advancing knowledge through research and monitoring done by, for, and with members of the public"* [305]. CS presents potential and opportunities for contributing to more walkable neighbourhoods, by offering residents a more spontaneous and "real-time" way of providing inputs, and sometimes involving them in project planning, data analysis, and advocacy [261]. King and colleagues have described three types of CS: for the people, with the people, or by the people [289]. CS "with the people" ensures members of the public are involved in the data analysis, whereas CS "by the people" generally includes members of the public from the design phase. CS "by the people" is a promising approach for the creation of new knowledge [289]. It seems particularly adapted to the planning of healthier environments through the active participation and ideas of those who experience these environments on a daily basis [261]. To date, research has been conducted in twelve countries and across diverse populations and types of neighbourhood [306]. CS builds on a history of citizen participation as a response to this lack of control and a renewed conception of citizen, being active participant in the collective decisions [307]. CS is applied in this project aiming collect a different type of users' inputs, more spontaneous and freer in format. Interview participants from the study described in Chapter 5 were invited to be part of this project as Citizen Scientists (CS) and participate in data gathering and analysis.

This chapter focuses on the data gathered by the CS and the analysis of these data. Using the free inputs of CS, this study aims to examine:

- **The features of the WE raised by CS**, with particular attention on possible feature that were not covered in the interviews; and
- **The associations between features of the WE raised and CS' perceptions of walkability**, noting differences to those identified through more structured methodologies (chapter 5).

2 METHODS

2.1 Citizen Science approach and Neighbourhood Discovery Tool

The gathering of local insights by CS is a key aspect of the approach. A specialised app was used to enable people of all ages and backgrounds to easily provide inputs - the Stanford University's Neighbourhood Discovery Tool [98]. Whenever a CS decides to document their environment, they "start a walk" through the app, which then geo-references their itinerary and the position of any point of interest (photo, good/bad rating, and explanation of why this feature matters through text or voice clip). The CS were invited to undertake as many or as few walks they want. The walks could be for any purpose, and the CS were welcome to capture data walking on their own, with another CS, accompanied by a friend or family member, or with the researcher. The involvement of CS is presented in Table 22.

Table 22: Citizen Science approach used in this study.

Phase	CS approach
Data gathering	CS were invited to gather data anywhere in Auckland – around their homes, or in other places where they walked.
Data analysis and identification of patterns	The CS were invited to provide feedback to the draft analysis of the users' interviews data collected previously (chapter 5) and on the practitioners' survey (chapter 7). This choice was made due to the nature of the project (availability of those larger scale data inputs) and of the financial limitations (the budget allowed only for 30 NZD "thank you" vouchers for the CS, and it was important to the team to be respectful of the CS' time).
Brainstorming: prioritisation of interventions and potential solutions	The research involved a survey and focus group of professionals whose work relates to streets (re) design and public health (Chapter 7). The CS were invited to brainstorm questions that should be discussed during the focus group, and delegate one of their members to the focus group.
Advocacy	CS will receive a summary of the findings from all studies and can use them when meeting with their local authorities. The CS were also offered the support of the primary researcher, if and when they meet local authorities.

2.2 Recruitment

The CS were recruited from the interviews conducted previously (chapter 5). During the interview, participants received a verbal information about the Citizen Science work, and if interested they were given an information sheet (Appendix 8A) and a consent form (Appendix 8B) that they could return to the researcher if they wished to participate. Briefly, the participants were informed that they would (a) be trained to use a specific app for recording their insights; (b) be invited to capture ideas when walking through Auckland (alone, with another participant, with a non-participant companion, or with me); (c) be invited to discuss the findings from the interviews and the professionals' survey and prepare the questions for the professionals' focus group (see chapter 7); and (d) be welcome to contact the researchers at any point to discuss questions or concerns.

The study was approved by Auckland University of Technology's Ethics Committee on 31st August 2020 (application 18/431). The information sheet and consent form can be seen in Appendices 8A and 8B. The participants received a small koha (gift) in exchange of their time.

2.3 Workshops and training

Three workshops were organised and facilitated by the primary researcher and Dr Moushumi Chaudhury. Prior to each workshop, the participants received a proposed agenda and an information pack for the next workshop. Details of the aims and information received prior to each of the three workshops are presented in Table 23 below.

Table 23: Workshops with Citizen Scientists

Workshop # and aims		Pre-workshop information
1	Meeting the Citizen Scientists and hearing their motivations about participating to this research; information about the project; introduction to Citizen Science; and training regarding the use of the Discovery Tool [98].	None other than the initially received information sheet
2	Checking in – data capture using the Discovery Tool [98], possible issues and questions; overview of the draft findings from the interviews and discussion.	Overview of the findings from the interviews (appendix 2)
3	Checking in – data capture using the Discovery Tool [98], possible issues and questions; overview of the draft findings from the professionals' survey and discussion. Decisions: questions to ask professionals within the focus group and CS delegation for the focus group.	Overview of the findings from the practitioners' survey and suggested questions for the focus group (appendix 3)

2.4 Data collection and processing

After having been trained to use the Discovery Tool [98] in the first workshop, the CS gathered data between March and May 2020. All CS chose to capture data on their own everyday walks, except for Olly, who is blind and preferred walking with me. Olly suggested that during these walks, I take photos of the elements he indicates, using the app, and activate the voice recording system, to record his insights.

It should be noted that on 23rd March, New Zealand entered a level 3 lockdown[13], followed two days later by a level 4 lockdown (stay at home, schools and workplaces closed except for essential workers) that lasted until 27th April [308]. Auckland returned to level 1 on 8 June 2020. During all levels of lockdown, local walks were allowed, but people were asked to keep physically distanced. All the CS decided individually when and where to walk, both before and during the lockdown.

Data recorded using the app uploads onto the password-protected Discovery Tool Data Portal [309]. The platform shows all the walks, with the information for each walk comprised of a series of items (photo, rating, voice clip or text input recorded to supplement the photos). All participants used voice clips only, and not the text input, and those clips were transcribed verbatim. Two "bugs" were noted with the app: (a) it might quit unexpectedly and therefore artificially terminate a walk (that can be continued by starting a new recording); and (b) some photos were corrupted (the uploaded version would not display or display partly as a solid grey area).

[13] Alert levels:
Level 2: gatherings limited to 100 people, 1m physical distancing, customers must be seated and served at tables in restaurants and bars
Level 3: stay at home except for essential travel, limited gatherings but schools and workplaces open; public venues closed
Level 4: lockdown: schools and workplaces closed except for essential workers
https://covid19.govt.nz/alert-system/about-the-alert-system

2.5 Data analysis

Insights from the CS were analysed using deductive and inductive content analysis. Deductive content analysis is adapted to testing a pre-existing theoretical framework [99] – in this case, the draft Social Model of Walkability, developed through this thesis. The coding used dimensions deduced from the model, developed in the previous chapters. The dimensions are:

- **Availability of destinations and public transport**;
- **Walking network** (including directness or presence or stairs);
- **Qualities of the WE**, including features of the walking infrastructure, traffic, natural elements, aesthetic quality of street environments, or amenities such as benches;
- **Broader transport system**, including the comparative advantages of other modes;
- **Perceived walkability**, or satisfaction of the hierarchy of walking needs;
- **Individual characteristics** (socio-demographics, disability, motivations or availability of travel options); and
- **Trip purpose and constraints** (e.g. having something to transport).

Each dimension includes categories (some given as examples above), which can have sub-categories (for instance, the walking infrastructure involves aspects such as footpaths width or intersections layout). The dimensions relative to the WE and the transport system as well as the categories and subcategories falling under each dimension are the same as previously used for coding the interviews (chapter 5). They are presented in appendix 5C2 with a short rationale for their inclusion. The perceptions were related to the levels of the hierarchy of pedestrian needs wherever possible, using the coding protocol previously applied for coding the interview (see Appendix 5C). The analysis focused on identifying potential discrepancies between the inputs and the theoretical model.

The software NVivo 20.1 [310] was used for coding the CS inputs. NVivo [310] can define codes and attribute them to selected text or photo items. Parts of a document can be allocated to as many different codes as necessary, by selecting elements (sentences, parts of a sentence or photo). Further, NVivo provides an overview of the number of items per code and can extract all the elements that had been associated with a particular code [310]. An extra category, “excluded”, was defined to identify inputs that cannot be used for analysis (typically inputs with no comment and rating).

3 RESULTS

From the 56 interview participants, nine initially accepted to continue being part of the project as CS. Four of those participants did take part in the workshops and actively gathered data. The five participants who had initially accepted being part of the project but did not collect data did not provide reasons for that.

The four CS were motivated by contributing to a more walkable city. The CS characteristics are presented in Table 24. The participants' real names are replaced by pseudonyms.

Table 24: Citizen Scientists' demographic data

Pseudonym	Age	Disability status	Remarks
Ethel	64	Has some difficulty seeing.	Ethel is the primary carer of her husband, who is older and has difficulties walking. Both enjoy going on daily walks, using public transport to access places where they can walk safely (typically smooth walkways away from the traffic and with benches and toilets available nearby). All Ethel's data were recorded on walks done with her husband.
Lenny	49	Blind, long cane user. Has some difficulties using public transport (related to access to bus stops)	Lenny works full time and commutes every day from South Auckland to the city, by bus. He enjoys local walks with his wife and 4-year-old daughter. He also walks locally alone or with his daughter, typically to the library and the play centre. Lenny recorded feedback from walks done with his wife and daughter.
Morgan	40	Non-disabled	Morgan is a keen walker, who routinely walks back home from work (6.5 km) and goes on long urban walks on weekends, with a particular interest in finding "secret" walking shortcuts. Morgan recorded all her insights walking alone. Her professional expertise is user experience, and she brought that aspect in the CS workshops.
Ollie	65	Blind, long cane user. Has some difficulties using public transport (related to access to bus stops)	Ollie walks every day from his home to the place where he volunteers (1.5 km). He also enjoys walking with his wife – typically to and from restaurants in Ponsonby (approximately 5.5 km return). Ollie chose to record feedback walking with the researcher, who would operate the app. It was also arranged for him to use a Dictaphone as an alternative method; however, there was an issue with the recording and it has not been possible to use those data.

Collectively, the CS gathered 101 inputs from 12 walks using the Discovery App [309] (8.5 inputs per walk). Four inputs (4%) were excluded – they were photos without information and rating. Eleven other inputs (11%) were fragments of information related to a previous input (for instance additional photo and comment). The CS live in central and southern Auckland, and reported walks located either in their neighbourhoods or further afield (Ethel and Morgan). The locations are presented in Figure 16 below.

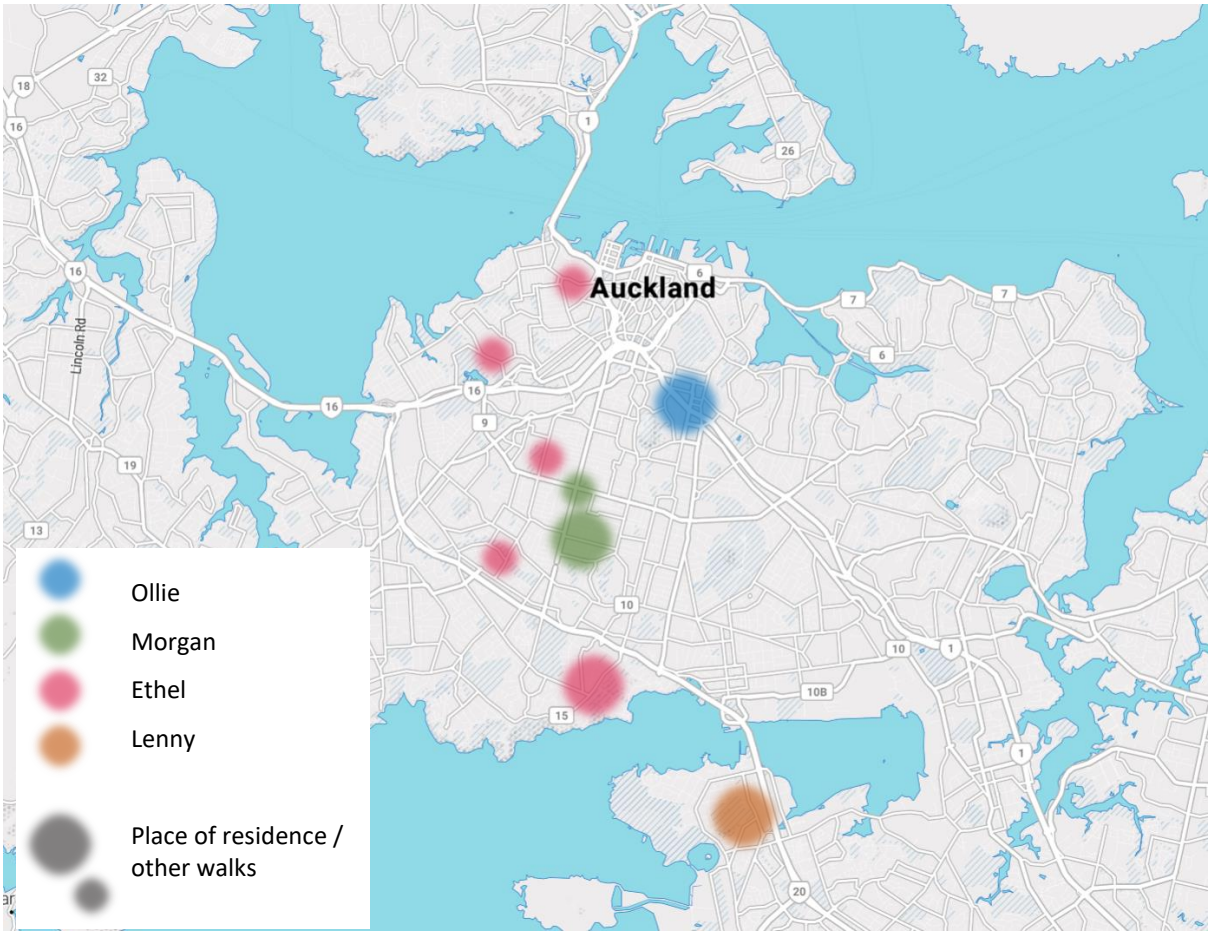


Figure 16: Places of residence of the Citizen Scientists (larger circles) and locations of the walks recorded further afield (smaller circles, not centred exactly on the home addresses)

3.1 A note on the methods

Participants generally saw the Discovery Tool as relatively simple and straightforward; however, the method was not well suited for blind participants. Firstly, using any app requires an adaptation (text to voice, reading the instructions) that did not prove convenient for the two participants. Second, photos are a key aspect of the input, in the Discovery Tool, but are obviously an issue for blind people. For these reasons, participants were offered to walk with the principal researcher or to use a Dictaphone that would be lent to them. One of the two participants walked with me, while the other one documented family walks, his wife taking photos and recording his voice messages.

3.2 Reported environmental features

The 97 included inputs contained 11 partial inputs (additions to a previous input, for instance an extra photo or comment). The partial inputs were included in the coding and labelled if they referred to categories other than those of the main input. This document considers a tally of 97-11 = 86 contributions. Two participants, both blind and using a long cane, recorded over two thirds of the contributions (n = 59, 69% of all contributions).

The contributions referred to 90 environmental features. The majority of the features (n = 67, 74%) had been tagged by participants as “Bad for the community”, and 23 (26%) were considered good[14]. Almost all the features (n = 88, 98%) were relative to the qualities of the WE. Two of the reported features (2%) related to public transport services and information. An overview of the features reported by dimension, category and subcategory is presented in Table 25 below.

The majority of the reported features (n = 54, 60%) relate to the two main categories noted: the footpaths and the crossings. For the footpaths, the available width was an important characteristic, often related to built-in obstacles that reduce it (16 out of 21 mentions, 76%). The usable surface was further reduced by temporary obstructions that could be caused by objects such as bins or roadwork signs, but also by people waiting for the buses for instance. The two blind CS reported most of the barriers, explaining that they cause difficulties of navigation (being forced to zigzag) or even injuries, when the obstruction is above the ground and not detected by the cane.

[14] Participants were free to label inputs as both good and bad, and the labelling was not compulsory. Some of the features reported were unlabelled. One missing label was corrected to “good” as the input was a new information sign, and as the participant (Ethel) mentioned in other inputs that she appreciated those signs. Therefore, it was assumed that the lack of rating was an omission.

Figure 17: A tree trunk obstructing the footpath at head height and not detected by the long cane; photo contributed by Lenny

> *In our family, this [Figure 17] is known as the killer tree. I don't like to walk down the side of the pavement as this tree would take your head off. I have met it a couple of times not with any serious damage, the better luck than judgement. – Lenny, blind*

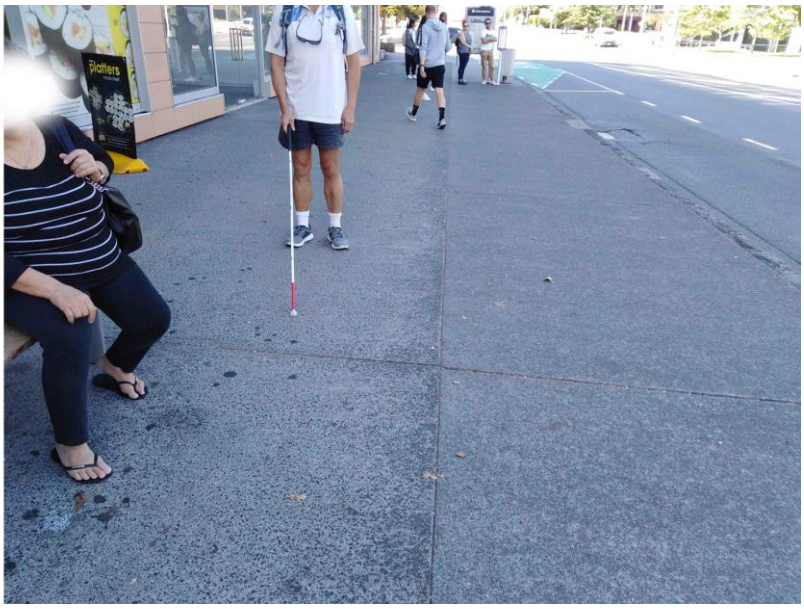


Figure 18: A wide footpath with built-in obstacles (here bench and information signs), also used by people waiting for the buses; photo taken by TB, walking with Ollie

> *Because I have been pushed over to the side of the pavement, because of the presence of the information board for the bus service, should I carry on walking in the straight line I will walk straight into another obstacle, the bench. – Ollie, blind [Figure 18]*

The blind participants reported a density of barriers. On a walk of approximately 400 m (from Auckland Hospital to Seafield View road), Ollie (blind) reported 23 features that either force him to zigzag (poles, bins, information signs, people waiting or roadworks signs) or can unexpectedly hit him in the face (overgrown hedges along a very narrow footpath).

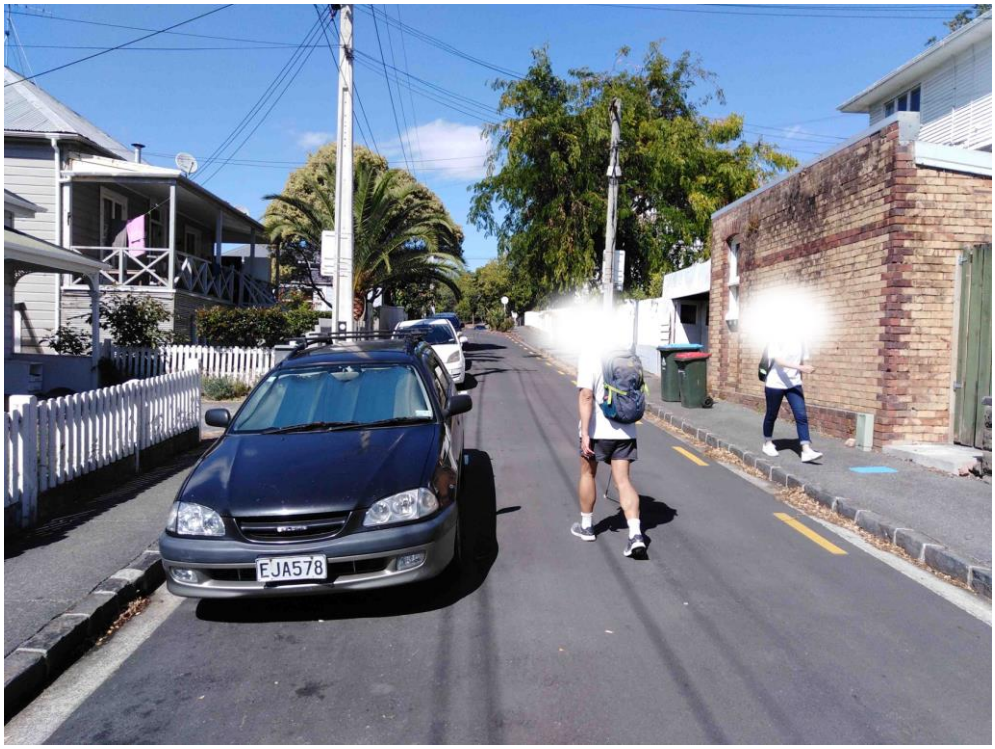


Figure 19: Ollie, walking down the carriageway on a street with narrow footpaths further narrowed by poles, bins, and hedges; photo taken by TB, walking with Ollie

> *The presence of those recycling bins, on the other side of the pavement, means that that side is also blocked off. It is forcing anyone to step onto the pavement. It is because of obstacles like this that although I live on the street, I very very seldomly walk on the pavements, and I am actually forced and feel safer walking smack bang in the middle of the roadway. Fortunately, Seafield view is only one way, and I can hear the traffic before they get near me. – Ollie, blind [Figure 19].*

Several categories were directly related to the footpaths design, namely the vehicle traffic (issues noted around access traffic cutting across the footpaths – "really dangerous" for Lenny) or the need of sharing the path with bicycle users (potentially intimidating, for Ethel and her husband). The presence of heavy traffic and the lack of shade along the path could further decrease attractiveness of the route. Lenny also noted situations where the path was either absent or discontinued, forcing him to walk along the road or through a carpark.

The crossings were the second most noted environmental category. The participants spoke mainly about informal crossing points, where drivers are not required to stop for pedestrians. These situations were particularly problematic for the blind CS: while the presence of tactile pavers was perceived as useful for orientation, they were struggling to cross busy roads, with few gaps in the traffic and noise levels making it difficult to hear them.

Figure 20: Informal crossing with tactile pavers and a median refuge; photo contributed by Lenny

> *This is a crossing, in quotes, at the bottom of Coronation Road. It's marked with tactiles but there's nothing to tell cars that they have to stop and it's on the way on and off the motorway so it's very busy. So there are tactiles but the crossing is useless. – Lenny, blind [Figure 20]*

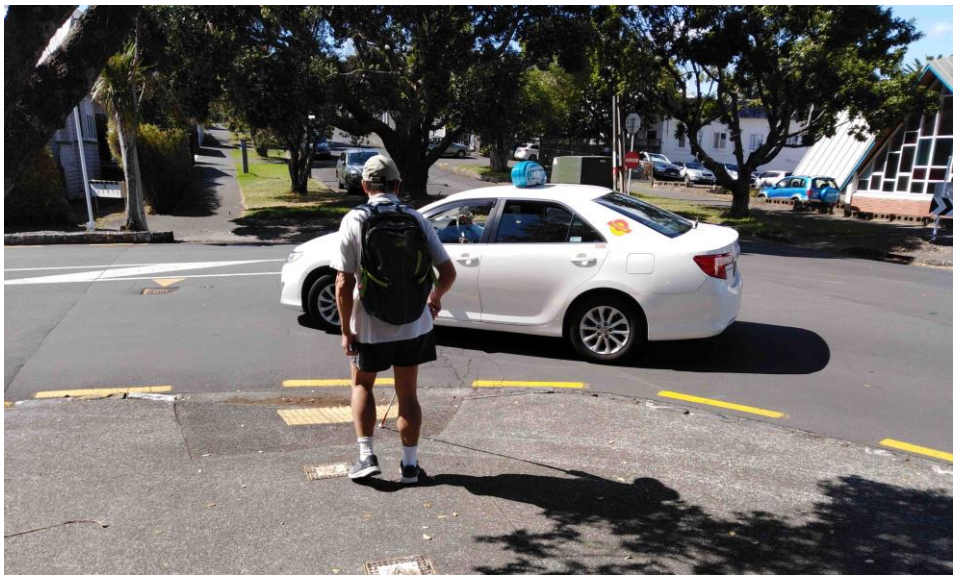


Figure 21: Informal crossing of a side street with tactile pavers and an open curb; photo taken by TB, walking with Ollie

> *I can't really see [the vehicles coming down the hill], I have to listen whether there is anybody and then I can cross. – Ollie, blind [Figure 21]*

Figure 22: Path along the Manukau harbour but separated from it by the road, without pedestrian crossing

> *This is the junction between Short Ave and Kiwi Esplanade and just to show that is no crossing - in fact there's no crossings along the whole Kiwi Esplanade - no crossing at all between the village and the water. - Lenny*

Table 25: Features reported by the Citizen Scientists

Dim.	Categories	Subcategories	N mentions		∑ category
Quality of street environments			Good	Bad	
	Activation - presence of other people, eyes on the street		1		**1**
	Crossings				**16**
		availability of appropriate crossing facilities	1	4	
		non-signalised crossings: layout, geometry, and traffic context		8	
		tactile pavers	2	1	
	Footpaths				**38**
		absence		2	
		design - width, directness		21	
		maintenance		5	
		materials & execution		3	
		temporary obstruction		7	
	Holistic design quality				**5**
		street - footpaths buffered from traffic	1		
		traffic calming	1		
		walkway through carpark		3	
	Interesting things to see				**3**
		details	1		
		nature and animals	2		
	Landscape				**2**
		greenery	1		
		views	1		
	Signage and wayfinding				**6**
		Information	3	1	
		Wayfinding	2		
	Street furniture		1		**1**
	Traffic				**9**
		traffic across the footpath		3	
		sharing the path with bicycle users		5	
		noise and pollution		1	
	Use of the space by other people, (in)civilities		1	2	**3**
	Shelter			1	**1**
	Toilets and water		1		**1**
	Amenities		2		**2**
Broader system					
	Public transport services				**2**
		availability and quality of services	1		
		information	1		
	Total		**23**	**67**	**89**

The CS reported two aspects that did not come up in the interviews:

- **Shared paths**, and the potentially intimidating effect of bicycle users passing by, especially on narrow sections (Heather, talking about her and her husband, and Lenny, specifying that he would avoid the Kiwi esplanade if he was walking by himself or with his young daughter); and
- **Signage and information**, for instance showing the itinerary of a walking path and providing information about presence of stairs, toilets, and benches; providing information about natural and historical features; directions; or waiting times for public transport. All contributions were provided by Ethel who rated them positively, finding them useful and interesting, in the case of informative boards.

3.3 Reported perceptions

CS' insights regarding the photos taken and their explanations regarding what they enjoy or find problematic were tentatively coded against the hierarchy of walking needs (draft Social Model of Walkability). The perceptions reported did not include ideas foreign to the existing hierarchy of walking needs with the exception of convenience – a dimension that was not salient in Alfonzo's first development [43] but that had been suggested in the analysis of Auckland Transport Active Modes Survey results, Chapter 4). While the ideas expressed aligned with the up-to-date version of the hierarchy of walking needs, coding inputs against specific levels of the hierarchy was relatively complicated due to inputs not necessarily providing all the dimensions that would have been used for classification, in the interviews. For instance, feasibility and accessibility relate to similar ideas, regarding their non-fulfilment; the difference is in the outcome, for the person: if they perceive that the trip cannot be done, the feasibility level is not fulfilled. However, the open nature of this data capture method allows people to provide as little or much information as they wish – this can mean that researchers do not always have all the elements that would be ideally needed for classifying perceptions. Classification is further made difficult by subtleties of language and expression (how participants describe their perceptions) [242]. A coding protocol was established (Appendix 5C), however it should be noted that data gaps implied interpretation and assumptions especially in differentiating between the first two basic levels, feasibility and accessibility. For this reason, the coding is presented as a tentative categorisation of inputs. An overview of the coding is in Table 26 below, and insights are examined in the following paragraphs.

Table 26: Reported inputs tentatively coded against the levels of the hierarchy of walking needs

Level of the hierarchy of walking needs	Characteristics	Mentions (n, %)	
Pleasure	Level of appeal of the walking environments	3	4%
Convenience	Practicality, efficiency of walking to a destination or public transport	3	4%
Comfort	Relationships with traffic, ease of crossing or walking along the path.	10	14%
Safety	Initially (see Alfonzo [43]), the level of safety related to crime and a personal dimension. In this research, it was extended to include safety from traffic.	35	50%
Feasibility OR accessibility	Possibility / viability of accessing a destination or undertaking a leisure walk (feasibility) or level of ease of accessing a destination or undertaking a leisure walk; the need for accessibility is noted as not fulfilled if a high difficulty is expressed	21	28%
Total		**72**	**100%**

The tentative association with the hierarchy of hierarchy of walking needs indicates a focus on the most basic perceptions: feasibility, accessibility, and safety (56 of the 72 coded inputs, 78%). The features of the WE associated with each dimension are described below.

Safety was the largest group of perceptions reported. One case was positive (Lenny noting the presence of tactile pavers in Mangere Bridge as helpful tools for orienting vis-à-vis traffic). Most inputs (34, 97%) were negative. They were associated to:

- **Obstacles and trip hazards**: built elements, differences of levels left behind after works, parked cars (for instance tow bars sticking out at shin-height), or natural elements (tree trunk at head height). These elements were reported mainly by blind CS (but also non-blind CS talking about people with low vision or ambulatory impairments).
- **Interactions with traffic**: discontinued walking network forcing to walk through a carpark, or carpark access cutting through the footpath, both reported by Lenny.
- **Sharing the path with bicycle riders**, reported by Ethel as “intimidating” for her and her husband. As seen above, Lenny avoids narrow shared paths, when walking alone. He also noted as an issue a sign “[…] that suggests that this is a shared path between the walkers and cyclists and the path is maximum of 1 m wide”.

Feasibility and accessibility issues were reported by the blind CS. Two inputs were rated positive, both relating to pedestrian crossings being built and for which the hopes were that they would make access to destinations easier. A majority of the inputs (19, 90%) were negative and related to:

- **Non-signalised crossings with heavy and/or fast traffic** (inability to cross while cars are present nearby and might drive through the crossing at speed, having the right of way – see Figure 20 and Figure 21 above, and quotes)
- **Absence of crossings** (see Figure 22 and quote above)
- **Footpaths obstructions and crowding,** sometimes coupled with a narrow design, forcing a zigzag that blind participants will prefer to avoid (see Figure 18, Figure 19 and quotes above).
- Sharing a narrow path with cyclists
- **Missing pedestrian infrastructure**, for instance no footpath along a lane that forms the access to the library and the playground, or no footpath available after having crossed an intersection.

Comfort was associated with two positive inputs: footpaths that are buffered from traffic (Lenny), and presence of benches (Ethel). Eight out of the 10 mentions were negative. They were related to the need to dodge obstacles (for instance shared bikes, parked cars or people waiting for the bus); uneven footpaths; unkept hedges (see Figure 23); and a footpath without shade and adjacent to strong traffic flows.

Figure 23: Unkept hedge along a footpath, "[…] lovely to meet particularly on a wet day." - Lenny

Convenience and pleasure related to six positive inputs, all submitted by Ethel. Convenience was associated to the presence of toilets and useful signage. Views of nature, informative signs, and provision of free outdoor gym equipment were labelled against the dimension of pleasure.

3.4 Associations between environmental features and perceptions

While the CS were a diverse group of people, reporting on a variety of environmental features, some patterns were identified regarding how the features are experienced or assessed. Overall:

- **Interactions with traffic were associated with the most basic pedestrian needs**: safety, feasibility and accessibility. The blind CS noted that navigating non-signalised intersections was difficult because it is not always possible to hear a gap in the traffic, and because of inconsistencies of design (for instance, absence of footpath on the other side). They also reported issues due to a lack of appropriate crossings. A sense of poor safety came from inputs regarding interruptions of the walking network that could force them to walk on the carriageway or through a carpark, or relative to the presence traffic on the paths (motor traffic accessing parking lots, or presence of bicycle users with whom to share the path). Complicated interactions with traffic could further be associated with the inability to access destinations (severance).
- **Footpaths design, layout, and obstructions were often associated to basic needs:** accessibility and safety, sometimes feasibility. These associations were contributed by the blind CS reporting on their daily experiences, but also by any CS thinking of wheelchair users or pedestrians with low vision. Footpaths condition could lead blind CS to choose other routes.
- **Comfort was associated with smooth and direct paths, and the presence of benches and toilets.** Comfort could be undermined by a lack of maintenance (for instance footpath surface or unkept hedges), or a strong presence of traffic along the path.

3.5 Elements of context and additional information provided

In the spirit of the Our Voice approach [261], the CS took a role of advocates, talking on behalf of other people, and questioned the design practice. All the CS, disabled or not, noted WE features that they thought would cause difficulties to others. Lenny and Ollie, both blind and using long canes, talked about barriers for wheelchair users (Lenny, see Figure 24 and quote below) and for blind people using guide dogs (Ollie, noting that in presence of a narrow and obstructed footpath, a guide dog would be unsure about where to lead its human). Morgan and Ethel reported footpaths in poor condition, after having been repaired, signalling they would be difficult for people who are mobility- or visually-impaired (Morgan: see Figure 25 and quote below). Ethel was also angry because of a footpath obstructed "where people might need to cross the road" (see Figure 26 and quote below).

Figure 24: Tree and narrow footpath damaged by the roots; photo contributed by Lenny

> *This is the second set of tree roots on this small bit of pavement and again they are on the main route to the village. Trip hazard, just makes walking down really difficult, and impossible in a wheelchair. – Lenny*

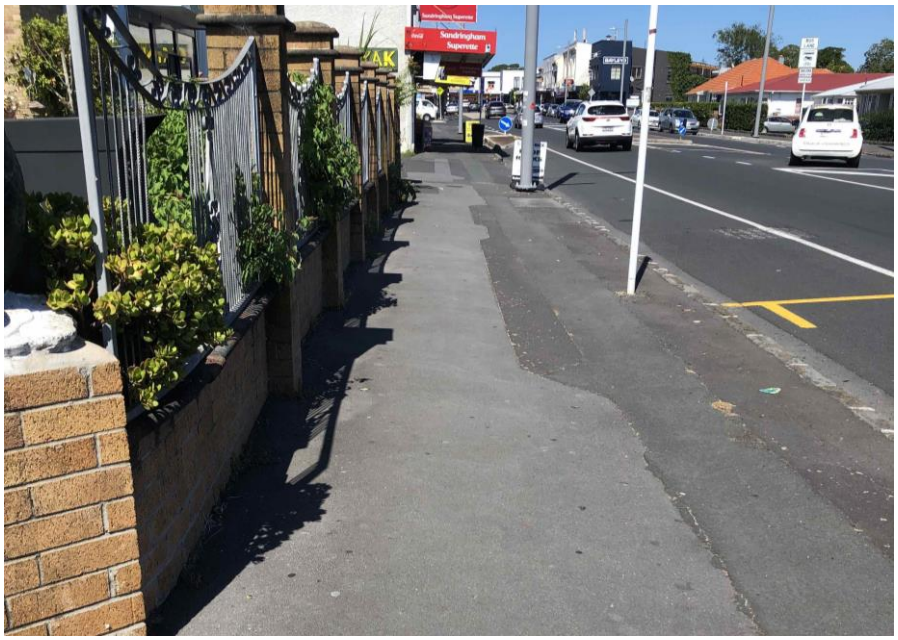


Figure 25: Poorly maintained footpath – "Anybody with mobility issues with really struggle to walk down here." - Morgan

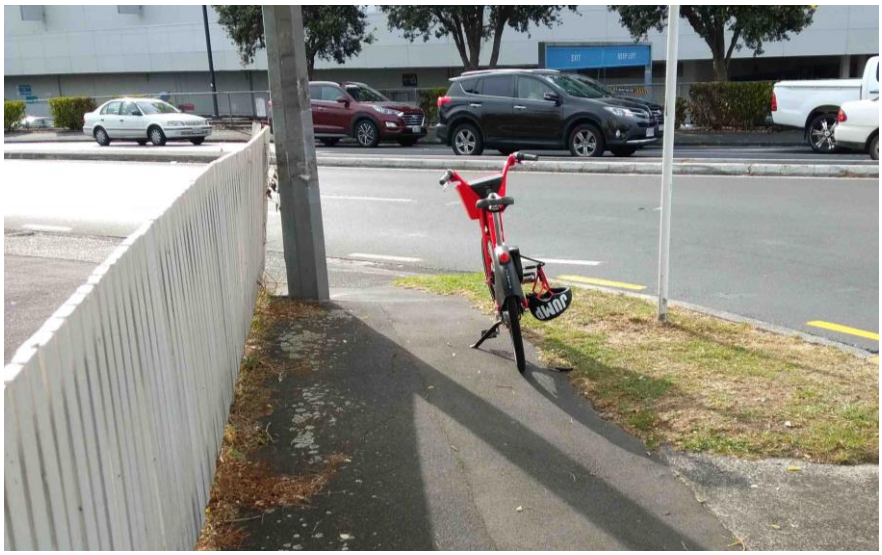


Figure 26: A shared bike parked on a narrow footpath; photo contributed by Ethel

> *Well it makes me really mad […] the situation where an Uber bike sitting right in the place where people might need to cross the road – Ethel*

The design practice was questioned indirectly, every time the CS noted features designed in a way that does not work for them (for instance: interrupted paths or lack of appropriate crossings described above). The two blind CS, Ollie and Lenny, mentioned however also explicitly the way walking environments are delivered. Ollie stressed that barriers kept being built, showing the example of a modern building situated between the main hospital and the University, and bordered by a high quality granite footpath obstructed by two electrical boxes (see Figure 27 and quote below). He also pointed out that roadworks signs could be placed in a way that obstructs footpaths. Lenny observed that although tactile pavers were being placed at non-signalised crossings with high traffic, that these crossing points remained of no help, given the priority to traffic and the inability to find a suitable gap.

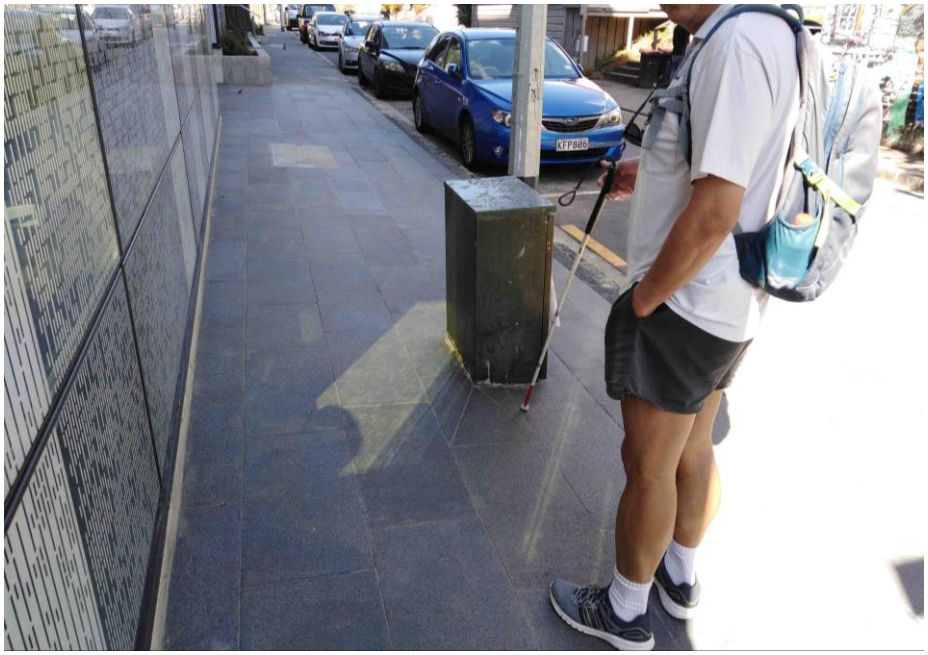


Figure 27: Footpath with a built-in obstacle (electric box); photo taken by TB, walking with Ollie

> *Again, this is a brand new building. How is it that the developers of this building were allowed to have this electricity equipment exposed. Whether it's them or the electricity department, surely there must be some type of guidelines which prohibits electricity protection boxes to be located smack bang in the middle of the pavement. - Ollie*

4 DISCUSSION

This chapter examined environmental aspects perceived as supportive of walking or as barriers, this time basing on inputs provided by Citizen Scientists (CS). The aim was to examine qualitatively what environmental features were raised, how these features compared to the inputs gathered through interviews (chapter 5), and how participants spontaneously associated environmental features with perceptions of walkability. For this purpose, the CS used an ad hoc smartphone ap [98] to record features of any walk of their choice. Deductive content analysis [99] was used to code the results against the draft Social Model of Walkability.

A group of four CS recorded insights from walks taken near their places of residence (central and southern Tamaki-Makaurau – Auckland, Aotearoa – New Zealand). The insights were coded against the dimensions of the draft Social Model of Walkability. The analysis focused on the environmental features, ways they were experienced, and possible reported consequences on walking.

The insights confirmed the systemic issues identified previously through literature review and interviews. Noted barriers could relate to design principles (e.g., provision and type of crossings) and delivery methods (e.g., footpaths patched by different underground interventions and not finished smoothly). While design standards evolve, issues pointed by the CS cover both inherited and new infrastructure. Gehl consultants had noted: “Historical high priority given to the vehicular traffic has left its conclusive mark on Auckland. A large scaled street layout dominates the city centre accommodating a high number of cars and putting pedestrians under pressure.” [78]. The CS illustrated how the historic built environments and rules can cause barriers (e.g., narrow footpaths on streets and roads with generous proportions but also a high allocation to motor vehicles; walking surface further narrowed by the installation of utilities and services (poles or electric boxes for instance); poor provision for pedestrian crossing; or large-scale crossings and intersections where traffic has right of way over pedestrians). The CS however also indicated issues observed in recently built or retrofit areas, noting again issues relative to design standards. These included:

- The provision of tactile pavers on casual, non-signalised crossings: the blind CS noted that while the tactile pavers help orient, the type of crossing itself is not navigable with intense traffic flows having right of way over pedestrians;
- The retrofit of non-signalised crossings that involves new materials (for instance, stone paving, by the Auckland Hospital) but does not include devices that can stop the traffic or alter priority rules;
- The addition of further obstacles to the footpaths, such as for instance electric boxes.

The inputs provided by CS differed however slightly from the interviews in Chapter 5. Specifically, the CS mentioned aspects that did not arise in the interviews (shared paths and signage) but the process also allowed for more richness and detail in the observations (for instance, mentioning specific "micro" features such as electric boxes obstructing footpaths, or explaining how the succession of these "micro" barriers impacts on the walkability of an area). These differences could be explained by the investigation method used or the scope of research.

- **The investigation method** allowed here free data capture in the walking environment, captured in a time and place chosen by the participant. The method presents significant differences to interviews, having had a structured set of questions. Recall could be different in both situations. Also, the Discovery Tool was developed as an intuitive and user-friendly platform [309], allowing to provide as little or much of information about a feature, which could lead to a higher willingness to provide insights.
- **The scope of research** included here any walk, as opposed to usual walks and nearby destinations not accessed, in the interviews. Considering any walk meant that the participants were asked inputs relative to a wider range of environments, that might have prompted them to record features seen for the first time. The participants were also asked if the feature they are indicating is good or bad "for the community", prompting them to imagine the experiences of others, while the interviews examined their personal experience.

4.1 A note on the methods

The participation of blind CS (first in an app-based data collection, to my knowledge), allowed to test the usability of the data capture methods, relying on a smartphone and an app [98]. The experience suggested some difficulties of use relative to the text-to-voice transcription and taking photos. Further development of data capture – using the app or another method – is recommended, and should be done in partnership with blind people, aiming to develop a solution that corresponds to CS objective of involving diverse people. A potential way forward could be a wearable camera and a recorder including GPS tracking and operated using physical switches (capture photo, capture voice recording, save and pass to next).

4.2 Strengths and limitations of the research

This study builds on the understanding of walkability as perceived by users. It has two main strengths. Firstly, the use of participatory action research, with a format that is freer than an interview, allowing therefore CS to contribute when and where they want, using either voice recording or text. This method provided an interesting new perspective to data previously gathered in interviews, namely exploring the effects of an accumulation of "small" barriers. Second, it involved the participation of blind CS, who provided extremely valuable insights relative to perceived walkability but also the data capture methods. The usability of the app was for instance discussed, and further development is suggested.

The study has three main limitations. First, the number of CS and inputs provided were relatively low. Second, CS were invited to label and express their feelings, which can be challenging [242]. Third, the coding of inputs relative to perceptions against different levels of the hierarchy of walking needs includes elements of interpretation. A structured coding framework was established, however, due to information gaps, the classification of perceptions should be considered as tentative.

5 CONCLUSION

This study explored people's perceptions of their walking environments using participatory action research, employed to better understand what matters to walkers and why. The insights provided by the CS conceptually aligned with the draft Social Model of Walkability. This method of investigation provided a valuable additional lens of exploration, alongside the previously used literature reviews, quantitative study and qualitative analysis (chapters 4 and 5). The CS contributions included two environmental features that had not been identified through the interviews (shared paths and signage) and provided rich insights into the ways a succession of "small" barriers can complicate a walking trip, for blind people.

To my knowledge, this is the first app-based CS study to have involved blind participants. Blind CS provided extremely valuable insights related namely to their everyday experiences, but contributed also to a reality-check of the methods used: namely, the smartphone app Discovery Tool [309], aiming to empower diverse people to participate, was relatively difficult to use, and the participants chose to ask another person to help them take photos and record insights. This experience suggests the need of developing a device that is easier to use for vision-impaired participants – maybe a wearable camera and recorder operated using a physical switches (capture photo, capture voice recording, save and pass to next).

CHAPTER 9: GENERAL DISCUSSION

This thesis was motivated by a sense of urgency for change and the willingness to help develop insights regarding ways to reduce barriers to walking in urban areas. It builds on a vast body of evidence regarding walking as a behaviour, walking environments (WE), walkability, disability, and user experiences (UX). It considers walking as both a mode of transport and a leisure activity, acknowledging its well established benefits regarding climate change, public health, efficient use of public space and resources, and wellbeing. Geographically, the focus is on urban areas, given the potentials of walking for accessing destinations or public transport [2, 3] and the key role urban areas play in enabling low-carbon mobility instead of hindering it [3, 5].

It is acknowledged that transforming existing environments should prioritise the removal of barriers to walking [13, 14] and improve people's experiences [17–19], tackling current inequities across demographic groups [12–14]. This work requires better understanding what the encountered barriers are and how they vary across people [12, 15, 16].

The thesis draws from two theoretical frameworks: **the Socio-Ecological Framework**, understanding walking as a behaviour influenced by individual, social/cultural, organisational, or environmental aspects [43–45]; and **the Social Model of Disability**, defining disability through the restrictions people encounter [46, 47]. A theoretical model linking WE to walking behaviour through the filter of people's perceptions and characteristics (**draft Social Model of Walkability**) was identified from previous research [43, 53, 54] and developed throughout the thesis.

The specific studies were designed as a sequence, each study building a foundation for the following ones. The first two studies examined international peer-reviewed publications, while the four empiric studies focused on Auckland. An overview of studies' specific aims, data used and analyses are presented in the introduction.

This general discussion is structured in five parts. Firstly, an overview of the contributions is presented against the research questions. Second, the findings of the thesis studies are examined in the light of previous research. Third, an overview of the developments to the model is provided. Fourth, the potential for change is discussed, from the perspective of professional practices and academia. Fifth, an overview of the strengths and limitations is provided.

PART 1: OVERVIEW OF THE CONTRIBUTIONS AGAINST THE RESEARCH QUESTIONS

The overarching research question - ***What is the role of the quality of urban walking environments in walking trips foregone or negative walking experiences, from the perspectives of disabled and non-disabled people, and professionals involved in delivering walking environments?*** – was split into four specific questions, against which the findings are presented below.

Table 27: Overview of the findings against the research questions

Questions		Findings
1	How is the relationship between walking environment and walking behaviour conceptualised, considering individual, social, and trip-related characteristics?	This question was the main topic of chapter 2 (findings discussed below). The draft Social Model of Walkability was developed building on findings from previous studies. The existing evidence presents however large gaps, due in part to inappropriate methodologies, over-simplifying complex relationships between WE and walking behaviour. The model was further critiqued, proposing to use it as a flexible framework primarily for identifying what is *not* walkable. The development and the critique are presented in Part 3 of this discussion.
2	What features of the walking environment contribute to perceived difficulty or impossibility of walking to destinations within reachable distance, and how do they vary between disabled and non-disabled people?	The quantitative analysis (chapter 4) examined walking levels (0 vs ≥5 trips per week) and their associations with perceived quality of WE. While the main predictor was the usage of public transport, perceived quality contributed to the prediction of walking levels. WE quality was either stated directly (e.g. "boring routes") or indirectly (e.g., mentions to fear regarding traffic). The secondary data used did however not include disabled people. The interviews (chapter 5) examined trips desired but not made and the barriers encountered by participants (disabled and non-disabled). The study outlined a key importance of the quality of the WE. Six critical features were identified and further characterised in chapter 6. Significant differences were noted between disabled and non-disabled participants. Citizen Scientists (chapter 8) provided valuable insights, showing namely how the accumulation of "small" barriers can increase the difficulty of a walking trip. The link between WE and perceptions of difficulty and otherwise are presented in Part 3 of the discussion.
3	To what extent do existing local planning guidelines enable the identification of barriers to walking reported by people?	In chapter 6, the characteristics of the six critical features were compared with local guidelines. The results showed the inadequacy of the local guidelines for identifying the barriers to walking, mostly because they (a) do not include specific thresholds for the metrics through which barriers can be detected, or (b) do not consider certain important metrics (e.g., the focus for non-signalised crossings is traffic volumes, while cornering speed and complexity were found to play important roles). Detailed findings are discussed below.
4	To what extent do practitioners from different disciplines involved in the design of the walking environment and public health agree on the barriers to walking in Auckland, and the priorities and challenges regarding retrofit?	The results of chapter 7 showed professionals' agreement on the systemic complexity of delivering walkable environments, and Auckland's main challenge: retrofitting the car-centred city within a context of low political priority for walking. The focus group further identified a vicious circle, linking the low priority to inadequate decision-making metrics, undervaluing users' experiences which are in turn not measured and not well understood. In line with this, the surveyed professionals displayed a variety of views regarding what could cause difficulties to people and did not use robust data relative to people's experiences, which could inform priorities of retrofit.

PART 2: FINDINGS IN THE LIGHT OF PREVIOUS RESEARCH

Chapter 2 - General literature review

The umbrella review based on the results of 17 reviews, eight analysing the notion of walkability, and nine examining the associations between WE and walking behaviour.

Despite the complexity and lack of agreed definition of walkability, some elements of consensus were identified, namely:

- The availability of destinations within a walkable distance [22, 55, 56];
- The importance of difficulties or safety concerns, *as perceived by people* [16, 21, 22, 27, 57, 58];
- High levels of difficulties of walking in inherited, car-oriented environments [22, 27]; and
- Inequities of access, namely between disabled and non-disabled people [16, 22, 57, 57].

Two major gaps in understanding were identified.

- **Firstly, there is no agreed theoretical framework linking the environment to walking behaviour** - it is still not clear what WE features matter, how much they matter [56], and how individual characteristics might moderate this importance [16, 57, 62].
- **Second, there is no consensus regarding how the quality of the walking realm influences the (non) choice of walking**: what matters, how much, for whom, in what circumstances [21, 22, 55].

Theoretical model

The widely accepted Socio-Ecological Framework remains intentionally broad and calls for specific models for specific outcomes, such as walking [43, 45]. A specific model was developed by Alfonzo, positing that the WE is linked to walking behaviour considering as explanatory variables the perceptions, individual, social, and trip characteristics [43]. This initial model development stemmed from Alfonzo's observation that the existing evidence presented "oversimplified relationships between two variables and are not typically useful (in terms of applied utility) as they are not part of a dynamic, theoretical model informing the walking decision-making process." [43]. Alfonzo framed perceptions as a hierarchy of pedestrian needs and dissociated objective (O) features and perceptions (P), putting them in a sequence. The dissociation aligns with previous findings explaining walking behaviour [49–51] and underpinned already the framework proposed by Mehrabian and Russell in 1974 [52]. Mehrabian and Russell posited that environmental features generate emotions

or perceptions, which in turn influence behaviours, stressing the importance of moderating individual factors (a given environmental feature can lead to different behaviours in different people experiencing it) [52].

The model drafted by Alfonzo underwent limited testing (studies by Mehta [53], Buckley and colleagues [54], Ma and Cao [49], Cambra and Moura [61], and Shatu and colleagues [145]). The studies confirmed the overall structure of the model. The authors mostly focused on determinants to walking, leaving largely open the question of the difficulties encountered in the WE (what they are, how they vary across people, and how they further relate to trips not walked).

Current evidence and measuring tools

In this thesis I suggest that walkability is currently inadequately measured. The identified reviews associating WE to walking behaviour showed three major issues:

- The use of proxy measures (e.g., residential density);
- A dichotomous assessment of the quality of the BE (typically presence or absence of certain features, but not their characteristics); and
- A lack of data and consideration for individual differences such as disability.

Beyond these issues, the use of diverse measures and methods induces great difficulty in building an overview of the current understanding of associations between WE and walking behaviour.

Overall, the general literature review gathered the knowledge base relative to a theoretical framework (draft Social Model of Walkability) and outlined the need for a better understanding of barriers to walking across people of different ages and abilities.

Chapter 3 – Specific literature review

This umbrella review examined the associations between specific **objective characteristics** of WE **(O)**; and **people's perceptions** of the satisfaction of their walking needs **(Pw),** the first link of the draft Social Model of Walkability. This umbrella review is to my knowledge the first to addresses the broad question of how objective WE characteristics are related to perceptions of satisfaction of walking needs. This topic is important namely given the understanding of Pw as an influence of walking as a behaviour [49–51] and the need for providing environments delivering positive user experiences [19, 57, 152, 176, 177], helping leverage walking for transport [5, 14, 91, 104]

Reviews published between April 2009 and November 2020 were included, covering the time period during which approximately three quarters of the research on walkability was published. The identified 2,889 publications were filtered for inclusion, and 21 were included in the review. Reviews' quality was assessed using the Methodological Quality Checklist [154] and two extra dimensions (were the results presented separately for (a) older people and (b) disabled people).

Limited and heterogenous evidence

The evidence presented important challenges to aggregation, including:

- Studies of diverse levels of quality;
- Lack of disaggregation of results by age groups or types and levels of disability;
- Results mixing findings from urban, suburban, or rural settings; and
- Unclarity regarding how O and P were measured in the primary studies.

The evidence was also overall poor, with only 27 associations O-Pw[15] and large gaps in terms of what O characteristics have been examined and what Pw they have been tested against. For instance, no information was reported regarding how people feel about: presence or absence of other people walking, noise levels, air pollution, or number of traffic movements to watch when crossing.

[15] A list of potential 56 categories of WE features was used to classify the O results. Pw contains 7 levels, after having added convenience and ethics to the original model (Chapter xxx). Therefore, the testing of each category of WE features against each perception would represent 392 associations. From the 27 noted associations, 11 (41%) relate to the results of one primary study only.

Mismatch between features as measured and as perceived

One review examined the associations between objective measures of a series features of the WE features and people's perceptions of the same features [50]. Low levels of agreement were noted, raising the important question of how we measure O. For instance, if "traffic" is perceived as a barrier to walking, do people refer to the traffic volume, its speed, or a combination of both? Are we dealing with a "dose-response" function or are there thresholds above which "traffic" is considered as high? Do the perceptions change depending on the context (for instance wide boulevard or narrow street)? And how do these perceptions vary across people?

Two aspects could have an impact on the accuracy of O measures: personal and geographic characteristics. Firstly, without an understanding of what matters to people and how this might vary across demographics, O measures run the risk of not capturing the important parameters, or extrapolating parameters identified for one group across the population. The question of demographics is crucial: there is a need to develop a "customer segmentation", when it comes to walking, and deal with possible inconsistencies between people's perceptions. Individual characteristics to consider may include (but are by no means limited to) different types of disability and mobility devices used [16, 24], age groups [122], or familiarity with the area [152, 180, 181]. A second potential source of error is related to geography: where are the O features measured, and does that area correspond to what the person imagines, when asked about their perceptions [311]? The problem might be limited when the interrogating people about specific contexts (e.g., "walking along this block") but potentially important when questioning about "your neighbourhood" or even a certain distance from home: Hwang had for instance noted that diverse perimeters were typically used in studies (circles ranging from 400m to 3,000m from home, census blocks, whole city, or a specific street) [129]. Diverse perimeters could be diversely relevant to or known by the person. Failing to account for "walkers' playgrounds" might lead to assessing areas that are in fact not relevant to users, or missing ones that are [57, 63, 179].

Associations between objective environmental features and perceived walkability

The identified associations O-Pw were consistent with previous research – for instance, street connectivity and crossing facilities were associated to perceived ease of walking. The findings provided however two important insights for the development of the model and outlined research gaps that can help inform future investigations.

The insights related to complex associations between WE features and perceived walkability: specific WE features can potentially be associated to several levels of the hierarchy of walking needs. Further, the associations between ensembles of features (holistic street environments) and perceptions suggests possible synergetic relationships. Research gaps related to the paucity of reported associations O-Pw, as well as insufficient reporting on the measures (what was measured, how, in what contexts), and on variables that can moderate the associations O-Pw (e.g., age or disability). Findings and gaps are discussed in more detail below, under the model development (Link: objective environment – perceived , 244).

Chapter 4 – Analysis of associations between perceived walkability and levels of walking

The chapter examined how Aucklanders' perceptions of their environments, motivations and individual characteristics associate with walking levels. This was the first empirical study, testing the second sequence of the model.

Secondary data relative to Auckland were used: Auckland Transport Active Modes Survey (ATAM [83]). The dataset was particularly adapted to this thesis as it captures (a) **people's perceptions of the WE** – for instance, are destinations too far, is the terrain too hilly, or how safe is it to walk?; (b) **internal motivators** such as fitness, or "me time"; and (c) **demographic characteristics** - age, gender, or use of public transport. The data also had several limitations, namely a lack of nuance (agreement/ disagreement to statements regarding WE), absence of perceptual data for disabled people, and inability to associate responses to specific geographical areas. Data were collected between 2016 and 2018 (inclusive, N = 4,114 survey respondents).

A subset of 33 variables containing potential predictors to walking (including perceptions of WE, motivators, and demographic characteristics) was chosen. Multiple pairwise associations were identified within the variables, which is not surprising if considering WE as complex systems.

Machine learning was used given the robustness of the method in processing datasets large numbers of input variables with high levels of multicollinearity [209]. The process consisted in fitting a model predicting walking levels based on the potential predictors, testing its reliability, and extracting information relative to the usefulness of each variable in predicting walking levels. The outcome considered only two cases: number of walking trips in the previous week corresponding to the lowest or highest tertile (respectively 0 trips and 5 and more trips).

Key importance of the broader transport system

Reasonable reliability was achieved for the prediction of the levels of walking (top or bottom tertile; AUC = 0.80). The main predictor variable of walking, by far, was the use of public transport (PT), with a relative importance of 44%. The other important variables in the model related to walking *as compared to other modes* – for instance saving money (implicitly understood as "cheaper than") or avoiding parking hassle. Perceived safety regarding traffic played a minor role (3.5%), while the other perceptions of WE had an importance under 2.5%. The result can come as a surprise giving the strong focus on the availability of destinations, both in research[16] and in the indices calculating "walkability"[17]. However, this finding in line with the understanding of synergies between walking and PT [213, 312] and more generally with the necessity of understanding the choice of walking within urban land use and transport systems [14, 144, 223]. In the general literature review (Chapter 2), a general tendency of walkability research to examine WE in a vacuum had already been noted. The findings of the present study stress this issue – indeed, ignoring the moderating effects of PT or alternatives could lead to important bias in the results.

Given the key role of PT, specific models were developed for the users and non-users of PT, aiming at better understanding those sub-groups. The reliability was lower for the two models (AUC = 0.69). In both models, the variables implicitly comparing walking to other modes continued playing important roles. Interestingly, seeing walking as "fun" had some importance for non-users of PT (10%), which could be explained as a choice between alternatives [213, 312]: walking *if and when* it is fun, and driving otherwise. The other variables helping predict walking levels included lack of other options as well as a range of potential barriers (e.g., safety by night or practicality).

[16] Barnett and colleagues noted for instance the lack of consideration for the participants' driving status / car ownership (examined in two of the 100 identified studies); or examined the availability of public transport, as measured (eight studies) or perceived (ten studies) [65]

[17] Walkscore ™ for instance almost exclusively focuses on destinations availability [118]

The findings could suggest an internal process of comparison of the alternatives at hand, weighing their potential benefits and caveats. Some previous findings support this idea, for instance Transport for London having identified that 18% of Londoners walk less because they have alternatives that work better [82]. However, Guell and colleagues warn against the over-simplification of modal choice [313]. For the authors, modal choice reflects the "messiness" of everyday life , and describing it as a rational process ignores the large (and possibly preponderant) importance of individual and social contexts or habits [313]. Thus, the identified importance of the broader transport in the choice of walking should be considered within the context of individual, social, and trip-related factors.

Results in the light of the draft Social Model of Walkability

The findings of chapter 4 aligned overall with the draft Social Model of Walkability but prompted also four developments, detailed in the second part of this discussion:

- **The transport system** was explicitly included as an entry variable;
- **Two new levels were added to the hierarchy of needs:** convenience (straightforwardness or efficiency) and ethics (ideas such as “helping reduce traffic congestion” or “environment”);
- **Two new facets were added to the hierarchy of walking needs:** the qualities of walking (a) *as compared with* the alternatives; and (b) *in combination with* another mode – typically PT.
- **The availability of other modes of transport** was re-positioned between the transport system and the hierarchy of walking needs.

Arguably, the relative importance of different dimensions could vary in different contexts (e.g., car-centred or not) and by demographic characteristics. More research is needed to better understand the importance of individual characteristics, namely disability and constraints, not included in the sample but for whom it is crucial to understand barriers to movement and facilitators [16, 24, 40, 57, 217, 218]. There is also a need to clarify the role of motivations and habits, possibly influencing choices [152, 180, 181, 225]. It should be examined for instance if individuals concerned about the environment consider the “ethics” level differently than others. This aspect should be particularly important considering societal changes, such as for instance a higher importance given to the environment and readiness to change for the younger populations [226].

Further, it was suggested that machine learning has potential for exploring complex patterns between environment; transport system; individual, social and contextual characteristics; and walking as a behaviour.

Chapter 5 – Naturalistic inquiry into associations between walking environments, perceptions, and walking behaviour

Chapter 5 examined experiences of walking in a car-centred environment: aspects sought for or avoided, difficulties encountered, reasons to choose walking and reasons why not to walk to desired destinations perceived as being within a walkable distance. Participants were adults of different ages (20-89), disabled or non-disabled, living in Auckland.

The interviews were structured in three parts:

- Walking behaviours, motivations and perceptions, speaking generally: frequency of walking, purposes of the walked trips, motivations, deterrents, perceptions of WE in general;
- Usual local trips: purpose, destination, importance, reasons underpinning the modal choice, and if the trip was walked: route chosen and aspects perceived as difficult, unpleasant, or on the contrary pleasant; and
- Possible destinations that are both desired and seen as within walkable distance but not accessed on foot (type of destination, importance, reason(s) not to choose walking).

The inclusion of destinations not accessed was particularly important given the lack of understanding of severance and other possible environmental barriers [62, 314]. The trips walked included both the trips to final destinations and the trips to PT. All the specific barriers indicated by the participants were observed in situ, after the interviews.

A coding protocol was developed and used for coding the answers against the hierarchy of walking needs came with challenges related to associating participants' comments to the hierarchy of walking needs .

Key study-design choices included:

- **Comparable and high availability of destinations for all participants,** motivated by the importance of the availability of destinations for walking and a lack of understanding of the roles played by the qualities of the WE (chapters 2 and 3).
- **Analysing the views of disabled vs non-disabled participants**. Were considered disabled participants who experienced at least some difficulty with one or more of the following: walking, seeing, hearing, remembering, or concentrating (see 'A note on language', in the introduction). Comparing the two populations responded to the lack of data relative to disabled people (chapter 2) and the need to better understand the disability as a moderator of the associations O-P (chapter 3).
- **Focusing on usual trips,** controlling for the possible moderating role of familiarity on perceptions [121, 146], and to facilitating recall regarding the barriers encountered.
- **Sit-down versus walk-along interviews,** aiming to examine multiple usual trips that could not have been covered in a walk-along interview, especially considering the number of older and/or disabled participants, and investigate destinations participants choose *not* to walk to.
- **Quantitative and qualitative data and analysis,** enabling processing a relatively large number of interviews, but losing some detail and granularity [245].

The results provided rich insights relative to the choice of (not) walking, O-P associations and possible moderating effects of disability and environmental features associated to perceived difficulty or impossibility. The findings were overall consistent with the model and helped inform and develop it. Further detail is provided in the second part of this discussion, examining the developments made to the draft Social Model of Walkability.

Chapter 6 – Investigation of the barriers to access reported by participants

Chapter 6 builds on the naturalistic inquiry in walking experiences (chapter 5) and on the acknowledged need to improve measures of the WE in a way that better aligns with people's perceptions (chapter 3). This chapter aimed to characterise the non-walkable.

The starting point was the specific barriers noted by interview participants in Chapter 5. The barriers were part of six types of features, named **critical features** (non-signalised crossings, footpaths width and obstructions, high traffic volumes, traffic-oriented streets, lack of light, and absence of other people walking). Characterising the barriers is important both for research (developing the draft Social Model of Walkability and informing how perceptions are associated to the WE) and for practice, acknowledging the indications that barriers experienced by people might go unseen by transport planners and urban designers [13, 20, 279]. Fewer than 20% interviewed transport planners consider that walking realm retrofit is prioritised according to the needs of people who use it, and only 6.7% thought that good data was available about people using the footpaths [13].

For each critical feature, a series of metrics was identified based on previous literature. Each reported instance of barrier was then measured against each of the corresponding metrics. The study then characterised each type of barrier, seeking a minimal definition based on measures. Further, the study examined if the barriers noted by the participants could have been predicted using the Healthy Streets methodology [95] and local design guidelines [93, 94].

The findings suggested a misalignment between the planning documents and the critical environmental features observed by people. New metrics and thresholds were suggested. The findings help identify WE features that will be impossible for some, and maybe "only" difficult or unpleasant for others.

By triangulating objective measures, survey data and guidelines, the study provided insights for (a) retrofitting WE responding to the need to prioritise the most salient barriers to walking [16, 24, 57]; (b) measuring WE in a way that is consistent with people's perceived walkability [50, 315]; and assessing critically the planning tools. The limitations include a focus on barriers previously reported by interview participants only and relatively low numbers of instances of barriers associated with certain critical features. Future research should develop characterisation based on more identified barriers, from more people of diverse ages and abilities, residing in different car-dominated cities. Thresholds relative to pedestrian flows should in particular be further developed, basing on more locations, at different times of the day and at night.

Chapter 7 – (Dis)agreements between professionals regarding walkability, users' needs, and implementation

After having explored the barriers from people's perspective and identified possible misalignments between what the guidelines prescribe and people's experiences, this chapter examined professionals' views, with two aims. Firstly, I sought to better understand (dis)agreements between professionals involved in the design of street environments and public health regarding users' experiences (UX), priorities, challenges, and evidence gaps for delivering quality WE in a car-centred city. The professionals were urban designers, road safety specialists, transport planners, public health specialists, and urban development and strategy experts. Second, I tested with professionals the assumption that the provision of WE is a complex socio-technical system (CSTS).

Participants were experts in their fields and worked either in Auckland or at the national level. An online survey first served to gather insights anonymously. The survey results were aggregated and discussed with the group of Citizen Scientists, so to identify key questions that should be addressed in the focus group. The focus group aimed to explore topics lacking consensus and challenges.

Data were analysed using a range of approaches: deductive content analysis [99] for the responses related to UX (incentives and barriers to walking), associating them further to dimensions of the model; inductive content analysis [99] for the open answers regarding what makes a walkable city, priorities, challenges, evidence available, as well as for the focus group transcripts; descriptive statistics for the quantitative levels of agreement regarding the dimensions of complexity; and comparisons of frequencies of high ratings of complexity and mentions of contributors to walkability across professional disciplines.

The findings suggested a certain agreement on the core components of walkability, systemic challenges, and complexity of transforming the car-centred city. However, the capacity to deliver evidence-based and prioritised actions appeared compromised, given the disagreements of views regarding barriers to walking and the paucity of good evidence, informing the nature of the barriers experienced by users. The results also suggested difficulties in multidisciplinary collaborations, given certain differences of understanding and a lack of shared evidence. Based on the survey responses, the focus group explored the underlying reasons of the poor consideration of UX and of the low political priority given to walking.

Agreements between professionals

Professionals agreed on the broad characteristics a city should have to support walking. The responses focused on the quality of WE and users' perceptions of safety, accessibility, or pleasant walking experience. The aspects noted were consistent with the draft Social Model of Walkability and comparable across disciplines. The agreement on the quality of WE is at odds with previous findings, outlining disagreements across professional disciplines relative to the importance of aesthetics and comfort [293]. The apparent agreement found here could be due to relatively low numbers of professionals of each discipline and a recruitment process that could have targeted more progressive practitioners. The participants also overall agreed on the systemic complexity of delivering walkable environments and on the challenge of retrofitting the car-centred city.

Disagreements between professionals and perceived challenges

The urgency to transform the WE to support modal shift towards carbon-efficient modes and the systemic complexity of doing so suggest the need of clarity regarding what should be done, and how actions should be prioritised. This chapter's findings indicated however systemic challenges to an ambitious and evidence-based retrofit of the WE.

Beyond the inherent difficulty of retrofitting a complex system encompassing transport and urban form, the results from this chapter revealed two major problems. Firstly, a lack of synergies was identified between professionals who should ideally collaborate. This observation relates to identified divergences of views regarding users' experiences (e.g., how well needs are understood and what barriers users encounter) and different ratings of systemic complexity, that could be related to differences of understanding of the WE as a system. Second, the focus group discussion led to the identification of a vicious circle: walkability is not prioritised and therefore not appropriately measured; users' experiences are overlooked and not used for prioritising improvements; engagement is mostly tokenistic; there is no overview of the most salient barriers to walking; investment decisions are disconnected from improving user experience; walking profile remains and walkability improvements are not prioritised.

The poor interest in and understanding of UX aligns with previous findings, both local [13, 279] and international [18, 90]. Middleton and colleagues explained this lack of interest and understanding both through the lack of political interest, as noted here, and through the false perception of walking as an ubiquitous activity, homogenous across users [18]. The lack of importance given to UX in decision-making makes it possible to plan without this understanding, and to engage with people in a shallow way, not directly related to the design of solutions. Arnstein had noted in 1969 already for decision-makers to consult just to provide the evidence that they "have gone through the required motions of involving 'those people.'" [259]

One participant in this chapter summarised the situation noting that "this is a system challenge, there is no biggest challenge". This view aligns with Burdett and Thomas' conclusion that achieving transport equity "will require fundamental changes to the way that transport, health, land use planning, and social services co-exist in a rapidly growing city" [12].

Several underlying causes of the systemic challenges can be hypothesised, relating to both regulations and culture. **From the regulatory perspective**, participants pointed out that the rules used to allocate funding do not consider projects' effects on strategic priorities such as inclusive access, healthy places, or environmental sustainability [295]. Instead, projects' funding-worthiness is based on benefit-cost ratios having a relatively narrow view of costs and estimated benefits, mostly in terms of vehicle travel time saving [286, 316]. Burdett summarised well the detrimental outcomes regarding accessibility:

> *Despite best practice guidelines, the absence of data about people means that their needs cannot be transparently prioritised when trade-offs are made in new design. Furthermore, maintenance improvements that could result in accessibility improvements become ad-hoc, based on nebulous criteria. [...] Consequently, outcomes of the process are that the social and health benefits to individuals and communities of accessible infrastructure are not explicitly considered. Invisible access problems, where infrastructure is not used because it is not accessible, remain unaddressed. [286]*

From a cultural perspective, the observed synergy gaps could relate to a historical lack of collaboration between professional disciplines [45] and between entities (including for instance disjointed approaches at the ministerial level [12]). The references to tokenistic engagement could also suggest a deeper issue relative to citizen participation in decision-making. Arnstein theorised participation in terms of power and representation in her influential paper "A Ladder of Citizen Participation" [259], now considered a landmark publication on participatory planning [317]. Authorities' unwillingness to transfer power to people was associated to inequity and the neglect of specific urban areas, typically those where residents are poorer, less educated, and less prone to speak up publicly. Arnstein hypothesised that programmes such as Model Cities, empowering citizens from marginalised communities, might begin counteracting systemic aspects of discrimination [259]. Her assumption was supported by the early successes of the Model Cities program, in the 1970s [318].

While the participation literature mostly focused on poor, African American and immigrant communities [318], the logic could be extended to other dimensions of exclusion such as disability. Disabled people are currently precisely demanding to be more involved in decision-making to ensure their ability to participate in everyday activities. This is the case in New Zealand [319, 320] but also in places that could be considered more accessible, like London [321].

Chapter 8 – Citizen Scientists' inputs regarding facilitators and barriers to walking

The last chapter revisited the notion of environmental aspects perceived as supportive of walking or as barriers, with an approach taking some distance from the previously realised structured interviews (chapter 5). In this case, Citizen Scientists (CS) recruited from interview participants were invited to record features of any walk of their choice, providing photos, voice recordings and a "good"/"bad" rating, using an ad hoc smartphone app [98]. A qualitative analysis assessed the environmental features raised and the reported perceptions of walkability, aiming to contrast these inputs with the inputs gathered through interviews (chapter 5). Deductive content analysis [99] was used to code the results against the draft Social Model of Walkability.

Four CS participated to this study. Two of them are blind, using a long cane, one has some difficulties walking, and one is non-disabled. As all the other interview participants, they live in Auckland and reported walks in Auckland's urban area. This is to our knowledge the first study of WE using app-based data collection working with blind CS, which came with some challenges (namely usability by blind people). Alternative solutions were found for this study and new technological solutions that could allow blind CS to investigate their environments independently were suggested.

The inputs from the CS indicated systemic issues identified previously through the literature reviews (chapters 2 and 3) and the interviews (chapter 4) and aligned with the model. Almost three quarters of the inputs were labelled "bad for the community" and related mostly to footpaths design and crossings, already identified through the interviews. The issues reported were similar in nature to those of the interviews, namely: having to slalom between footpath obstructions, feeling threatened by vehicles crossing the footpath to access carparks, and experiencing difficulties crossing roads using non-signalised crossings. Interestingly however, the blind participants' inputs were more detailed than in the interviews, noting successions of "micro" obstructions along the path and painting an image of a "death by a thousand paper cuts". It is imaginable that reporting barriers through the app could be easier than in interview context. Participants also spoke of two aspects that had not been mentioned in the interviews: (a) **shared paths**, where CS could feel intimidated or at risk due to fast bicycle traffic; and (b) **wayfinding and information**, particularly appreciated by one participant. The fact that same participants provided different insights can be related to different methodologies (focusing only on three usual trips, in the interviews, while as CS, participants could contribute any trip, usual or not).

The CS noticed issues with inherited, but also newly built or retrofitted infrastructure. The fact that even recent interventions can be problematic could relate to the lack of understanding of users' needs, noted when investigating professionals' views (chapter 7) and in line with previous research [13, 20, 286]. This result also echoes findings from the investigation of the reported barriers against the design guidelines (chapter 6), where it was suggested that the existing rules and recommendations can be misaligned with users' perceptions. The rules relative to crossings and footpaths missed some aspects important for users (e.g., for the crossings: median refuges do not work for blind people and can be intimidating for other users – Nora, 85, noted for instance that "you stand in the middle [on a narrow refuge], but the trucks are wider than you think").

PART 3: DEVELOPING THE DRAFT SOCIAL MODEL OF WALKABILITY

This section examines the draft Social Model of Walkability through the findings of this thesis and previous literature. First, the entities of the model are examined one by one, considering the bases laid by previous research (Chapter 2) and the developments made through this thesis. Second, the key associations posited in the model are assessed.

As a reminder, the initial state of the draft Social Model of Walkability, such as after the first umbrella review, is presented above, in the findings from the general literature review (Chapter 2). The draft Social Model of Walkability considers specifically the linkages between WE and walking behaviour. Broader models, generalising travel behaviour, include the process generating the demand for a trip (decision to engage in an activity [322, 323] and possibly filter questioning the need for doing so in person [323]). The draft Social Model of Walkability does not address the trip generation but focuses on how the environment provides for any beforehand chosen trip.

Critique of the model

The findings made through the literature reviews and the qualitative studies suggest considering the model as a useful conceptual framework linking the measurable environmental attributes and the perceptions of walkability with walking as a behaviour, accounting for moderating effects of personal, social, and trip-related characteristics. I suggest however that the model should be used as a conceptual framework only and not a tool for modelling the choice of walking. This suggestion is informed by three considerations, briefly discussed below: rationality, consistency, and uniformity.

Rationality. The model assumes that the choice of walking is a rational decision related to a series of inputs relative to the trip and personal circumstances. This assumption possibly underestimates various apparent ambiguities observed in decision-making [313]. These apparent ambiguities relate to vast difference in how people decide, based on the same "inputs", possibly related to different aspirations (e.g., valuing a pleasant commute experience over the travel time, or vice-versa) or personal values (e.g., going to the nursery by bicycle so that the child would experience that mode) [313]. The assumption might also be at odds with the idea of bounded rationality, or: people making decisions despite a lack of complete information, or in complex situations making it impossible to decide in an optimized way [49, 225]. In these cases, people might search for one satisfactory solution instead of the optimal one [49, 225].

Consistency. One defined model, with its interdependencies and weightings, would assume that the choice patterns are constant in time, underestimating within-person changes such as mood, influence of news or personal events (called “noise” by Daniel Kahneman [324]). Some of my interview participants also reported that their perceptions of the ease or pleasantness of their trips, but also their choices of walking or not, could be influenced by states of mind. For instance, Morgan walks back home when she wants to take this extra time (over an hour) as a form of mindfulness exercise. These complexities echo Guell and colleagues’ claim that modal choice cannot be described through theoretical models because these over-simplify complexity and describe the dynamics of social life in a falsely static form [313]. Guell argues that modal choice reflects the "multiplicity and messiness of everyday life" – modal choice is not a purely rational decision based on clean inputs, and is fluid because people keep adapting to the changes in their circumstances [313].

Uniformity. A unique model would assume similarities in decision-making in time, for a given person (as seen above), but also across people. It is however suggested that the order and relative importance of the walking needs might vary across people [53, 147], as do travel needs in general [322]. For instance, an investigation of people’s perceived walkability grouped interview respondents into 11 clusters differentiated by the relative values given to comfort, pleasantness or safety [147]. In the interviews realised, large differences were observed between participants’ reactions to similar objective situations: for instance, Freddie chooses to drive and Jeremy chooses to walk, despite similar inputs (same route and trip purpose, same age, non-disability, availability of a car in both situations).

For these reasons, I argue that while the draft Social Model of Walkability is a useful conceptual framework, it should not be applied to predicting the choice of walking. However, there is much value in focusing on a subset of the problem, namely the relationship between the perceptions of difficulty or non-feasibility and the desired trips not walked. Such focus would target barriers some users face, and help prioritise improvements (i.e., fixing first the “deal-breakers”). That is the pathway taken within this thesis, examining what is perceived as *not* walkable and aiming to understand how it is influenced by the WE, the transport system, and the person-level factors. While the exact weight of those barriers in the decisions not to walk is not known, identifying the barriers remains a necessary pursuit.

Below, an overview of the draft Social Model of Walkability as developed throughout this thesis is presented. Further, relating to the outlined need to assess what is *not* walkable, a model of non-walkability is proposed (p. 253).

Overview of the developed model

The model is presented in Figure 28 below and in the following points.

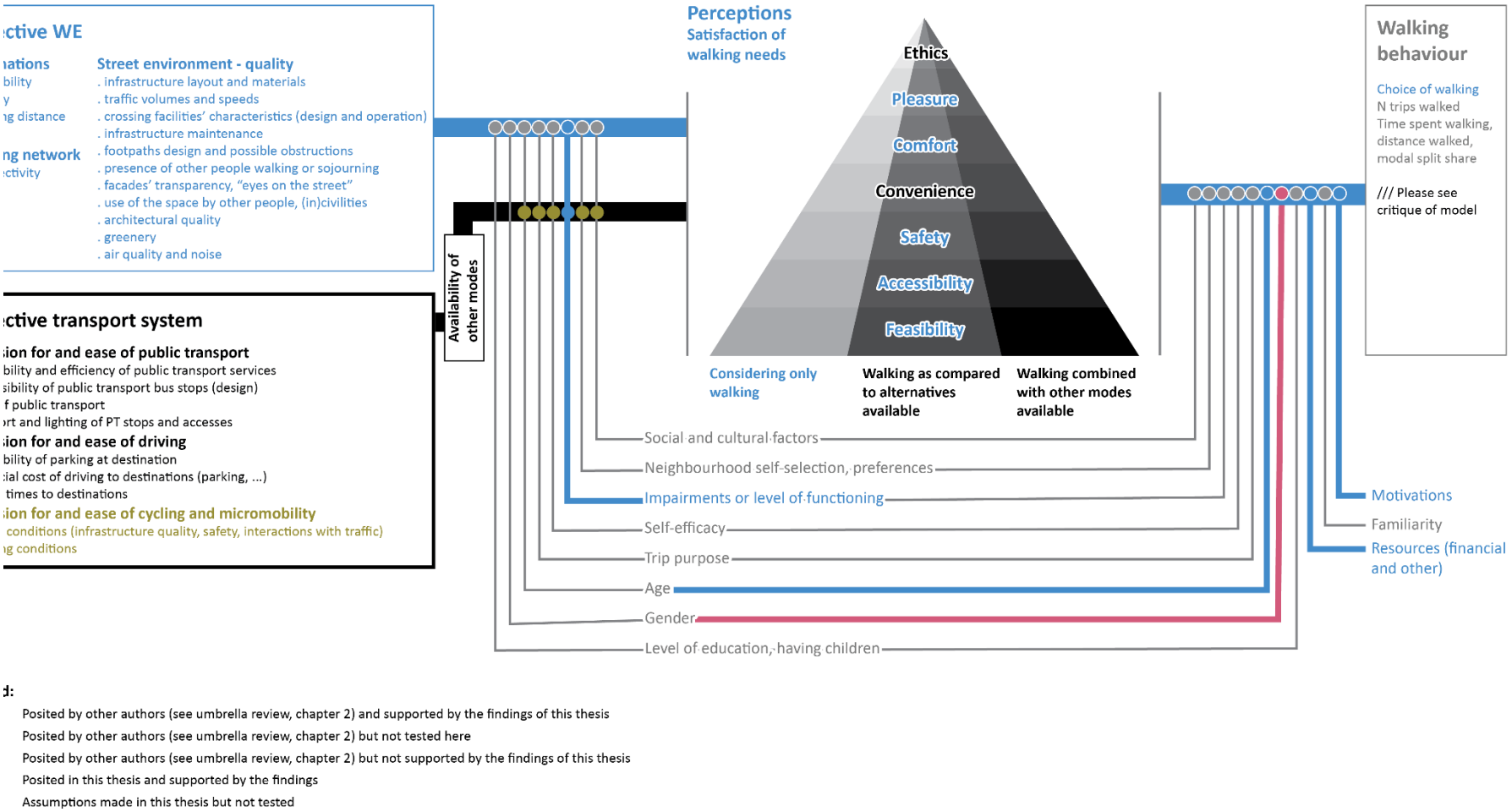


Figure 28: Social model of walkability, as developed through this thesis

Model entities

The components of the model are described below. For each, after a reminder of the initial stage (outcome of the general literature review, Chapter 2), the developments made through this thesis are presented.

Walking environment

Findings from previous research

The WE, objectively measured and encompassing the built environment, the natural features, and the traffic (movement, by any mode), is the first entry variable. Previous model developments [43, 49, 53, 54, 61, 145] distinguished between objective features of the WE and perceived walkability. This split is useful given the understanding that both dimensions relate differently to behaviours [64, 65] but also given the low agreement between the perceptions and measures of similarly defined features [50]. The following quote of one of Mehta's participants illustrates the point:

> *Yes, I prefer to walk on this block. It has character like much of Central Square. But at the same time it is more relaxing. There are places to sit. You can look at people as you go by. People are sitting around and hanging out [and] not just going somewhere. It is not sterile like the next block. [53]*

The participant talks about qualities of WE ("character", "sterile" or "relaxing") and WE features (e.g., places to sit). This raises two challenges: first, understand what objective features of WE relate to perceived qualities. While the participant suggests that the presence of people and their activities contribute to the pleasantness of a place, it is to be determined if there is for instance a certain threshold relative to numbers of people above which a space is considered active, as opposed to "sterile", and how this threshold varies across people? Second, when the participant talks about WE features, it is to be defined how the features *as measured* and *as perceived* relate to each other. For instance, does noticing "places to sit" relate to a number of seats, their distribution in space, a combination of both, or yet another measure? This point is further discussed below, within the link between environment and perceptions.

Interestingly, initial developments tended to associate the perception of feasibility with personal limits, and not WE. Alfonzo noted: "Ultimately, it may be that those who have mobility limitations—temporary or permanent—do not really have the choice to walk." [43]. The testing done by both Mehta [53] and later Buckley and colleagues [54] did not address feasibility, both interviewing people present in the examined street (i.e., for whom the trip had been feasible). However, Buckley and colleagues note that "Feasibility and accessibility focus directly on the individual and ask whether

personal or other limits preclude a walking trip while at the same time relating back to walkability design's infrastructure and connectivity." [54] [added emphasis].

Findings from this thesis

This thesis uses the theoretical framework of the Social Model of Disability [46], defining disability through the barriers encountered in society. From that perspective, feasibility is seen as resolutely associated to the WE and transport system, where barriers are to be identified and addressed so to enable everyone's participation.

The first challenge related to defining the WE features. A list of WE features was first established for coding the findings of the reviews associating WE with walking behaviour (Chapter 2). The list was problematic as it included categories that were not necessarily precise enough or mutually exclusive (e.g., "busy street" coded results from reviews not specifying if "busy" related to traffic speeds, traffic volume, a combination of both, or yet another aspect).

This list was further refined for being used during the consecutive studies (for instance for coding interview data and CS inputs). Refining the list related mainly to defining categories that are specific enough and mutually exclusive. However, although the refined list was a helpful tool for coding data, it is obvious that the identified split is in no way absolute, for two main reasons:

1. **Insufficient description of the quality of the feature and lack of guarantee of a sufficient description** – for instance, it could be argued that the distance to destinations is not meaningful without specifying their quality. Further, distance and quality could interact (e.g., willingness to walk longer towards a more desired destination). There is a balance to be struck between the accuracy of the WE feature and the need to group similar features into categories. It is hypothesised that the diverse choices regarding what is measured and how play a role in the almost systematically poor relationships between features as measured and as perceived [50].
2. **Difficulties to capture holistic environments** – listing environmental features presupposes considering them in isolation, while it is understood that interactions and synergies exist (e.g., considering distance to destination and availability of a shelter against rain separately misses the fact that a sheltered route will appear shorter to those who walk it [325]).

This thesis progressed the characterisation of the WE focusing on the barriers to walking: what they are, how they can be objectively characterised, and how they are formalised in planning documents. Firstly, barriers to walking identified by interview participants were characterised through objective measures (chapter 6). Measures were then compared to the Healthy Streets (HS) methodology [95], considered as an example of best practice, as well as national [93] and local guidelines [94] addressing the design of street environments. The noted misalignment between the characterisation of barriers and the guidelines is discussed against each of the critical features.

Non-signalised crossings. The findings of this thesis suggest that problematic non-signalised crossings should be determined considering simultaneously traffic volume, complexity, and speeds (low complexity can be an issue if high speed, and vice versa). This contrasts with the focus on traffic volumes, in the considered guidance documents. The national guideline provides one illustrative threshold, stating that "On busier roads, kerb extensions and a raised median or pedestrian island can provide excellent safety benefits and a satisfactory level of service at flows above 1500 vehicles per hour." [93]. HS also assesses the appropriateness of non-signalised crossings based on traffic [95], although proposing different thresholds (minimum score for traffic > 1000 vehicles per hour; best score: <200 vehicles per hour).

Eight of the barriers reported by participants had pedestrian islands and traffic volumes lower than the indicated threshold from the national guideline [93]. Participants reported that pedestrian refuges were at best not satisfying and at worst not usable at all (especially true for blind people, unable to predict if a refuge will be available and feeling exposed while standing in the middle of fast-moving traffic). Two problematic crossings would have scored maximum points from the HS methodology. In both cases, findings suggested the importance of the number of traffic movements the pedestrians are exposed to and turning radii. Complexity and turning radii are not discussed in the considered guidelines, despite their importance. Turning radii are associated to higher vehicle speeds [326] but can also mean a lesser mutual visibility between the pedestrian and the driver, if the traffic trajectory is not orthogonal to the pedestrian crossing. Both the traffic speed and the complexity could add to the perceived difficulty and risk.

Traffic along the path. While the national guideline [93] broadly describes motorised traffic as deterrent to walking, it does not provide explicit thresholds regarding traffic volumes and speeds along the path. The sections reported by participants (chapter 5) had traffic volumes above 14,000 vehicles per day, seven times higher than the maximum recommended on local paths, "designed to create safe and pleasant neighbourhoods that encourage walking and cycling for local trips" [268].

Footpath design. All three considered planning documents stress the importance of a pedestrian through route that is direct, unobstructed, wide enough for the pedestrian flows and buffered from walls, kerbs, or street furniture. These recommendations are in line with the findings of the study: participants reported situations where the through route is not direct, not wide enough, and/or not buffered enough from the traffic circulating along. However, the documents do not provide indications regarding route indirectness and buffering against traffic. Further, while they delineate different areas of the footpath (e.g., through route vs furniture area), these area cannot necessarily be visualised or measured on the ground. The findings hint once again towards the complex and multidimensional nature of WE. In the case of footpath widths, I argue that the important dimensions are the traffic along the path and the forced changes of direction for those who walk, due to variety of obstacles. While temporary and permanent obstructions were noted, it could be imaginable that other situations might refer to other aspects, such as maintenance (e.g., the need to avoid a rough spot/uneven ground, especially with a wheelchair [327]).

Holistic car-dominated environments. Places reported by participants were distinguished by an interplay between several variables for which the local guidelines and often the best practice do not provide specific rules or thresholds. Those variables included street width (typically two or more lanes per direction) and/or high traffic volumes and speeds, lack of facade transparency and a lack of pedestrian activity (low surveillance) with long distances between pedestrian crossings, making it difficult to use the other side of the street. The measures indicate potentials for re-thinking the street as a public space in a holistic way. Recent research in Portugal showed an association between an ambitious redesign of the WE and people's experiences [61]. The guidelines do not provide tools and metrics to define which streets would most need this type of intervention.

Absence of people. The guides do not provide thresholds or indications regarding the presence of people and thresholds below which it might be perceived as insufficient. HS assesses the surveillance qualitatively, the best score being given to places with constant surveillance, considering both the oversight from nearby buildings and from other people using the street. It is argued that more specific indications should be given regarding façade transparency and numbers of people in the street, also considering the levels of surveillance over time (are there periods when both metrics are critically low?).

Lighting. The national [93] and local guidelines [94] refer to the lighting standard AS/NZS 1158.3.1 which recommends lighting levels based on pedestrian activity and fear of crime [328]. The issue for identifying areas for retrofit relates to the overall absence of data of both pedestrian volumes and fear of crime. A level of 10 lx is recommended in case of high fear of crime [328]. Three of the four indicated locations had low average horizontal illuminance (1.6 lx and lower) and vast lengths without any light at all except for occasional spillages from nearby houses. The fourth area had a level of 8.1 lx but was described by the participant as being very lonely (railway overbridge), supporting the idea of considering illumination and human presence together [161].

The list of barriers reported should not be considered as complete (for instance, missing or inadequate dropped kerbs have not been assessed because although a participant mentioned this issue, no specific instance was reported and could be investigated). Therefore, it is probable that the characterisations would change with more data points. However, the approach provides a pragmatic way of identifying what is non-walkable in a multi-dimensional way (for instance, non-signalised crossing with turning radii higher than x and number of traffic movements to watch higher than y).

Again, the need to define the outcome should be reminded: if a characterisation is developed so to identify the non-walkable, it cannot be assumed that WE features having characteristics slightly better than those thresholds incentivise walking. Indeed, these features could be "just good enough", but nowhere near what would make people want to walk more or walk instead of choosing another mode.

Transport system

Findings from previous research

Previous research has linked public transport (PT) and driving to walking levels, respectively as a potential enabler [64, 113, 128] and a potential alternative [110, 297, 298]. However, it is interesting to note that the transport system is often missing in research designs and walkability indicators (Chapter 2). The consideration of PT was not systematic, and the measures used were diverse (i.e., not necessarily comparable or adequate). From the seven reviews considered in Chapter 2, four addressed the question of PT [64, 65, 113, 128]. The mentioned however PT in broad terms, such as for instance "access to public transport", without further detail [65]. This aspect raises questions about what is being considered (e.g., does the metric relate to the presence of a PT stop, and if so, within which distance? Is the quality of service considered? Is the relevance of the service available considered, i.e., are only services that help the person get where they need to considered? Are the accessibility to the PT station and vehicle considered?). Barnett and colleagues' systematic meta-analysis [65] showed that the primary studies examining PT (18 identified) examined either the objective or subjective availability of PT. This fundamental difference and the lack of information

regarding the other important aspects raises the concern of considering "availability of PT" as a measure aggregating diverse constructs, more or less relevant to the choice of walking.

The availability of travel options such as driving was also poorly controlled for, and a quasi-absence of assessment of perceived walkability as compared to driving as an alternative was noted (Chapter 2). This is problematic, given the understanding of the convenience of driving as a major "barrier" to walking [110, 223].

Alfonzo's draft model did not formally include the broader transport system as part of the entry variables or outcomes (e.g., trips combining walking and PT) [43]. Similarly, the assessment of the satisfaction of walking needs did not consider the comparative quality of alternatives such as driving [43]. Both Mehta and Buckley and colleagues' testing was done in areas close to high quality PT and noted the importance of the PT stations for the pedestrian traffic observed, without however suggesting the addition of PT is not suggested in the model [53, 54]. Testing different potential motivators for walking, Buckley and colleagues' did not include the access to PT as a potential motivator to walking [54].

Ma and Cao brought the lens of modal preferences as possible moderators of the relationships between O, P, and behaviour [49]. The effect was slight for the association between O and P (e.g., those who prefer driving perceive destinations as less accessible, whereas those who prefer other modes perceive them as more accessible). A strong effect was however noted between perceptions and behaviours [49].

Findings from this thesis

The findings from this thesis outlined the importance of the transport system as both a potentially enabler/incentive and barrier to walking (chapters 4 and 5).

Public transport (PT) was associated with (a) walking levels (the use of PT being the main variable explaining walking levels – chapter 4); and (b) perceived feasibility or convenience of end-to-end trips (chapter 5). Glenn, for instance, appreciated "sailing past the traffic" on her commute to work, for which she did not use her car. Ethel is for her part always in the search of new accessible routes for her daily walks with her husband, and the bus allows them to go walking in other parts of the city. Interview participants also mentioned trips that could ideally be done combining walking and public transport but could be plagued with barriers encountered in the WE or else because of inadequate public transport service. For instance, Nora does not go into the city centre despite having efficient public transport close to home, because "to cross that road you take your life in your hands"; and Kamaal noticed that the structure of the PT network made certain journeys almost impossible (the

network is predominantly radial, with stronger connections to and from the city centre, but few lines connecting outer suburbs). Trip purpose can encourage combining walking and PT even in difficult conditions – for instance Lenny, blind, waits sometimes for 10 minutes to cross the road to get to his bus to work. He mentions that while his wife could drive him, the desire for independence makes him choose this option. Important characteristics of PT discussed were availability, quality of service, access to stations, and to a lesser extent cost.

Driving associated to walking levels (Chapter 4) through the dimensions of convenience, cost, and to some extent ethics (relative to greenhouse gas emissions namely). For non-users of PT, factors such as parking hassle were a predictor of walking levels, suggesting a comparison of the relative benefits of walking and driving. Interestingly, only this group spoke of fun being a motivator to walking. It could be understood that when the walk is not fun (possibly in a car-centred environment), driving might be chosen.

A sequence identified from interviews is:

- Presence of a PT service perceived as useful;
- Assessment of feasibility, convenience or cost of the end-to-end journey, including the access to the PT station, to the vehicle, and the on-board experience;
- Assessment of the feasibility, convenience and cost of the end-to-end journey compared with those of other options available, or decision (is it worth it?) in the absence of alternatives.

This thesis contributed to research by explicitly examining the availability and comparative quality of alternatives in the choice of walking. The findings prompted including the broader transport system in the theoretical model both as entry variables and as lenses for understanding the perception of walking needs (two dimensions were added: perceived satisfaction of the qualities of walking as compared to alternatives, and perceived satisfaction of the end-to-end trip including walking and PT).

Perceived walkability

As noted earlier, previous model developments have positioned perceived walkability as a mediator between objective environment and behaviour [43, 49, 53, 54, 61, 145]. This marks a departure from the issue related to an interchangeable usage of objective and perceived characteristics (chapter 2), ignoring the poor association between the two constructs and the possible important interplay of individual characteristics (chapter 3).

Findings from previous research

The key idea of Alfonzo's initial development of a socio-ecological model for walking was the hierarchy of pedestrian needs (or: perceived walkability) [43]. Alfonzo extrapolated on Maslow's hierarchy of human needs [329], positing that people will assess how their walking needs of different orders are satisfied. In Alfonzo's paper, once the most basic need (feasibility) is satisfied, higher order needs are considered (accessibility, safety, comfort, and pleasurability) [43].

The hierarchy had further been tested and confirmed by Mehta [53], and Buckley and colleagues [54]. Importantly, Mehta suggested that the order of the hierarchy of walking needs might be variable and proposed the addition of two levels of walking needs: usefulness and belonging. Usefulness was presented as a combination of the availability of desired destinations their quality. It can be argued that usefulness is an attribute of the destination and part of what motivates the desire to make a trip (no matter by which mode). As noted earlier, the Social Model of Walkability does not address the process of trip generation. Therefore, the element of usefulness had been included. On the other hand, belonging conceptually relates to the notion of familiarity, identified as an individual characteristic moderating the association O-P [152, 180, 181]. Therefore, the notion of belonging was considered as an individual characteristic.

This important groundwork presented a few discussion points, addressed by other authors and this thesis. These are:

- **An apparently fixed order of walking needs**, which might not be the case across people or at different times, as discussed above (Critique of the model, p. 231);
- **The consideration of qualities of walking in themselves**, and not as compared to those of alternatives, or in combination with public transport, as discussed above (Transport system, p. 238);
- **A dissociation between personal safety and traffic-related safety**, respectively in the levels “safety” and “comfort”;
- **No clear place in the model for the notion of convenience**;
- And importantly **the association of some barriers with users themselves** – Alfonzo noting for instance that “Ultimately, it may be that those who have mobility limitations—temporary or permanent—do not really have the choice to walk.” [43].

The draft Social Model of Walkability embraced the Social Model of Disability in its claim that disability is related to barriers found in the environment, as opposed to being a characteristic of the person [46].

Findings from this thesis: walking experience of usual trips

One of the interview topics were the trips usually walked. Participants were asked about the features of WE encountered and perceived as difficult, unpleasant, or on the contrary enjoyable. The qualities of the WE played a major role in the walking experiences and are discussed below (link between objective and perceived walkability, p. 246).

The studies realised within this thesis overall confirmed the hierarchy of the walking needs and further developed it in two ways.

1. **Two new levels were integrated: convenience and ethics** – convenience relates to the ease of use, while ethics regroups attributes related to making a positive contribution to the society (e.g., walking because it helps reduce traffic congestion or helps protect the environment);
2. **Two new dimensions were added to the hierarchy of walking needs:** (a) the relative qualities of walking, as compared with the alternatives at hand, and (b) the qualities of walking in combination with another mode – typically PT. The two dimensions acknowledge the choice of walking within the broader transport system, a dimension often missing in walkability research (see above, Transport system, p. 238).

Findings supported Mehta's idea that the relative importance of different dimensions could vary across contexts (e.g. car-centred or not) and demographics [53]. The strategies and trade-offs between convenience and safety are an example of those possible changes and were observed both as a difference between participants and in the context of different trip purposes. More research is needed to better understand the importance of individual characteristics, namely disability and constraints, as well as to clarify the role of motivations and habits, possibly influencing choices [152, 180, 181, 225]. It should be examined for instance if individuals concerned about the environment consider the "ethics" level differently than others. This aspect should be particularly important considering societal changes, such as for instance a higher importance given to the environment and readiness to change for the younger population [226].

Link: objective environment – perceived walkability

Both objective characteristics of the WE and of the transport system constitute the objective environment in which walking takes place. This section examines how the objective environment is associated with perceived walkability.

Findings from previous research

The initial model developments by Alfonzo [43] and Buckley [54] are somewhat ambiguous in suggesting that certain perceptions are related to certain environmental features, although the model presents the physical attributes and perceived walkability (affordances) as two separate constructs. Mehta had slightly adapted the model when testing it, clearly separating physical characteristics and perceptions [53]. However, as noted above, while Buckley and Mehta test the importance of certain WE features [53, 54], using interviews implies testing attributes *as perceived*, vs *as measured*, which is problematic given the low agreement between the two constructs [50].

The second umbrella review (chapter 3) specifically focused on the associations between objective features of the WE (O) and perceived walkability (Pw). As mentioned, the findings conceptually aligned with the model, suggesting however a certain level of complexity and evidence gaps.

The complexity related to two aspects. Firstly, individual O features could be associated with several levels of Pw. For instance, street lighting could be associated to both safety [159, 161] and comfort [159], while the crossing conditions (type of crossing and traffic) were associated with accessibility [163], safety [163], and convenience [163, 164]. This finding warns against an observed tendency of deterministically allocating certain features to certain perceptions (e.g.,: lighting and safety), potentially missing their other contributions to walking experience. This aspect further relates to the need to better understand how people perceive the determinants of different levels of Pw, and how this varies across demographics (see evidence gaps, below). Second, the importance of holistic WE quality and ways how specific O features contribute to it was outlined: for instance, shared spaces could be perceived as pleasant or on the contrary unsafe, arguably in relation to their design [165]. Cambra and Moura's recent study of the holistic redesign of one of Lisbon's major pedestrian streets stressed the need of better understanding the roles of and synergies between specific O features, and how these might affect walking experience across diverse people [61].

The evidence gaps related to five aspects important for the future developments of the draft Social Model of Walkability:

1. **Lack of evidence regarding what O features are associated with each level of the hierarchy of walking needs –** finding associated to the general paucity of data regarding walking: while some figures relative to walking levels exist, the diversity of experiences is overlooked, and there is not enough critical understanding regarding how walking environments might associate with positive or negative experiences and how this might vary across people [18].
2. **Insufficient evidence regarding holistic environments** – most of the identified O-Pw associations relate to isolated O features (e.g., pedestrian overbridges associated to ease or difficulty of crossing, or brighter lighting associated with reassurance). This is problematic given the loss of contextual elements that could be important for understanding the associations. In the examples given, this would include the characteristics of the barrier bridged by the overbridge (e.g., width, traffic conditions, availability of alternative crossing) or of the area that is better lit (e.g., oversight from the nearby buildings, or human presence on the street). Assessing holistic environments is particularly important given (a) the rising popularity of holistic interventions such as low traffic neighbourhoods or complete streets; and (b) evidence that these changes can be perceived diversely by diverse groups - in the UK for instance, disabled people warned of the strong polarity created by low traffic neighbourhoods across demographics, an aspect possibly overlooked by the designers [321].
3. **Lack of certainty regarding what characteristics of O features should be measured and how** – as described above.
4. **Insufficient reporting on the measures** – as noted in the general literature review, there is a large variety in the definitions of O features, the ways how they are captured, and the perimeters where they are measured. The diversity makes aggregation challenging, but the absence of detail also induces an additional and unnecessary element of uncertainty.
5. **Insufficient reporting of individual, trip-related and social characteristics** – the identified reviews did not systematically report on characteristics known to or expected to influence O-Pw associations. There was namely a lack of reporting on disability which is problematic because it can lead to clustering together very different O-Pw associations (e.g., a non-dropped curb might not be noticed by a non-disabled person but perceived as a barrier by a wheelchair user). Reporting on disability should acknowledge diverse needs within this group, namely related to type and level of disability and mobility device used [16, 24]. Other important aspects include age [122], trip purpose [16, 221, 330], availability of options [142, 223], modal preferences [49, 250], or geographical and social contexts [311, 313].

The findings outline the complexity related to associations between objective features and people's experience of their environment, aligning for instance with Johansson and colleagues' finding that different people walking same routes had different perceptions of urban design qualities and different affective experiences [331]. The authors deduced that "at individual level, the association between built features and walking is not straightforward" [331]. Evidence retrieved suggested an important and urgent need to better understand these associations, especially for those most likely to suffer most from environmental barriers. This need echoes previous findings, in New Zealand [13, 20] and elsewhere [18, 62, 332].

Findings from the interviews and the assessment of the walking environments

Interviews (chapter 5) provided insights into the associations between environmental features and (a) walking experience; and (b) perceived barriers to walking. The barriers to access (named critical features) were further objectively characterised (chapter 6). Thus, the association between objective characteristics and perception of non-feasibility was tested.

Traffic volumes, speeds and traffic-oriented infrastructure were generally associated to difficulty and/or unpleasantness for participants of all ages, disabled or non-disabled. These findings align with previous evidence identifying traffic as a potential stressor and deterrent to walking [131, 253, 254], especially in conjunction with infrastructure built to process high traffic volumes [20, 62, 122, 255]. Footpaths surface and obstructions were also often noted, especially (but not exclusively) by older and disabled participants. Findings suggested that disabled people are more immediately preoccupied by barriers to access. Recent evidence from Auckland reported strong negative outcomes on older and disabled people, including an altered relationship to place, isolation from social networks, and reduced independence [20].

The interview did not ask participants to rate their perceptions of safety on the trips walked, nor to indicate features that could be seen as unsafe. This choice was made to avoid priming participants. However, several participants spontaneously declared that some barriers were not necessarily difficult or unpleasant, but rather unsafe. There was a palpable sense of stress related to interacting with traffic. While practitioners might perceive pedestrian distraction as a safety issue [252], my participants rather displayed high levels of vigilance and strategies for dealing with complicated environments and avoiding or mitigating danger. This tendency was sometimes counter-balanced by trade-offs, non-disabled participants describing taking risks (for instance crossing away from a formalised crossing) to avoid a lengthy detour. Disabled participants and some of the non-disabled participants would on the contrary describe high levels of compliance and strategies for alleviating risks. Blind people in particular put a lot of effort into memorising routes and making tactical choices (e.g., making an important detour to cross using a zebra crossing instead of a casual crossing close to

a roundabout; or taking a bus for part of a walking trip that would take only 10 minutes, for the sole purpose of avoiding crossing a specific road). These strategies align with previous findings, for instance from Smith and colleagues, having noted a high mental burden and complicated arrangements made by disabled youth living also in Auckland [41].

Participants identified six types of environmental barriers to walking, named critical features. The identified critical features[18] were unsurprising in the light of the previous literature (chapters 2 and 3). It was interesting to note that a given feature (for instance non-signalised crossing) can be a barrier to access for some participants, while "only" difficult or unpleasant for others, not deterred from walking the trip despite that feature. As discussed above, findings suggest that the association between critical features and perceived feasibility was moderated by disability and trip purposes. If at least one interview participant identified a feature as non-walkable (chapter 5), all the instances of that feature were measured, regardless of if participants identified the instances as difficult or impossible. This choice acknowledges that if a fit and non-disabled person identifies a feature as difficult, that same could be a barrier of access to someone else.

Commonalities were found and thresholds of "non-walkability" were suggested for each of the six critical features. Interestingly, as noted, these thresholds did not always correspond with design guidelines or best practice. For instance, critical non-signalised intersections were characterised by (a) traffic volumes; (b) turning radii as a proxy for the speed of cornering traffic; and (c) complexity, measured by the number of movements a pedestrian is exposed to. Best practice [95] and local design guidelines [93, 94] put emphasis on traffic volumes, missing crossings that can be difficult because of a complex and fast context. It was also observed that the considered planning documents aim at describing the ideally walkable, while our investigation was aiming at the most non-walkable.

The list of barriers examined should be considered as partial: it considered only WE features that were (a) reported by participants; (b) relative to usual or unmade trips; and (c) specifically geo-located (for instance, intersection between street X and street Y). The list of examined barriers did not include certain features that had previously been identified (for instance, absence of curb cuts [16, 24]). It is also understood that beyond environmental barriers, disabled people's trips can be riddled with numerous other difficulties such as ableist attitudes, inaccessible public transport, or inadequate information [41, 216, 279]. The interview questions (chapter 5) focused on environmental features, reason why these other attributes were less discussed.

[18] Non-signalised crossings, footpaths width and obstructions, high traffic volumes, traffic-oriented streets, lack of light, and absence of other people walking

Individual characteristics

Findings from previous research

Alfonzo's initial model development [43] placed individual characteristics as moderators of the relationship between physical environment and walking behaviours. The model was developed in order to present a holistic view of the environmental and life-cycle related influences on walking behaviour [43]. Alfonzo noted that health research had focused on individual characteristics while planners examined predominantly physical environments [43]. However, in both approaches, she saw the risk of oversimplifying a complex process and providing results that are not useful or meaningful. She noted that "Examining [life-cycle variables] separately as independent predictors or determinants of walking […] leads to an overly simplistic model of the factors that affect a person's decision to walk. Placing these variables into a social-ecological model and treating them as interprocesses or moderators in the decision to walk creates a more complete, dynamic framework within which to investigate their effect on physical activity." [43] The principle of informing individual differences was a key recommendation from Gebel and colleagues, writing about the improvement of the quality systematic reviews in this field [143]. Interestingly, as noted above, Alfonzo treated disability separately to other individual characteristics, seeing it as a potentially inherent limitation to walking [43].

Previous studies further tested the model, considering diverse individual characteristics [49, 53, 54, 61, 145]. They considered motivations [49, 145], familiarity with the area [53, 54]; gender, level of education, family structure, age [49, 145]; availability of drivers' license and motor vehicle, level of income [145] and modal preferences [49]. Only one study noted having included disabled participants [61], without however providing insights regarding possible moderating effects.

Individual characteristics were indicated as moderators of the associations O-P and P-w. **Associations O-P** were moderated by modal preference [49]; gender, age, and family structure [49, 145]; [49, 145]; availability of drivers' license and motor vehicle, and level of income [145]. Level of education moderated the association in one of the two studies that examined it [49]. **Associations P-w** were moderated by modal preference and level of education [49].

When examining the walkability literature (Chapter 2), it was noted studies' design or reporting were often not appropriate for testing the draft Social Model of Walkability. Indeed, as previously suggested [143], reporting against individual differences is inconsistent and overall poor, especially for disabled people (Chapters 2 and 3), and the available evidence does not provide a full picture of how different characteristics might moderate the relationship between the WE and walking.

Findings from this thesis

This thesis applied some caution regarding using **individual characteristics**. Indeed, the risk of using individual characteristics as proxies appears real: for instance, gender might be a proxy for differences in income, availability of private vehicles, or more local and complicated travel patterns. Similarly, using old age as an explanatory variable runs the risk of considering as homogenous a group that contains a higher proportion of disabled people than the general population [77], but also fit or relatively fit non-disabled people. For London for instance, TfL's comprehensive investigation into the experiences of diverse communities showed multiple associations between gender, age, income, or being part of an ethnic minority [278], supporting the caution relative to the selection of individual characteristics. With most of the evidence on associations between WE and walking being cross-sectional (chapter 2), evidence consists of correlations, without indications of causation. Attention is therefore needed for selecting variables that could at least conceptually have a causal effect on walking levels. Age, gender, or ethic group were voluntarily omitted from this group of possible moderators, given the risk that these variables are in fact proxies for underlying causes (e.g.,: financial situation, availability of vehicle, disability, or being in charge of children).

In the draft Social Model of Walkability, the individual characteristics moderate both relationships between O and P and between P and decisions. This double moderating role is important and different to implicit assumptions of studies associating WE directly to walking behaviour. However, the relative potency of different characteristics and their potential interplays remain to be verified. Singleton noted that "*People of similar age, gender, or income may share similar travel values and make similar travel decisions; older people may be more likely to walk than to cycle. However, there is still considerable individual variation in such travel decisions"* [322].

Disability was a particular focus in this thesis, given the high but insufficiently understood barriers to walking (chapter 2) and the noted dearth of data regarding O-P associations (chapter 3). Interestingly, very few studies comparing the perceptions of walkability of disabled and non-disabled participants were identified.

Interviews provided important insights in this regard (chapter 5). Disabled participants were more likely to talk about environmental qualities in terms of the most basic pedestrian needs, feasibility, accessibility, or safety, while non-disabled participants could report similar environments in terms of (un)pleasantness. This finding aligns with results from Meher and colleagues, who identified that infrastructure causing fear or stress for disabled people could go unseen by non-disabled people [20]. The authors stressed "the need to shift from approaches focusing primarily on individuals avoiding risks of injuries to one appraising and remediating features of built environments that create highly burdensome risks in ableist societies" [20].

This thesis is however limited in its consideration of disability: the number of participants did not allow to formally analyse differences between different groups of disabled people (by type and level of disability, but also by mobility aid used). The cohort did not include deaf people, and few neuro-divergent people. Recently, Colombo-Dougovito and colleagues noted for instance that the voices of autistic people remain largely unheard, which is an important issue, understanding that they can face barriers largely different to those experienced by people with motor or sensory disabilities [333]. Similarly, diverse types of neuro-divergence, depressive syndromes, or cognitive disabilities should be considered as specific moderators of the relationships between environments and walking behaviours. Previous evidence noted for instance depression as an insufficiently understood moderator [334] but a risk factor of social exclusion [335].

Familiarity and habits were implicitly controlled for, given that the interviews focused only on usual trips. For that reason, the barriers reported can be assumed to be significant to the participants: they remain salient even though located on usual routes, well known and walked potentially “on auto-pilot” [18]. While familiarity and habits are understood to influence modal choice but also to moderate relationships between objective and perceived environments (see above), Harms and colleagues’ review of associations between route familiarity and behaviour noted that evidence was poor and inconclusive regarding perceptions or risk [121].

Outcome

At the initial stage, the outcome was a relatively broad vision of walking behaviour: Alfonzo imagined the choice, duration, and type of walking [43]; further, authors tested the choice of routes [53, 145] and the choice of walking (declared motivations of those who had made it [54]; observed modal choices and their associations with perceptions and preferences [49]; or observed pedestrian volumes [61]).

This thesis examined several different outcomes: (a) dichotomised walking levels (no walking for transport or five and more walked trips in the previous week – chapter 4); (b) choice of walking in general or for specific trips (chapter 5); and (c) reasons for not choosing walking for accessing destinations perceived as desirable and within walkable distance (chapter 5). The reasons for *not* walking were seen as particularly interesting, in the effort of understanding barriers and therefore priorities of retrofit.

The model can be used as a framework for understanding different walking behaviours. However, it is suggested that the structure and the relative importance of the modules might vary depending on which outcome is chosen. For instance, the choice of walking can be associated to aspects contributing to pleasantness (e.g., aesthetics or visual appeal as noted in the interviews and by other authors [54, 336]). However, the choice of *not* walking can rather relate to the non-satisfaction of more essential needs such as difficulties of crossing the road (interviews and [20, 41, 62]. These extreme differences should be seen within the context of the variety of moderators of the O-P-w sequence, namely related to diverse geographies, trip purpose, or availability of alternatives, discussed below.

Link: perceived walkability and walking behaviour

This link between perceived walkability (Pw) and walking behaviour is in reality a series of links, depending which outcome (behaviour) is considered: choice of walking, choice of not walking, route, frequency, distance, etc. As mentioned above and identified through the quantitative analysis (chapter 4) and interviews (chapter 5), different outcomes are likely to be triggered by different perceptions.

The thesis provided insights relative to the relationships between Pw and (a) the choice of walking / walking levels; and (b) the choice of not walking to desired destinations within a distance perceived as walkable.

The walking levels choice of walking or walking levels were examined within the quantitative analysis of the associations between Pw and walking levels (chapter 4, analysis of secondary survey data), and the interviews (chapter 5: interviews, examining the reasons and context of the modal choice).

The overall motivations for walking expressed by interview participants were consistent with previous findings and with the model. Namely, the participants mentioned internal motivations [54, 246, 247]; the qualities of the walking environment [53, 54, 65, 248]; the broader transport system, considering the comparative convenience of walking relative to other modes [110, 222, 223] or the lack of choice). The results align the key importance of broader transport system identified previously (chapter 3), despite the apparent absence of PT in the responses, as the interviews trips from origin to destination. Therefore, when people reported trips combined walking and PT (typically commute trips, with the associated high frequency), the choice could have been expressed in terms of lack of alternative (for instance driving) or comparative advantage of walking *and* PT as opposed to driving.

The relative absence of destinations availability could seem at odds with previous findings, explored in the general literature review. However, when participants noted the convenience of walking to their destinations, an idea of proximity was implicit. It can also be assumed that the topic might not have been top of mind for participants who all lived in areas with relatively high WalkScore ™ values. The lack of mentions of habits [152, 247] could for its part be explained by the status quo bias: habitual choices tend to be preferred, probably because cognitively easier [152, 181, 250].

A model of non-walkability

Following from the critique of the model above and the aim to provide insights relative to the improvement of the WE, a model of non-walkability is suggested. The model uses the framework of the draft Social Model of Walkability but examines negative potential outcomes, namely:

- Trips within walkable distance not walked, but made using another mode
- Trips within walkable distance foregone
- Walked trips resulting in negative experiences (e.g., stress or difficulty)

The model is presented in Figure 29 below. The left hand side (WE and transport system) now includes a subset of the possible features, or: those that can discourage from walking or induce negative walking experiences.

The draft model of non-walkability summarises the barriers to walking identified in this thesis and the interplay of individual, trip-related, and social characteristics. I posit also that the three outcomes of non-walkability are useful guides for both research and practice. Acknowledging the absence of some potential walkers, in the street (those who drove or stayed at home for instance) prompts the design of studies that engage with these individuals, aiming to better understand their deterrents, as well as the difficulties experienced by those who walk. The outcomes are also a challenge for practice: indeed, they imply that pedestrian counts are not a sufficient metric, given that they do not provide information on numbers of people who do not walk, experiences of those who do, or aspects that might be associated with the choice of not walking or poor walking experience. There is a large scope in capturing current levels of service through the experience of those present and investigating the reasons of omitted walking trips.

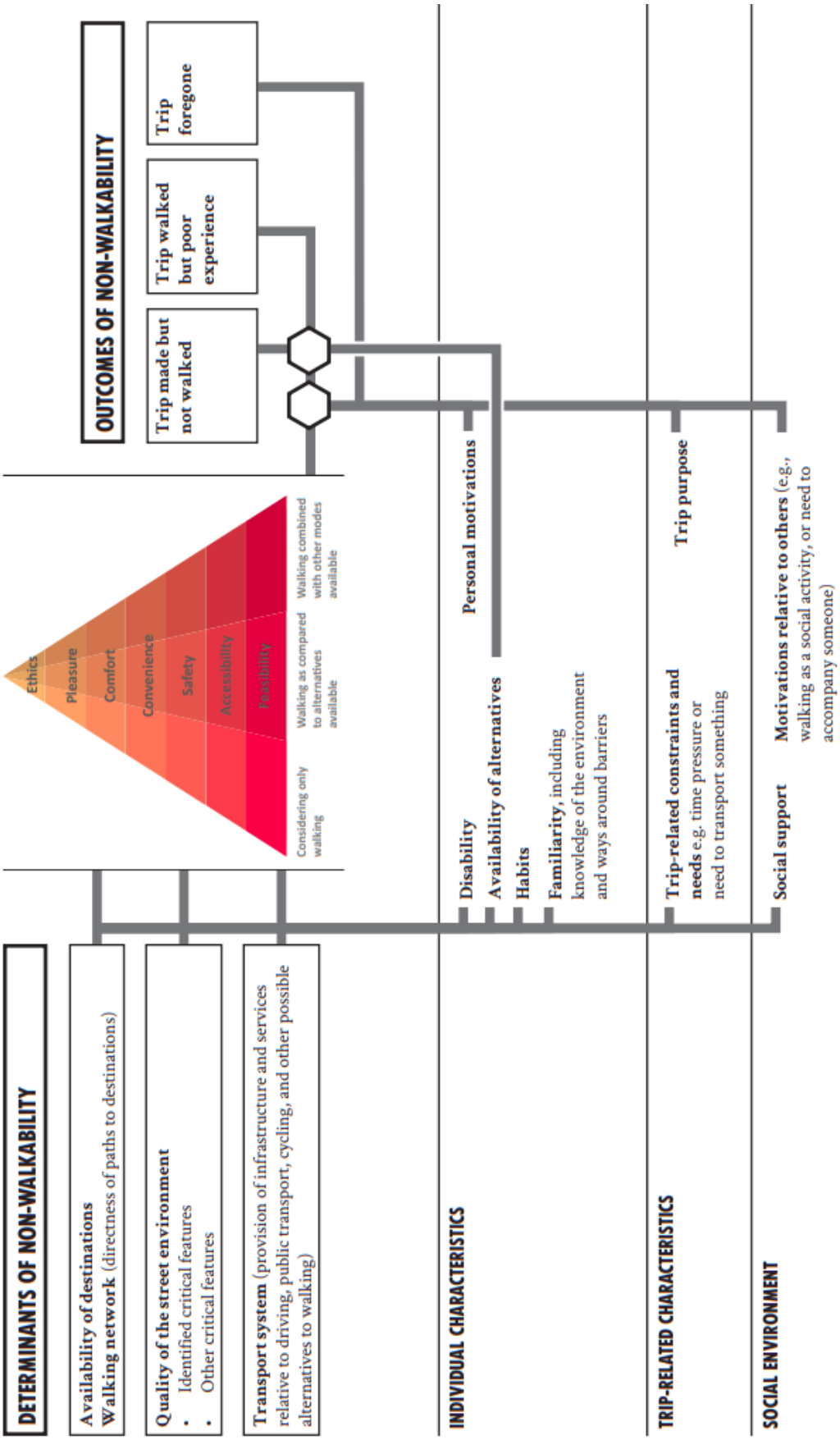


Figure 29: Draft model of non-walkability

PART 4: POTENTIALS FOR CHANGE AND FUTURE RESEARCH

This thesis identified some interesting potentials regarding building more walkable cities, from the perspective of both professional practices and research.

Professional practice

The retrofit of inherited, car-oriented environments is a necessary step towards urban areas that support walking, rely less on carbon-intensive travel, and improve public health and inclusion. This thesis has outlined several levels of complexity relative to improving the walking realm, namely:

- The general lack of consensus regarding what walkability is and therefore how to improve it (chapter 2)
- WE as a complex socio-technical system, involving diversity of actors, regulations, people, and technologies, and subject to external forces (chapter 7)
- A diversity of professional disciplines involved in the delivery of the WE and a lack of shared data and knowledge regarding users' walking experience (UX) and barriers encountered (chapter 7)
- A low level of political priority for improving walkability, further linked to insufficient data collection, tokenistic engagement, inadequate understanding of UX and lack of consideration of UX in funding decisions (chapter 7).

There are however timely opportunities and potentials. Firstly, Waka Kotahi / New Zealand Transport Agency (Waka Kotahi) acknowledges (a) the opportunities to decrease car reliance by providing better facilities for walking and cycling, and reducing the amenity of driving; (b) reprioritisation of street space as an efficient intervention in this regard and can be cost-effective (tactical urbanism); (c) the need for land use to contribute to reduce the need of cars in urban areas [36]. Second, Waka Kotahi has launched a program to support financially rapid and low-cost temporary street transformations aiming at improving UX for walking, cycling, and sojourning [304]. Third, Auckland has embraced Vision Zero in its aim to tackle the road trauma crisis the city is facing [337]. Vision Zero aligns with a street retrofit reducing traffic speeds and increasing the safety and amenity of walking [337]. Fourth, the Government's recent decision to drastically reallocate transport funds in favour of walking, cycling and public transport, within the plea of decarbonizing the transport system [338]. Fifth, the imminent instigation of an Accessibility Act, addressing the accessibility of NZ public spaces and buildings [339].

The findings suggest the need to test how urban retrofit is evidenced and delivered in a multidisciplinary way. Three main strands of action are suggested:

- **Aligning budgets and decision-making processes** to reflect the strategic priority of transforming the built environment to support active modes and public health. Namely, budgets allocated to the improvement of the walking realm should be proportional to the task, and decision-making should include metrics relative to the elimination of barriers and improved user experience. This task should be the responsibility of the Ministry of Transport, in collaboration with Waka Kotahi.
- **Mapping out the needed data** and commissioning its collection and future maintenance. Three types of data are needed: **(a) mapping of locations and potency of barriers to access**; these data should result from an automated network scan based on locally defined thresholds relative to perceived barriers (continuing the work started in this project – chapter 5); **(b) mapping of the potentials for walking**, or: expected intensity of local trips, calculated using a tool such as Space Syntax [190]; **(c) current walking levels**. The overlay of the potency of barriers to access and the potentials to walking can provide a prioritisation for intervention.
- **Strengthening multidisciplinary approaches, at all levels.** Recently, the New Zealand Infrastructure Commission suggested the incoming Minister of Infrastructure fosters coordination between ministries delivering infrastructure, but underlined that this role was not a requirement [89]. Such coordination should be explicitly included in Ministers' portfolios. Further, national summits on walking could serve as a platform for professionals of multiple disciplines involved at different decision-making level as well as for academics to meet and exchange.

Realising those tasks would require continuing the work started in this project, namely: collecting insights from a larger number of users of all ages and abilities, using a diversity of mobility aids, and refining the definition of barriers based on those insights.

Future research

The findings from this thesis suggest an urgent need of a systemic approach to walking, as suggested in the socio-ecological model. In line with the Social Model of Disability, a range of built barriers to walking were identified, suggesting that those disabled by the WE are a much broader group than the users of visible mobility devices.. As indicated in this thesis the first priority should be around **defining the non-walkable** or characterising through specific measures those environmental features that diverse people report as barriers to access. Taking the perspective of the model, the non-walkable is defined by people, and expected to vary across people. Future research should build a continue to build a solid **understanding of users' needs** and expectations, and how these might vary across individual, social, and trip-related characteristics. Participatory methods are recommended as a way forward, as previously recommended by Andrews and colleagues, amongst others [63]. Such approaches have been developed and implemented by the consumer market with the success we know, in the last decades [19, 144].

It is also urgent to recommend **ways of measuring WE attributes, experiences, and individual factors**, in a way that is implementable but avoiding damageable over-simplifications. This work should be done by an international group of experts, potentially in the format of a working group related to the Walk21 conference (similarly to the ongoing work done regarding measuring walking behaviour).

Within this thesis, machine learning was used for finding patterns in a large dataset including pairwise associated variables (chapter 4). It could be imaginable to use the method to identify characteristics of barriers to walking, based on a larger dataset containing a range of potential explanatory measures for aspects considered as non-walkable. This aligns with Cambra and Moura's reflection that even though a large scale holistic improvement is associated with both higher walking experience and higher walking levels, the relative importance of different aspects and ways it varies across people need to be understood [61].

PART 4: STRENGTHS AND LIMITATIONS

This thesis had six main strengths. First, it was comprised of studies designed as a sequence, each building on the previous ones and developing the theoretical model. Second, the thesis helped develop a draft Social Model of Walkability, expanding it namely by explicitly adding the wider transport system as an input variable and perceptions of walking *as compared to* alternatives or *in combination with* public transport. Third, a critical perspective was taken on the applicability of the model, its limits and potentials. Four, the identified associations between objective features of the WE and walking behaviour considered the mediating effects of perceptions or the moderating effects of individual, social, and trip-related characteristics. The findings responded therefore to a noted research gap relative to the lack of context of previous associations between objective WE features and walking behaviours. Five, experienced barriers to walking were investigated triangulating participants' insights gathered through interviews, Citizen Scientists' inputs, observations and surveys of the built environment. Finally, local planning guidelines and the Healthy Streets assessment tool were critically examined based on the barriers as perceived by people and measured. This analysis indicated gaps relative to the scopes and the content of these technical documents.

This thesis also had important limitations. Firstly, using umbrella reviews probably resulted in omissions of findings, namely relative to the associations between objective features of the WE and perceptions. Second, interviews were structured, possibly limiting and orienting participants' insights. While the interviews provided information on the type of environmental features that people struggle with, the findings lack nuance regarding the characteristics of those features. This limitation could be overcome by future studies examining how (combinations of) environmental attributes associate with low perceived walkability across diverse people. Third, the number of interview participants did not allow to talk about differences between different disabilities, mobility devices used, and age groups. No deaf participants were recruited, and participants included for instance only one blind person using a guide dog, only one manual wheelchair user and one electric wheelchair user. This limitation is significant as it suggests that only aspects of the breadth of people's experiences was captured. More evidence is needed regarding how people of different age groups, with different types and levels of disability, using different mobility devices and with different habits and backgrounds experience their environments. This research would certainly bring additional insights regarding aspects that can cause difficulties to some people and the consequences of those difficulties. Fourth, the quantitative analysis, analysis of barriers and professionals' insights related to data from one city (Auckland), claims cannot be made about other environments. Findings aligned with previous research and it is suggested that they could be applicable to other car-

dominated cities, however more evidence is needed to back this claim. The above recommendations regarding future research should be realised in diverse urban areas, especially those where barriers to walking are expected to be important (namely cities with important traffic-oriented infrastructure). Fifth, the professionals' survey involved 28 participants, a relatively limited number especially considering that different subgroups/professions were targeted. Therefore, the findings are not representative of the professionals involved in the design of the WE or dealing with its outcomes. The low number also limited the ability to contrast the views across disciplines. More evidence regarding the underlying reasons of disagreements would be helpful and useful for supporting multidisciplinary understanding and collaboration. From the academic perspective it could maybe lead to an "urban systems designer" curriculum, covering namely urban design, transport systems, and public health. Sixth, only four Citizen Scientists participated in the thesis research. It is imaginable that a larger number of Citizen Scientists, with different ages, abilities, and backgrounds, would have contributed slightly different insights. The low number of Citizen Scientists implies that the findings offer only a limited insight into the diversity of associations between environments and walking experiences. It is recommended future research involves people of diverse ages, abilities, and backgrounds, in the gathering and analysis of insights relative to barriers and facilitators to walking.

CHAPTER 10: CONCLUSION

In the context of global heating, urgent solutions are needed to transition away from fossil fuels by changing day-to-day patterns such as travel. Walking has wide-ranging and now well established benefits related namely to environmental impacts, public health, inclusivity, or efficiency in terms of costs and space consumption. However, *how* to create more walkable cities and retrofit inherited car-oriented environments is still debated.

This thesis sought to better understand environmental barriers to walking in car-centric urban environments. Three key dimensions of interest shaped the investigation. Firstly, the negative impacts the walking environments can have on walking experience and the choice of walking. Second, how walking experiences and barriers to walking vary between disabled and non-disabled people. Thirdly, how walkable environments are delivered by different professional disciplines involved in the design and retrofit of urban environments and public health. Departing from a large and growing body of research examining enablers and facilitators of walking, focus was intentionally put non the *non*-walkable, defined by characteristics of the walking environment that present difficulties or barriers for at least some users.

The thesis was framed within two theoretical frameworks: firstly, the Ecological Model of physical activity, in its assumption that the choice of walking is related to diverse dimensions of influence, including built environment, policies, individual and social characteristics [44]. Second, the Social Model of Disability, understanding disability as a range of barriers people encounter around them, and not an inherent personal characteristic [47]. Disabled people are understood as a diverse group experiencing diverse barriers [24, 340]. “Walking” was understood as encompassing any mobility aid a person might need. Walking environment (WE) is understood as a complex phenomenon including built environment, green infrastructure, human presence, and traffic.

Given the existing volume of research on walkability and the noted lacks of consensus, this thesis first examined critically how walkability is understood and conceptualised (chapter 2). This work outlined five key aspects that informed the following studies: (a) walkability is a contested phenomenon; (b) walkability is inconsistently measured; (c) people’s experiences tend to be overlooked; (d) different people can have diverse needs and experience a wide range of potential barriers, which are insufficiently understood; and (e) a promising theoretical model linking WE and walking as a behaviour was drafted.

A theoretical model was identified and developed. The initial literature review identified the promising work in this direction by Alfonzo [43], further tested and adapted by several teams [49, 53, 54, 61, 145]. The model (named here Social Model of Walkability) links objective features of the WE to perceived walkability and walking behaviour, with moderating effects of individual, social, and trip-related characteristics. The consideration of the Social Model of Disability prompted placing individual characteristics as a moderator, and not (as suggested by some authors) as an inherent limitation of movement. Considering disability as an avoidable social construct, the thesis resolutely looked towards improving the environment, and not changing the people.

The identified draft Social Model of Walkability formed the theoretical backdrop of this thesis. The understanding of the research context of walkability (chapter 2) was used in the design of a specific umbrella review (chapter 3) and empirical studies (chapters 4 to 8) examining:

- **The link between objective WE characteristics perceived walkability**: through a specific umbrella review (chapter 3); interviews (chapter 5, asking people of diverse ages and abilities what might be difficult, unpleasant, or enjoyed); environmental survey (chapter 6, informing objectively the environmental barriers indicated by interview participants); and Citizen Science (chapter 8, relating Citizen Scientists' inputs with the reported features).
- **The link between perceived walkability and walking as a behaviour**, through a quantitative analysis (chapter 4, examining secondary data from Auckland Transport's Active Modes Survey [83]) and interviews (chapter 5, asking people of diverse ages and abilities why they choose to walk or not to specific destinations).
- **Individual characteristics as moderators,** through a quantitative analysis (chapter 4, examining the importance of demographic characteristics in predicting walking levels) and interviews (chapter 5, examining differences between experience lived by disabled and non-disabled participants).
- **(Dis)agreements between professionals working in different disciplines relative to the design and operations of WE or public health** regarding people's needs, priorities of retrofit, and challenges relative to delivering quality WE (chapter 7; online survey and focus group further exploring underlying patterns).

The findings from the interviews illustrated the diversities of lived experiences, similar features prompting diverse responses in different people in different contexts. Interestingly, across ages and disabilities, participants had negative feelings to report regarding traffic and traffic-related infrastructure, suggesting that addressing these barriers can benefit a broad range of people. In line with previous research, disabled participants appeared to struggle with variety of systemic issues of the WE associated with the most basic walkability needs (feasibility, accessibility, and safety) and

experience a high mental burden of traveling. Circumstances were important, and necessary trips could prompt to walk despite high barriers, while optional trips could be foregone.

Results obtained from Citizen Scientists' contributions supported the previous findings and showed the potential of participatory action research to reveal "micro" aspects of the WE and their cumulative importance on experiences. This thesis was also the first to our knowledge to involve blind Citizen Scientists in an app-based data collection, an experience that proved extremely rich both in terms of findings and practical inputs (namely: accessibility barriers of the smartphone app used to record the insights).

Associating interview findings and objective measures of the built environment proved a powerful combination, allowing to trace back experienced barriers to walking to specific environmental characteristics. The results were useful to reality-check the appropriateness of planning guidelines and best practice for identifying barriers to walking. It is suggested that the planning documents might not be well adapted to identify the "worst of", or most salient barriers to walking, in order to prioritise retrofit.

Engaging with practitioners in charge of delivering walking environments or dealing with their consequences offered important insight into challenges regarding the delivery of better adapted environments and (dis)agreements on users' needs and priorities. Challenges included both regulatory and cultural systemic challenges (insufficient understanding of users' experiences, a lack of political priority given to walking, a lack of systemic and multidisciplinary approaches, and a disconnect between investment decisions and user experiences). A vicious circle perpetuating these blockages and preventing the necessary action to retrofit urban environments for walkability was identified. The results were consistent with previous findings and provided specific insights for a future systemic approach to walkability.

The studies provided key insights both from the theoretical and practical perspectives. The findings helped develop the Social Model of Walkability and outline pragmatic take-aways for the practice. Major developments were proposed for the Social Model of Walkability, explicitly adding: (a) the transport system; (b) the relative dimensions of perceived walkability (as compared with alternatives and combined with public transport); and (c) two extra levels on the hierarchy of needs (convenience and ethics). The addition of the transport system also called for explicitly considering the relevance of alternatives to walking or public transport as a companion mode (e.g., regardless the roading network, does the person have a drivers' license and a car available to use?). A critique of the model was presented, suggesting its use as a flexible framework and not a tool designed to predict walking behaviour. The importance and relevance of focusing on the non-walkable were however stressed, and a model of non-walkability, linking WE barriers to negative walking outcomes, was drafted.

It is recommended future research further develops the draft Social Model of Walkability and the model of non-walkability through three main suggested investigation strands: (a) **the characterisation of the non-walkable** examining the people's perspectives and the differences across individual, social, and trip-related characteristics; (b) a **better understanding of people's perceptions:** how they are influenced by the WE, how they influence walking behaviour and how these associations vary across individual, social, and trip-related characteristics; and (c) the **development of methodologies relative to measuring WE attributes, experiences, and individual factors**, in a way that is implementable but avoids over-simplifications that could undermine the results.

The challenge for the practice is also important, and work is necessary on three fronts, policy, governance, and implementation. On all three levels, priorities should relate to a multidisciplinary approach; metrics relative to the pursued strategic goals such as accessibility or better walking experience (investment prioritisation and performance tracking); trials improving street environments (funding allocation, implementation, efficient monitoring and evaluation, shared learnings) and empowerment of diverse citizens as decision-makers, taking inspiration from pioneer programmes such as Model Cities [318].

Important potentials exist for rethinking and transforming car-centric cities in ways that decarbonise day-to-day travel patterns, support walking, promote health, facilitate participation and equalise opportunities for people of all ages and abilities. Improved walkability is part of the solution. Both research and practice should prioritise an evidence-based improvement of walking environments rooted in a multidisciplinary and systemic approach.

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APPENDICES