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Local food environments for a healthy equitable city: evidence to inform urban planning policy and governance in Melbourne, Australia

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Abstract

Obesity is a major public health challenge and a risk factor for many non-communicable diseases. Further, inequities in the distribution of obesity and diet-related disease across populations are also of concern. Spatial access to food outlets may influence dietary intake and diet-related health outcomes, however the evidence is inconsistent and inconclusive. Key methodological challenges that may contribute to inconsistent findings include the heterogeneity of food environment access measures and choice of geographic scale.

This thesis investigated spatial access to food outlets and associations with dietary intake and body mass index (BMI) in Melbourne, Victoria, Australia; a city experiencing rapid population growth and suburban development. The aims of this mixed methods research were to conceptualise and develop local food environment indicators to inform urban planning policy and practice, and to identify governance actions to advance healthy, equitable local food environments within cities. A new conceptual framework was developed to guide the analysis, which offers utility for future research.

Population survey data for 3,128 adults were analysed to examine associations between access to supermarkets and fast food chains, dietary intake and BMI. Quantitative analysis showed that food outlet access varied across socio-economic areas and across urban-growth and established areas of Melbourne. Supermarket density within 800 m and 1000 m was protective of BMI for respondents residing in high disadvantage areas, whereby BMI decreased as supermarket density increased. In established urban areas, fast food chain density within 800 m and 1000 m buffers was associated with higher BMI, whereas the relative density of supermarkets to supermarket and fast food chain outlets within 800 m and 1000 m was associated with lower BMI. The latter is consistent with the hypothesis that a greater proportion of supermarkets to food outlets overall is associated with healthy weight.

Spatial analysis identified low socio-economic areas where limited access to supermarkets was compounded by public transport disadvantage. The findings highlight the variation in the local food environment at the intra-city level, which has implications for urban planning policy and practice. A more nuanced understanding of the intra-city variation has potential to guide and

target urban planning policy interventions to specific geographic areas, where health and access inequities exist.

Key stakeholder interviews with 27 government, non-government and private sector policymakers and practitioners from the portfolios of urban planning, public health and urban economics were conducted in Melbourne. Using health governance frameworks as an analytic lens, the qualitative data contextualised and explained the quantitative results. While government, non-government and private sector stakeholders have a role in influencing food environments, responsibilities were dispersed. Therefore, modifying the local food environment for improved health outcomes requires coordinated and comprehensive governance action, including urban planning and design policy, partnership development, and leadership from multiple levels of government and sectors.

Based on the quantitative and qualitative analysis, spatial indicators of the local food environment to guide urban planning policy and practice were conceptualised and developed, filling a research gap. In the Australian context, three spatial measures have potential as local food environment indicators for assessing and monitoring food environments. These are: i) supermarket density within 800 m; ii) fast food chain density within 800 m; and iii) relative density of supermarkets to supermarket and fast food chain outlets within 800 m. The indicators are supported by recommendations to translate research findings into policy and practice.

Rapid population growth concentrated in cities is a global challenge, linked to increases in diet-related diseases including obesity. However, urban planning policy and governance actions have the potential to improve population health outcomes and to reduce the inequitable distribution of diet-related non-communicable disease. This thesis therefore contributes to evidence to inform urban planning policy and governance for healthy local food environments.

Changing the local food environment for improved health and health equity requires integrated action across multiple levels of government and sectors, including civil society. This thesis provides direction and suggests recommendations on the way forward for research, policy and practice to advance healthy, equitable local food environments within cities.

Declaration

This is to certify that:

- the thesis comprises only my original work towards the PhD except where indicated in the preface;
- due acknowledgement has been made in the text to all other material used; and
- the thesis is fewer than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.

Date: 13 August 2018

Preface

Within this thesis I have included four peer-reviewed journal publications that comprise part of thesis chapters.

In each paper I was first author, reviewed the literature, formulated the research question and study design, conducted the analyses and drafted the manuscript. My co-authors provided input into the study design, interpretation of the results and editing the manuscript. My research contribution is indicated below each paper.

All work included in this thesis was carried out after my enrolment as a higher degree research candidate. I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and contains no material previously published or written by another person, except where reference has been made in the text.

Peer-reviewed publications arising from Doctoral thesis

1. Murphy, M., Badland, H., Koohsari, M. J., Astell-Burt, T., et al. (2017). Indicators of a health-promoting local food environment: a conceptual framework to inform urban planning policy and practice. *Health Promotion Journal of Australia*, 28(1), 82-84.

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   Academic contribution: Murphy, M. (80 %)

2. Murphy, M., Koohsari, M. J., Badland, H., & Giles-Corti, B. (2017). Supermarket access, transport mode and BMI: the potential for urban design and planning policy across socio-economic areas. *Public Health Nutrition*, 20(18), 3304-3315.

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   Academic contribution: Murphy, M. (80 %)

3. Murphy, M., Jordan, H., Badland, H., & Giles-Corti, B. (2018) Local food environments: Australian stakeholder perspectives on urban planning and governance to advance health and equity within cities. *Cities & Health*, *2*(1), 46-59.
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   Academic contribution: Murphy, M. (85 %)

4. Murphy M., Badland H., Jordan H., Koohsari, M.J., Giles-Corti B. (2018). Local food environments, suburban development and BMI: a mixed-methods study. *International Journal of Environmental Research and Public* 2018, 15(7), 1392
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   Academic contribution: Murphy, M. (85 %)

Peer-reviewed conference presentations arising from Doctoral thesis

1. Murphy M., Badland H., Koohsari M.J., Astell-Burt T., Trapp G., Villanueva K., Mavoa S., Davern M., Giles-Corti B. (7-9 September 2015). Conceptualising urban planning policy-relevant indicators of the local food environment. *Population Health Congress*, Hobart, Australia.
2. Murphy M., Koohsari M.J., Badland H., Giles-Corti B. (2-7 April 2017). Inequities of Food Access and Obesity Risk in Urban Melbourne: Opportunities for Urban Planning Policy. *World Congress on Public Health*, Melbourne, Australia.
3. Murphy M., Jordan H., Badland H., Giles-Corti B. (26-29 September 2017). Governance for healthy equitable food environments within rapidly urbanising cities. *International Conference on Urban Health*, Coimbra, Portugal.

I would also like to acknowledge Esmé Murphy for her proofreading assistance with this thesis, in accordance with Parts D and E of the Australian Standards for Editing Practice. Proofreading covers spelling, punctuation, tense, grammar and usage, all in the interests of clarity and readability.

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I would like to acknowledge the great contribution, scholarly support, guidance and generosity of spirit of my three supervisors Professor Billie Giles-Corti, Associate Professor Hannah Badland and Dr Helen Jordan, and of former supervisor Dr Mohammad Javad Koohsari. I also extend my sincere thanks to my PhD Advisory Committee: Professor Margaret Kelaher, Associate Professor Rebecca Bentley and Dr Lukar Thornton. I was fortunate to benefit from the combined expertise and experience of some of the greatest place-based, built environment and food environment researchers and epidemiologists during my PhD research, and greatly appreciate their intellectual rigour, insights and encouragement.

I acknowledge the contribution of the Australian Government Research Training Program Scholarship. For three and a half years it provided me financial support that enable me to pursue these studies. I also acknowledge the contribution of the NHMRC Centre of Research Excellence in Healthy Liveable Communities. By being part of this broader research program, I was able to access wider resources and support that otherwise would not have been available. I would particularly like to thank Rebecca Roberts and Dr Suzanne Mavoa for GIS advice, and Dr Koen Simons and the Statistical Consulting Centre for statistical advice.

There are former PhD students and researchers from the Place, Health and Liveability program to thank, including Melanie Lowe, Geoff Browne, Claire Boulange and Lucy Gunn. In the broader PhD student community at the Melbourne School of Population and Global Health, I would particularly like to recognise the support and friendship of Lila Moosad and Allison Yates, and the diligent Graduate Research Officer, Myra Hoad.

While undertaking this PhD, I continued to work one day a week at the Victorian Department of Health and Human Services. I have truly benefited from a culture that supports flexibility of employment, while also fostering leadership and academic pursuit.

Thank you to the qualitative interview participants for your time, insights and effort.

Finally, I would like to thank Dr Richard Lane and Lillian Lane Murphy for enduring this PhD journey with me. Both of you have been so patient and supportive, have been excellent research assistants and travelled along with a lot of encouragement, understanding and humour.

Glossary of acronyms

ABS	Australian Bureau of Statistics
AustLII	Australasian Legal Information Institute
BMI	Body Mass Index
CATI	Computer Assisted Telephone Interviewing
DHHS	Department of Health and Human Services (Victoria)
FFQ	Food frequency questionnaire
GIS	Geographic information systems
GPS	Global Positioning System
IRSD	Index of Relative Socio-economic Disadvantage
LFE	local food environment
LGA	local government areas
MAUP	Modifiable Areal Unit Problem
MB	Mesh block
PHS	Preventive Health Survey
PWC	Population-weighted centroid
SA1	Statistical area level 1
SA2	Statistical area level 2
SSB	sugar-sweetened beverage
WHO	World Health Organization

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Chapter 1. Introduction

The places in which we live have an impact upon our health and wellbeing (Macintyre and Ellaway, 2000). In the 19th century, cities were transformed by industrialisation and unprecedented population growth. As cities grew, poor sanitation, contaminated water and overcrowded housing led to outbreaks of infectious disease (Corburn, 2007, Leon, 2008). The nexus between urban form and public health became evident in the mid-19th century, when the spread of cholera was linked to a public water pump in London. Following the removal of the water pump handle by the physician John Snow, the number of deaths declined (Snow, 1855). Over time, urban planning and design emerged to play a critical role in safeguarding population health through the design and construction of urban sewerage and water supply systems, the introduction of building codes and decent housing, and the establishment of urban parks and playgrounds (Corburn, 2007, Perdue et al., 2003).

In 21st century cities, urban form and public health remain inextricably linked, but the key challenges to population health are no longer communicable diseases (Rydin et al., 2012, Giles-Corti et al., 2016). According to the World Health Organization (WHO), non-communicable diseases account for 71 per cent of all deaths worldwide, with the majority caused by cardiovascular disease, cancer, respiratory disease, and diabetes (World Health Organization, 2018). High body mass index (BMI) is a leading global risk factor for non-communicable disease, and it is a growing risk across countries at all stages of economic development (G.B.D. Risk Factors Collaborators, 2017). Among potential drivers for overweight and obesity are increased availability and accessibility of energy-dense foods that have contributed to habitual excess energy intake, while at the same time there are decreased opportunities for physical activity (G.B.D. Risk Factors Collaborators, 2017). These drivers are linked to the built environment, broadly defined as the structures and places, made or modified by humans, in which human activity takes place (Rao et al., 2007, Planning Institute of Australia, 2009).

More than one half of the world's population now lives in cities, with projections that the trend towards cities will continue such that by 2050 more than two-thirds of the global population will be urban (United Nations, 2018). Today, the challenge is to gather the evidence that will inform urban planning so that the burden of non-communicable disease in rapidly growing cities can be

reduced. This thesis explores this issue, specifically examining how access to food outlets influences dietary intake and BMI for those that reside in urban areas, while seeking to identify opportunities to improve diet-related health outcomes and health equity within cities.

1.1 The built environment, health, and health equity within cities

The social determinants of health and health equity are terms which reflect the conditions in which people are born, grow, live, work and age (Commission on Social Determinants of Health, 2008). While access to affordable nutritious food, transport, employment and social support are among the 'upstream' factors that influence health that operate at a macro or environmental level (Marmot and Wilkinson, 1999), access to these resources is not evenly distributed within cities. This can manifest as health inequities: those differences in population health outcomes that are avoidable and unjust (Commission on Social Determinants of Health, 2008, World Health Organization, 2010).

Evidence across high-income countries suggests that there are socio-economic inequities in dietary intake. It has been shown that diet-related diseases including obesity, and health outcomes are socio-economically patterned; that is, the lower socio-economic groups experience worse outcomes than the higher socio-economic groups (Marmot, 2010). Some studies have shown that low socio-economic areas have poorer access to 'healthy' food outlets, and greater access to 'unhealthy' food outlets (Beaulac et al., 2009). Therefore, disparities in access to health and unhealthy food outlets exist may contribute to inequities in dietary intake and diet-related diseases including obesity, and health outcomes. Consequently, there is a growing interest in understanding how the spatial distribution of built environment resources, such as food outlets, is associated with health and health inequities (Kawachi and Subramanian, 2007, Macintyre, 2007).

Geographic information systems (GIS) can be used to investigate these associations by generating spatial measures of the local food environment, which are small geographic areas in which people shop for food within a walkable or short driving distance from home (Morland, 2015b). GIS enables an analysis of the spatial patterning of food outlets and their potential influence on dietary intake and diet-related health outcomes (Thornton et al., 2011b).

It is important to understand how built environments can influence health and healthy equity at a neighbourhood-level within cities as the first step towards identifying the urban planning and

design policy interventions that are required to create health-promoting local food environments, and thus improve health outcomes and ameliorate inequities.

1.1.1 The built environment in an Australian context

The context for this research is Melbourne, Australia; however, the approach and findings are relevant to other rapidly growing cities in high-income countries.

Australia has a population of over 24 million people (Australian Bureau of Statistics, 2017). Over the next 30 years Australia's population is projected to increase by almost 12 million, with 75 per cent of this growth to occur in four capital cities, Sydney, Brisbane, Perth and Melbourne (Infrastructure Australia, 2018).

The Melbourne metropolitan region is experiencing rapid growth, with a population of 4.5 million across 31 local government areas (LGA), including six urban-growth areas in municipalities on the urban boundary (Department of Environment Land Water and Planning, 2016a). It is expected that Melbourne's population will almost double to 8.0 million by 2051 (Department of Environment Land Water and Planning, 2016a).

1.2 Local food environments, dietary intake, and BMI within cities

Many studies have investigated how local food environments influence dietary behaviour and health outcomes, hypothesising that access to healthy food outlets is protective of health, while access to unhealthy food outlets is detrimental to health (Black et al., 2014, Caspi et al., 2012b, Rahmanian et al., 2014, Cobb et al., 2015, Zenk et al., 2015). The evidence for associations between access to food outlets, dietary intake and weight outcomes is inconclusive, however, and is limited in several ways.

Methodological challenges that may account for inconclusive findings include the heterogeneity of food outlet access measures used across studies (Caspi et al., 2012b, Black et al., 2014, Giskes et al., 2011), and the modifiable areal unit problem (MAUP), which describes the variation in results when analyses are undertaken at different spatial scales (Openshaw and Taylor, 1979). Geographic scale is an understudied area in local food environment research (Barnes et al., 2016a). Furthermore, differential associations may arise between local food environments and dietary and weight outcomes across population sub-groups and across socio-economic areas within cities (Feng et al., 2010, Powell and Han, 2011, Leal and Chaix, 2011, Zenk et al., 2015).

Local food environments may matter more for those with access to fewer resources, particularly where public transport and/or private vehicle access is limited.

In the context of rapid urban growth, it is also important to understand how patterns of suburban development influence local food environments, and dietary and health outcomes, but the evidence in an Australian context is limited. This research aims to fill this knowledge gap. Rapid population growth can lead to uncontrolled urban expansion, sprawling low-density residential development, and reduced access to healthy food (World Health Organization, 2016a). Urban sprawl may affect dietary intake by increasing the distance to food outlets (Lopez, 2004); in high-income countries, car-dependency and urban sprawl are associated with overweight and obesity (Ewing et al., 2014, Mackenbach et al., 2014). Local food environments may differ across areas of varying residential density and suburban development, perhaps leading to varying associations with dietary intake and BMI (Ahern et al., 2011, Congdon, 2017).

Methodological challenges and understudied research areas need to be investigated further to provide more robust evidence about spatial measures of the local food environment associated with optimal dietary and health outcomes across varying urban environments. A more nuanced understanding of the variations in local food environments at the intra-city level is required to inform urban planning policy and practice and hence to support healthy, equitable local food environments.

1.2.1 Spatial measures to inform urban planning policy and practice

Engaging policy makers in making sustainable changes to improve the food environment has been identified as a gap by the food environment literature (Anderson Steeves et al., 2014). Caspi and colleagues (2012b) note that it is not enough to simply characterise the food environment, recommending that more work be done to link these characteristics to public health outcomes. Lytle (2009) argues that public health requires reliable, valid food environment measures that have utility across different populations and health concerns . Mills (2014) calls for urban planning law reform in Australia to ensure its capacity to support public health priorities such as obesity prevention.

Consistent local food environment spatial measures associated with optimal dietary and health outcomes are required to inform interventions to improve population health and reduce inequities within cities; and research is also required that identifies the pathways that enable translation of the spatial measures into a policy and practice environment.

Accordingly, this study thesis aims to fill a research gap by conceptualising and testing food environment measures to identify a set of consistent spatial metrics associated with optimal dietary and health outcomes across socio-economic areas and across areas of varying suburban development. Quantitative and spatial research is used to develop spatial metrics to inform urban planning policy and practice, and to assess and monitor local food environments within cities. The qualitative research component seeks insights from policy-makers and practitioners to identify opportunities to improve local food environments.

1.3 Research aim and questions

The aims of this research were to conceptualise and develop local food environment indicators to inform urban planning policy and practice, and to identify and make recommendations for governance actions to advance healthy, equitable local food environments within cities.

There were five research questions developed to investigate these aims:

1. How does the local food environment influence dietary intake and health outcomes in an urban adult population aged 18 years and over?
2. Is there spatial patterning of food outlet access, dietary intake and health outcomes across socio-economic areas, and across urban-growth and established areas of Melbourne, Australia?
3. What spatial measures of the local food environment are associated with individual-level dietary intake and health outcomes, and how can they guide urban planning policy and practice?
4. What contextual factors influence the availability and accessibility of food outlets in urban areas of Melbourne, a city experiencing rapid growth and suburban development?
5. What are the governance barriers and opportunities to support the development of a healthy, equitable local food environment?

1.4 Delimitations of the thesis

There were boundaries that defined the scope of this research.

First, the study focused on accessibility and availability of food outlets in the residential environment using GIS access measures. The assessment of food outlets did not consider the price, placement or promotion of food within the 'in-store' food outlet environment, nor did it

consider non-residential food environment exposures, such as the environment around workplaces or schools (Glanz et al., 2005).

Second, the analysis uses objective GIS-based measures of the local food environment. By contrast, other food environment studies have used subjective, or perceived measures of the food environment based on surveys and self-report data (Caspi et al., 2012a, Barnes et al., 2015).

Third, the study only focused on supermarkets and fast food chains.

Fourth, the study focuses on an adult population in an urban environment of a high-income country, and therefore the generalisability of findings may be limited; specifically, the study was situated within an Australian context.

1.5 Structure of the thesis

This thesis adopts a mixed methods study design, incorporating quantitative, spatial and qualitative data collection and analyses, as depicted in Figure 1.1. (For a more detailed depiction with specific methods utilised, refer to Figure 4.1).

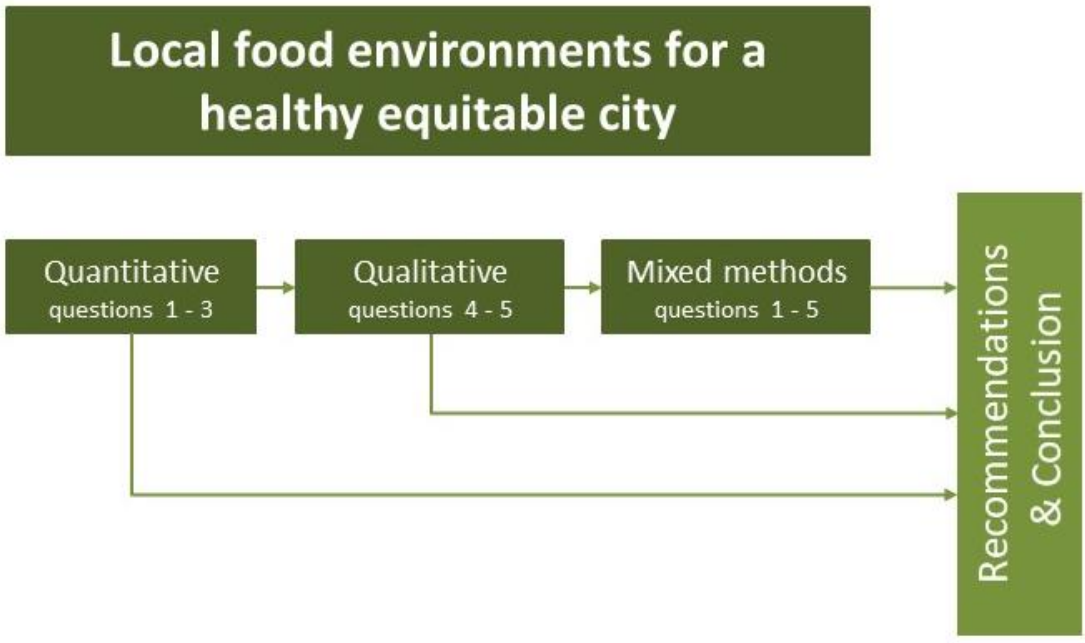

Figure 1.1. Structure of thesis

Chapter Two examines two relevant bodies literature in order to develop the rationale for this research. First, it reviews the determinants of dietary intake and diet-related diseases including

obesity, and health outcomes in cities, incorporating an equity perspective, and draws predominantly on adult studies in high-income countries. Major limitations and gaps in the body of research are identified. Second, it reviews the literature on urban planning and policy interventions to support the development of health-promoting local food environments. In the context of rapidly growing cities and suburban development, there is a knowledge gap associated with spatial metrics to inform urban planning policy and governance opportunities to advance healthy local food environments.

Chapter Three develops the new conceptual framework that guides the research analysis by describing the potential pathways from urban planning and other government policies to dietary behaviour and health outcomes. The conceptual framework was published in the *Health Promotion Journal of Australia* (accepted 6 May 2016) in an article titled 'Indicators of a health-promoting local food environment: a conceptual framework to inform urban planning policy and practice' (Murphy et al., 2017a).

Chapter Four outlines the mixed methods study design and the rationale for adopting quantitative and qualitative research approaches. A mixed methods approach was adopted to provide a comprehensive investigation of each research question, and to facilitate translation of the research findings into urban planning policy and practice.

Chapter Five presents the quantitative methods, followed by Chapter Six that outlines the results of the quantitative analysis stratified by area-level disadvantage. This analysis provides insights about achieving healthy and equitable local food environments through urban planning policy and practice. Part of the results were published in a paper titled 'Supermarket access, transport mode and BMI: the potential for urban design and planning policy across socio-economic areas' (Murphy et al., 2017b) in the journal *Public Health Nutrition* (accepted 24 July 2017).

Chapter Seven introduces the theoretical lens for the qualitative study, describing the qualitative methods utilised. Chapter Eight presents results from the qualitative data examining urban planning policy and governance to support local food environments. It includes a paper, 'Local food environments: Australian stakeholder perspectives on urban planning and governance to advance health and equity within cities' (Murphy et al., 2018b) published in the journal *Cities & Health* (accepted 16 August 2018).

Chapter Nine explores the relatively unknown research area of local food environments, BMI, and suburban development in an Australian context, drawing on quantitative and qualitative data and analysis. The results were published in a paper, 'Local food environments, suburban development and BMI: a mixed-methods study' (Murphy et al., 2018a) in the *International Journal of Environmental Research and Public Health* (accepted 22 June 2018).

Chapter Ten contextualises the thesis findings by considering relevant literature, and discussing the strengths and limitations of the research, as well as the implications for policy and practice, and future research. It includes a set of recommendations for government and other stakeholders. Chapter Eleven concludes the thesis, summarising and integrating the findings in relation to the research aims and questions, and outlining the contribution to knowledge.

1.6 Significance of this research

This thesis makes theoretical, empirical, and methodological contributions to local food environment research.

The key theoretical contribution is the application of ecological approaches (Sallis et al., 2008, Glanz et al., 2005, Story et al., 2008) to the development of a new conceptual framework. This describes urban planning and other government policy pathways from built environment attributes that influence dietary intake, through to weight status and long-term health outcomes. Hence, the framework seeks to conceptualise how urban planning policy decisions influence the built environment, in turn affecting dietary intake and diet-related diseases including obesity, and health outcomes.

The thesis contributes to an understanding of the importance of considering geographic scale in local food environment research. Further, it investigates geographic scale for different food outlet types, dietary intake and BMI across socio-economic areas and across established and urban-growth areas within cities. The thesis therefore provides empirical evidence in relation to spatial thresholds associated with optimal health outcomes, which can inform urban planning and design policy and practice within cities. For the first time, the extent of implementation of a Victorian urban planning policy on supermarket access is assessed. The thesis generates new evidence on urban planning policy implementation and transport access across areas of varying socio-economic status and suburban development.

Adopting a mixed methods research design, the thesis uses a governance for health theoretical lens (Kickbusch and Gleicher, 2012, Ruger, 2011) to identify urban planning and governance opportunities for translating empirical research findings into practice. A key methodological contribution is the embedded knowledge translation and exchange approach that incorporates government, non-government and private sector stakeholder perspectives. This approach enables the development of recommendations to government and non-government agencies in support of health-promoting, equitable local food environments. The thesis provides new evidence to inform urban planning policy, identifying opportunities for governance actions to translate research findings into the policy and practice environment to advance healthy, equitable local food environments within cities.

Chapter 2. Literature review

2.1. Introduction

A large body of literature discusses the multiple individual, social and environmental factors that contribute to dietary and health outcomes and inequities. This chapter provides the context for this study by synthesising and critically appraising the research. There are six areas of relevant literature that provide the background for this study.

First, the chapter begins by reviewing the evidence on dietary intake and non-communicable disease from an equity perspective. This section demonstrates that dietary and health inequities are substantial global challenges that have also been documented in the Australian context. It provides the rationale and motivation for this research to advance healthy local food environments for population health and health equity. Second, the chapter reviews ecological frameworks for health, which posit policy and built environments influence dietary and health outcomes. Applying an ecological framework is useful for understanding the multiple individual, social and environmental factors that contribute to dietary and health inequities, and for offering a structure for identifying interventions points to advance healthy local food environments. Third, the chapter focuses attention on local food environments. The literature on access to food outlets in high-income countries is reviewed, with a focus on variations across socio-economic areas and areas of varying suburban development within cities. The fourth section of the chapter reviews and appraises the extensive literature on associations between access to food outlets, dietary intake and diet-related health outcomes in high-income countries. Due to the large number of studies, this section focuses on key systematic reviews. Following this appraisal of the literature, the fifth section identifies inconsistencies and research gaps in this body of research. Methodological approaches and challenges to measuring food access are presented, along with the current state of the evidence. Sixth, the chapter concludes with a review of built environment and policy interventions to improve local food environments and dietary intake.

2.2. Dietary intake, obesity, and non-communicable disease

A healthy diet and an adequate supply of nutritious, affordable food are essential for good health outcomes (Wilkinson and Marmot, 2003). At a fundamental level, high BMI is caused by

the energy imbalance between dietary intake, physical activity and sedentary behaviour (Butland et al., 2007). In 2011-12, less than 4 per cent of Australian adults were meeting dietary guidelines for vegetable consumption of approximately 5 serves per day, an average decline of 10 per cent since the previous survey in 1995 (Australian Bureau of Statistics, 2016b); however, one quarter of Australian adults met the guidelines for fruit consumption of two serves per day, a similar proportion as in the 1995 data (Australian Bureau of Statistics, 2016b). Consumption of vegetables is associated with a reduced risk of weight gain, has a protective effect on cardiovascular disease, and reduces the risk of stroke and some cancers (National Health and Medical Research Council, 2013). Daily fruit consumption is protective against cardiovascular disease, and is associated with a reduced risk of obesity, weight gain and some cancers (National Health and Medical Research Council, 2013). Dietary risks are related to habitual dietary patterns low in fruit, vegetables, legumes and whole grains, and high in processed meat, sugar-sweetened beverages, sodium and trans fatty acids (G.B.D. Risk Factors Collaborators, 2017). According to the Global Burden of Disease Study 2016, dietary risk was a leading risk factor for death and disease, with diets low in fruit of particular importance (G.B.D. Risk Factors Collaborators, 2017). The study also identified high BMI as one of the fastest growing and leading risks for disease and death across low- and high-income countries (G.B.D. Risk Factors Collaborators, 2017).This literature demonstrates that diets high in vegetables and fruit are important for good health and reduced BMI. Dietary patterns high in fruit and vegetables have been shown to displace energy dense nutrient poor foods and are therefore associated with lower overall energy intake (National Health and Medical Research Council, 2013).

Dietary risk and high BMI are not evenly distributed in Australia. In 2011-12, 63 per cent of Australian adults were overweight (35%) or obese (28%), up from 56 per cent in 1995 (Australian Bureau of Statistics, 2013c). A higher proportion of women living in the most disadvantaged areas were overweight or obese (64%) compared with the least disadvantaged areas (48%), while higher proportions of men and women living in rural and remote areas were overweight and obese when compared with those living in major cities (Australian Bureau of Statistics, 2013c). The Australian Burden of Disease Study 2011 found that people in the lowest socio-economic quintile experienced overweight and obesity disease burden at a rate 2.3 times greater than those in the highest socio-economic quintile (Australian Institute of Health and Welfare, 2017). Moreover, Walls and colleagues (2012) estimate that obesity prevalence in Australia is expected to increase from 20 per cent in 2005 to 34 per cent by 2025. However, obesity prevalence for secondary-educated Australian adults will rise to 44 per cent compared

with 30 per cent for tertiary-educated Australian adults (Backholer et al., 2012). Similar social patterning of obesity has been observed in other high-income countries (McLaren, 2007, El-Sayed et al., 2012).

According to the Australian Burden of Disease Study, adult overweight and obesity is a risk factor for 11 types of cancer, and for cardiovascular disease, kidney disease, diabetes, dementia, gall bladder disease, gout, back pain and osteoarthritis (Australian Institute of Health and Welfare, 2017). Obesity has also been identified as a risk factor for depression (Australian Institute of Health and Welfare, 2012). Social gradients have been found in every disease: the lowest socio-economic groups experienced the highest burden, while the sharpest gradient was found for diabetes, kidney disease and heart disease (Australian Institute of Health and Welfare, 2017).

Fruit and vegetable consumption also follows a social gradient. In Victoria, Australia, self-reported survey data shows that the proportion of women not meeting both daily fruit and vegetable consumption guidelines decreased as household income increased, and that a significantly higher proportion of tertiary-educated women met vegetable guidelines and fruit guidelines, compared with all women (Department of Health and Human Services, 2017b). Additionally, a significantly higher proportion of rural women met vegetable guidelines compared with all women. Among men there was less variation; however, a significantly lower proportion of men who spoke a language other than English did not meet both guidelines compared with all men (Department of Health and Human Services, 2017b).

Social gradients in weight were also found among Victorian adults. Using self-reported height and weight, 30 per cent of Victorian adults were estimated as overweight and 19 per cent as obese, but significantly lower proportions of tertiary-educated men or women were obese, and a significantly lower proportion of women with a household income greater than $100,000 were obese (Department of Health and Human Services, 2017b). Additionally, a significantly higher percentage of rural adults were obese compared with adults living in metropolitan areas (Department of Health and Human Services, 2017b). However, it should be noted that the use of self-reported height and weight is a limitation and a potential source of error (Nyholm et al., 2007, Rowland, 1990).

The National Health and Medical Research Council's Australian Dietary Guidelines were developed based on an assessment of the evidence for dietary patterns to promote health and protect against diet-related disease. These guidelines highlight the priority of achieving and

maintaining a healthy body weight, consuming a diet high in fruit and vegetables, and limiting consumption of energy dense nutrient poor foods high in saturated fat, added sugar or salt (National Health and Medical Research Council, 2013). Improving dietary intake and reducing overweight and obesity can reduce the burden of non-communicable disease.

The next section presents the major theoretical frameworks for understanding factors that influence health, with a focus on environmental, social and individual factors that influence dietary intake and diet-related diseases including obesity, and health outcomes. In chapter three these theoretical frameworks are applied to inform the development of a new conceptual framework for local food environments to guide urban planning policy and practice.

2.3. Ecological models and theoretical frameworks for health

Ecological models of health depict the factors that influence behaviour at the intrapersonal, interpersonal, organisational, community, environmental and public policy levels (Sallis et al., 2008). They have therefore been applied to identify intervention points for behaviour change by targeting multiple factors across multiple levels of influence (Sallis et al., 2008). Central to ecological models is the framing of individuals as being embedded in families, communities, societies and populations; and the concomitant understanding that health is determined by both 'compositional' factors that relate to the characteristics of individuals, and 'contextual' factors that describe the broader influence of the micro- or macro-environment on individuals (Kawachi et al., 2002).

The places in which we live have an impact upon our health (Macintyre and Ellaway, 2000) Further, the conditions of daily life associated with the places where people are born, grow, live, work and age are determinants of health and health equity (Commission on Social Determinants of Health, 2008). In their seminal work on the social determinants of health, Marmot and Wilkinson (1999) identified access to affordable, nutritious food alongside other 'upstream' determinants including transport, employment and fair work, stress, early life conditions, social support and social exclusion. Such social determinants are the upstream causes of poor health; as such they provide direction for developing interventions to reduce the population disease burden through preventive action. The Commission on Social Determinants of Health (2008) recognised the importance of place on people's health, recommending upstream action to promote healthy and safe behaviours through urban planning for active transport and healthy eating.

2.3.1. Ecological models for dietary behaviour

Ecological models have been applied to healthy eating, describing upstream determinants and more proximal interpersonal and intrapersonal influences on health behaviours. Glanz and colleagues (2005) proposed a conceptual model that described the policy and environmental factors and individual factors that influence dietary behaviour. The model depicted *environmental variables* (refer Figure 2.1) as acting directly on dietary behaviour, or by acting through demographic, psychosocial, or perceived environmental intermediaries (Glanz et al., 2005). They identified the *community nutrition environment* as the type, location and accessibility of food outlets within neighbourhoods; the *organisational nutrition environment* as food availability in the workplace, home, school, and other settings; the *consumer nutrition environment* as the affordability, promotion and placement of food within the food outlet; and the *information environment* as comprising food advertising and media (Glanz et al., 2005).

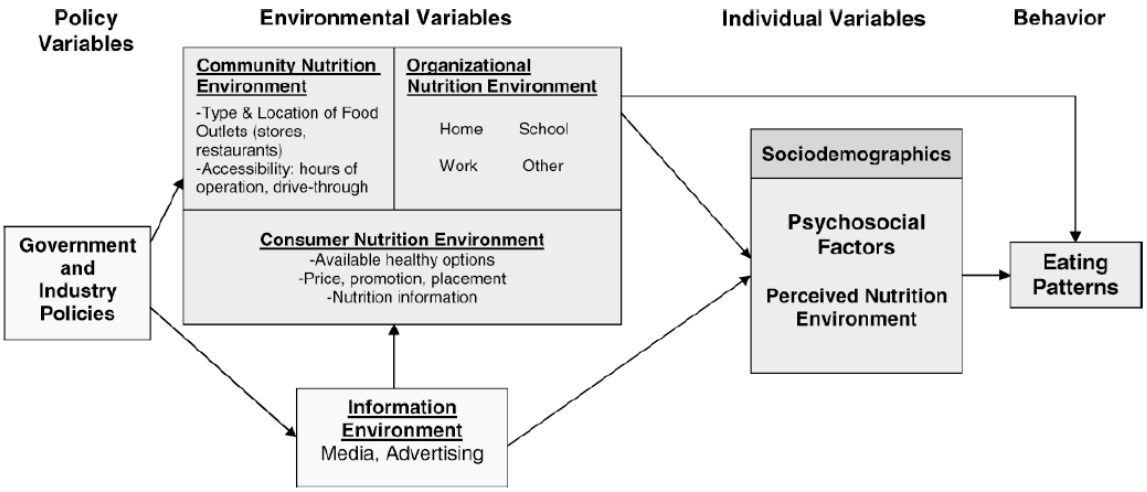

Figure 2.1. Model of community nutrition environment (Glanz et al., 2005)

This well-recognised conceptualisation of nutrition environments has been adapted by researchers including Story and colleagues (2008), Swinburn and colleagues (2013a), and Freedman and colleagues (2013), and has informed the conceptual framework that underpins this research (Murphy et al., 2017a).

Rather than a linear depiction, Story and colleagues (2008) extended this framework by adopting concentric circles to represent individual factors nested in social environments, nested in physical environments within macro-level environments. Individual-level characteristics that influenced food choice were motivation, self-efficacy and behavioural capabilities; whereas

social norms, social support and role modeling were mechanisms that influenced food choice at the social environment level (Story et al., 2008). The physical environment included the organisational and community nutrition environments of Glanz's model, while the macro-level factors included cultural norms, food marketing, and the food production and distribution system (Story et al., 2008). Swinburn and colleagues (2013a) depicted the physical, economic, policy and socio-cultural food environments that influence diet; however, they also included the food industry, government and societal actors that influence food environments and the interactions between the components. By including the organisations and sectors that influence food environments, they were also able to identify the roles and responsibilities of each actor and the actions required to create healthy food environments (Swinburn et al., 2013a). Finally, Zenk and colleagues (2015) proposed a conceptual model that extended previous models, with pathways from area-level measures of socio-economic status and racial composition to local food environments, food purchasing, dietary intake and obesity. The model includes bi-directional arrows between area-level influences and local food environments which reflect a broader literature on endogeneity and neighbourhood influences on health. For example, residents may self-select into areas that match their individual preferences for food, or food retailers may locate to areas to meet the demand for specific food types from local residents (Kawachi and Subramanian, 2007, Moon, 2010).

Together, these ecological representations of the food environment advance our understanding of how food environments influence dietary behaviour and diet-related health outcomes, with each ecological model bringing with it different emphases. However, as this study focuses on urban planning and policy interventions to modify local food environments to improve dietary and health outcomes, it requires a conceptual framework that can be used to identify neighbourhood-level spatial measures associated with dietary and health outcomes, measures that can inform urban planning policy metrics. Further, this research investigates the spatial patterning of dietary and health outcomes across areas of disadvantage and varying suburban development, which may have implications for urban planning policy and its implementation across geographic areas. To fill this gap, a new conceptual framework to guide urban planning policy and practice was developed, and is discussed in chapter three.

The following section reviews the evidence on how food outlet access varies within cities across high-income countries.

2.4. Access to food outlets

2.4.1. Variation in access by socio-economic areas

It is hypothesised that local food environments affect dietary intake and diet-related health outcomes (Laraia et al., 2015, Zenk et al., 2015). As discussed in section 2.2, in Australia there is a social gradient for dietary behaviour and health outcomes in which those of lower individual-level socio-economic position generally have poorer dietary intake and more adverse health outcomes. In response, researchers have investigated whether geographic variation in access to 'healthy' or 'unhealthy' food contributes to dietary and healthy inequities. Supermarkets are regularly used as a proxy measure for healthy food access as they provide the range of foods required for a healthy and affordable diet (Bader et al., 2010, Block and Kouba, 2006), including high quality fruit and vegetables (Laraia et al., 2015), and offer cheaper prices for healthy food items when compared with convenience stores (Gustafson et al., 2012). Fast food chains are regularly used as a proxy for unhealthy food access. Fast foods are energy-dense and nutrient-poor; eating at least one fast food meal a week is associated with weight gain, overweight and obesity in both children and adults (National Health and Medical Research Council, 2013).

'Food deserts' first appeared in public policy in the United Kingdom (U.K.) in the 1990s to describe 'poor urban areas where residents cannot buy affordable, healthy food' (Cummins and Macintyre, 2002, p. 436). The evidence for food deserts across high-income countries is contested (Cummins and Macintyre, 2002). While many studies have documented the existence of food deserts in the United States (U.S.) (Beaulac et al., 2009, Walker et al., 2010), for other high-income countries, such as Australia, New Zealand or the U.K., the evidence is equivocal (Beaulac et al., 2009, Cummins and Macintyre, 2006). Contrary to the notion of food deserts, New Zealand studies have found that more disadvantaged areas had better access to both fast food outlets and supermarkets (Pearce et al., 2008, Pearce et al., 2007). By contrast, an Australian study in Melbourne found that residents in low disadvantage neighbourhoods had a greater number of supermarkets within a 2 km buffer of their home and lived closer to the nearest supermarket than residents of high disadvantage neighbourhoods (Ball et al., 2009). Another Melbourne study in high disadvantage outer suburbs found that the majority of residents lived within an 8 to 10 minute car journey of a supermarket, concluding that they had good access to food to support a healthy diet; however, advantaged areas had closer access to a supermarket (Burns and Inglis, 2007). Similar to the New Zealand study, in Brisbane, Australia

high disadvantage areas had closer access to the nearest supermarket than mid- or low-disadvantage areas (Winkler et al., 2006).

More recently, the concept of 'food swamps' has emerged to describe geographic areas where there is an excess of unhealthy food outlets located in disadvantaged neighbourhoods relative to healthy food outlets (Rose et al., 2009). In contrast to food deserts, the evidence for food swamps appears to be more consistent across high-income countries (Fleischhacker et al., 2011, Black et al., 2014). A review of fast food access studies reported that fast food outlets were more prevalent in low-income than mid- or high-income areas (Fleischhacker et al., 2011). A Canadian study found that low socio-economic neighbourhoods had greater exposure to fast food outlets (Smoyer-Tomic et al., 2008). Similarly, previous Australian and New Zealand studies have found that access to fast food outlets was socio-spatially patterned: more disadvantaged areas had greater access to fast food outlets (Pearce et al., 2007, Thornton et al., 2016b).

In summary, numerous studies have aimed to establish whether access to healthy and unhealthy food outlets is socio-economically patterned across neighbourhoods, and if it is thus a potential risk factor for dietary inequities. However, many of the studies are U.S. studies (Black et al., 2014), and further research is needed to understand the influence of food outlets on food choice, dietary patterns, and diet-related disease in other high-income countries such as Australia.

2.4.2. Variations in access by suburban development

Patterns of suburban development within cities are associated with health outcomes (Rydin et al., 2012, World Health Organization, 2016b). In high-income countries, low-density residential development and expansion outwards at the boundaries of cities is associated with increased use of motorised transport, and higher rates of overweight and obesity (Rydin et al., 2012, Ewing et al., 2014). In contrast, compact higher-density suburban development with proximal access to a range of destinations is associated with less vehicle use, more active travel, and lower BMI (Sarkar et al., 2017, Ewing et al., 2014, Giles-Corti et al., 2016). Variations in suburban development relate to differences in built environment attributes such as housing density and land use mix, which may influence health outcomes (Ewing et al., 2014, Xu and Wang, 2015). Ewing and colleagues (2003) developed an 'urban sprawl index', finding that low-density residential development and low street accessibility characterised by large blocks and low connectivity, was associated with less walking and higher weight . Also known as a 'compactness

index', other built environment attributes were later included such as land use mix, a measure of the diversity of land use types (for example, retail, residential, recreational, agricultural, or public transport) (Ewing et al., 2014). Similar to the earlier index, residents in more compact areas had a lower BMI; however, associations between compactness and physical activity were not found, leading the authors to recommend greater precision in assessing physical activity and further research into the spatial component of dietary intake (Ewing et al., 2014).

Several studies have investigated spatial access to food environment attributes and how these vary by suburban development (Ahern et al., 2011, Bernsdorf et al., 2017, Lind et al., 2016). A New Zealand study found that access to fresh food outlets within the city of Christchurch varied from less than one minute in the city centre to 20 minutes travel time on the urban-rural fringe (Pearce et al., 2006). While variations in spatial access to food outlets between urban and rural areas is expected (Powell et al., 2007, Pearce et al., 2006), it is the intra-city variation that may lead to differential health outcomes within cities, and would therefore have implications for urban planning policy.

A national U.S. study investigated associations between both physical activity and food environment attributes and obesity, and how these varied by measures of 'urbanicity' (Xu and Wang, 2015). Urbanicity was defined using U.S. National Center for Health Statistics and U.S. Census classifications based on population size and population density, with six classifications ranging from large metro (central or fringe), medium metro and small metro to non-metropolitan categories of micropolitan and non-core (Xu and Wang, 2015). The study found that street connectivity and walkability were associated with reduced obesity risk only in highly urbanised areas, whereas the ratio of fast food to full-service restaurants was associated with increased obesity risk only in moderately urbanised areas (Xu and Wang, 2015). The study demonstrates the differential associations between food environment attributes and health outcomes across areas of varying suburban development. The authors concluded that obesity risk factors may be geographically specific, and that examining the variability in associations between built environment attributes and obesity across different levels of urbanisation is important for public policy (Xu and Wang, 2015).

Several Australian studies have investigated access to food outlets across urban and rural areas (Thornton and Kavanagh, 2012, Thornton et al., 2016b) and in rural towns (Innes-Hughes et al., 2012); however, there do not appear to be studies that have investigated access to food outlets within cities across areas of varying suburban development. Thornton and colleagues (2016b)

used the Australian Bureau of Statistics Remoteness Structure (Australian Bureau of Statistics, 2013a) as a measure of urban-rural locality and found that the mean number of fast food outlets in the Statistical Area Level 2 (SA2) administrative area varied from 1.5 outlets in the major cities category of Greater Melbourne to 0.8 outlets in inner regional Victoria (Thornton et al., 2016b). The SA2 area has an average population of approximately 10,000 persons (Australian Bureau of Statistics, 2011d).

While there is a gap in the literature on spatial access to food outlets within established and urban growth areas of Australian cities, there is one study that examined the 'in-store' food environment across urban, urban-fringe and non-metropolitan areas of Victoria, Australia (Cameron, 2018). This study found that urban-fringe and non-metropolitan supermarkets had less shelf space for fruit and vegetables and more shelf space for soft drinks than urban supermarkets (Cameron, 2017). Another Australian study assessed the cost of a selection of healthy food items, also known as a 'healthy food basket', in 26 local government areas across Victoria, finding that the cost increased as distance from Melbourne's city centre increased (Palermo et al., 2016).

To summarise, previous research in high-income countries has shown that spatial access to food outlets varies across socio-economic areas and across areas of varying suburban development, and that this may contribute to differential health outcomes. In the Australian context, while several studies have investigated spatial access to food outlets across socio-economic areas, little is known about the variation in spatial access to food outlets across established residential and urban-growth areas within Australian cities. Informed by ecological models, the following section presents evidence on the question of whether spatial access to food outlets influences dietary intake and diet-related diseases including obesity, and health outcomes.

2.5. Associations between food outlet access, dietary intake and health

There are many studies that have investigated associations between access to food outlets and dietary and health outcomes. The underlying hypothesis of these studies is that greater access to food outlets selling healthy food items is associated with healthier dietary intake and diet-related health outcomes, whereas greater access to unhealthy food outlets is associated with unhealthy dietary intake and poorer health outcomes (Black et al., 2014). Behavioural outcomes commonly cited in the literature to assess healthy and unhealthy dietary intake are fruit and vegetable intake and fast food intake, respectively (Caspi et al., 2012b, Rahmanian et al., 2014,

Black et al., 2014). Food environment exposure is regularly assessed by measuring food outlet density, a measure of food outlet availability, or by food outlet proximity, a measure of food outlet accessibility (Charreire et al., 2010, Thornton et al., 2011b).

In this section, systematic reviews of studies investigating food environment exposure, dietary intake and weight status in high-income countries are presented.

2.5.1. Associations with dietary intake

Caspi and colleagues (2012b), reviewing food environment studies, found moderate evidence that local food environments influenced diet. Significant associations between dietary intake and food outlet density were found in the expected direction in nine studies (60%), whereas only four studies using proximity measures (31%) detected associations in the expected direction (Caspi et al., 2012b). Black and colleagues (2014) found expected associations in 20 studies (65%) that used density measures, compared with 11 studies (46%) that used proximity measures showing expected associations with diet. Overall, the review found strongest evidence for associations between supermarket/grocer/greengrocer density measures and a healthy diet, followed by convenience store/fast food density measures and unhealthy diet (Black et al., 2014).

2.5.2. Associations with diet-related health outcomes

A number of reviews have been conducted examining the associations between local food environments, BMI and overweight/obesity (Giskes et al., 2011, Cobb et al., 2015, Zenk et al., 2015). Giskes and colleagues (2011) found that weight status was consistently associated with supermarket or fast food access in the expected direction; however, associations with dietary behaviour were inconsistent. Zenk and colleagues (2015) found the most consistent relationship was for the protective effect of supermarkets on body weight. While Cobb and colleagues (2015) found evidence to support the protective effect of supermarket density on obesity, most associations between supermarket access measures and obesity (72%) were null. They also found evidence that proximity to fast food outlets was associated with obesity, but 67 per cent of findings had null associations (Cobb et al., 2015).

2.5.3. Summary of associations

In summary, the evidence for associations between food environment exposure, dietary intake and weight status remains inconclusive; nevertheless, trends have been observed where

supermarket density may be associated with healthier dietary intake and lower body weight, while density and proximity to fast food outlets may be associated with an unhealthy diet and higher body weight.

Methodological challenges that may account for the inconsistent findings observed in food environment research are reviewed in the following section (Caspi et al., 2012b, Black et al., 2014, Cobb et al., 2015).

2.6. Limitations of food environment studies

In order to clarify the role of local food environments on dietary intake and diet-related health outcomes, key methodological challenges that pertain to the measurement of food environments need to be addressed. These include the heterogeneity of food access measures (Caspi et al., 2012b, Black et al., 2014, Giskes et al., 2011); geographic scale (Caspi et al., 2012b, Rahmanian et al., 2014, Lucan, 2015); differential associations between food environments and population sub-groups (Leal and Chaix, 2011, Zenk et al., 2015, Giskes et al., 2011, Feng et al., 2010); and use of secondary food outlet data (Forsyth et al., 2010, Black et al., 2014, Caspi et al., 2012b). These factors are discussed below.

2.6.1. Heterogeneity of food outlet access measures

Food outlet availability can be spatially assessed by measuring food outlet density within an administratively defined area such as a census block or postcode; within a defined geographic area such as a square kilometre; and within a circular or road network buffer around a household location (Charreire et al., 2010, Thornton et al., 2011b). Food outlet accessibility can be assessed by measuring the distance to the food outlet from the centroid of a geographic area, or from the household address by road network or Euclidian (straight-line) distance (Charreire et al., 2010, Thornton et al., 2011b). Euclidian distances to the nearest food outlet are likely to be shorter than the road network distance, which is considered a more accurate measure of the distance people travel to the food outlet (Burgoine et al., 2013, Thornton et al., 2011b). The modifiable areal unit problem (MAUP) describes the variation in results when analyses are undertaken using different geographic units and different spatial scales (Openshaw and Taylor, 1979). MAUP comprises a 'zoning' effect where different results arise depending on the configuration or grouping of areal units, while the scale effect occurs when different results arise depending on the size and aggregation of the areal unit (Openshaw and Taylor, 1979, Kwan,

2009). The heterogeneity of food access measures may contribute to inconsistent findings observed across studies (Caspi et al., 2012b). The scale effect is discussed further in section 2.6.2.

Additionally, food access measures based on administrative units are noted as being problematic because actual exposure depends on where the individual resides within the areal unit (Lucan, 2015, Morland, 2015a); for example, the dietary intake of an individual living close to the boundary of an administrative area is as likely to be influenced by the contiguous administrative area as their residential neighbourhood (Lucan, 2015). Known as the 'edge effect', it describes the bias that can be introduced when measuring food access within a geographic area that does not consider food outlets beyond the study boundary (Van Meter et al., 2010, Sadler et al., 2011).

Finally, while food access measures based on a residential household location are more likely to represent an individual's food environment, a range of buffer sizes appear in the literature, typically ranging from 400 m to 4000 m (Caspi et al., 2012b). Despite this, few food environment studies investigate geographic scale to determine optimal buffer sizes for dietary intake and body weight (Barnes et al., 2016a). Food environment researchers have argued for reliable, valid food environment measures that have utility across different populations and health outcomes (McKinnon et al., 2009, Lytle, 2009, Caspi et al., 2012b) .

2.6.2. Geographic scale

Associations between measures of food outlet access and dietary and health outcomes vary depending on how an individuals' food environment is spatially defined and on choice of geographic scale (Caspi et al., 2012b, Rahmanian et al., 2014, Lucan, 2015). The physical activity literature has shown the importance of geographic scale when assessing the links between walking and urban design (Learnihan et al., 2011). Learnihan and colleagues (2011) found that the association between walking for transport and neighbourhood walkability was strongest at a fine geographic scale compared with the suburb scale. More recent studies have shown the importance of geographic scale and food environment exposure in detecting obesity risk (Fan et al., 2014) and fruit and vegetable intake (Thornton et al., 2012). Fan and colleagues (2014) found individual obesity risk could be detected at medium geographic scale (1 km buffer) for limited-service or fast food restaurants, whereas a larger geographic scale was required for supermarkets. This may be because people travel longer distances by car for grocery shopping therefore indicating that different types of food outlets are sensitive to geographic scale.

Thornton and colleagues (2012) compared multiple methods for measuring access to supermarkets and associations with fruit and vegetable intake. They found that statistical associations were sensitive to the supermarket access measure and buffer size (Thornton et al., 2012). Mejia and colleagues (2015) investigated associations between different types of food outlets, dietary intake and obesity within a range of buffer sizes in Los Angeles County, finding that for most analyses there were no significant effects. While the study had several limitations that may have contributed to the null findings, the authors hypothesised that food purchasing was weakly related to walkable access to food outlets in a highly motorised city such as Los Angeles (Mejia et al., 2015).

Distances people travel to purchase food

There is considerable heterogeneity across studies in the size of buffer used to assess food environments, buffer size being a proxy for estimating the distances that people will travel to purchase food. While some buffer distances are intended to reflect a walkable distance or the distance that people will drive for grocery shopping (Feng et al., 2010, Caspi et al., 2012b, Thornton et al., 2010a), it is recognised that the distances that people will travel is not well understood, particularly in relation to food and eating behaviours (Matthews et al., 2009). Further, car ownership influences an individual's utilisation of the local food environment, (Lucan, 2015, Caspi et al., 2012b, White, 2007, Morland, 2015a), with studies in Melbourne and Adelaide, Australia finding that good access to healthy food is affected by car access (Burns and Inglis, 2007, Burns et al., 2011, Coveney and O'Dwyer, 2009).

A study in Brisbane, Australia that defined the shopping catchment as a 2.5 km radius from the centroid of the census collection district acknowledged the arbitrary selection of this distance (Winkler et al., 2006). A study in the United Kingdom found that participants travelled an average distance of 1.9 km by car to do their food shopping (White et al., 2004), while a U.S. study of five cities found the average distance travelled to a grocery store/supermarket was 3 km (that is, 1.9 miles) (Liu et al., 2015). Another U.S. study in Detroit found that residents travelled an average 5 km to shop for groceries, and that travelling further distances was associated with a range of individual and area-level factors including race/ethnicity, age, socio-economic status, lower satisfaction with the neighbourhood environment, neighbourhood poverty, and a longer distance to a supermarket (Zenk et al., 2014). In the U.S., which is characterised by more low density residential development and urban sprawl (Townshend and Lake, 2009), distances travelled to purchase food appear to be higher than in the U.K.

Leal and Chaix (2011) reviewed studies that investigated the influence of built environment attributes on cardiometabolic risk factors, including obesity, noting the importance of assessing the geographic scale at which the exposure affects health outcomes, and recommending the use of a range of buffers in sensitivity analyses. Geographic scale and the distances that people travel to shop at different types of food outlets are therefore interrelated methodological challenges which may be contributing to inconsistent findings across food environment studies. Local food environments appear to be context-specific, relating to the distances that people travel to purchase food.

2.6.3. Variation in local food environment effects across sub-populations and areas

Researchers hypothesise that local food environments may matter more for some population sub-groups than others, such as those who have fewer choices because they have fewer resources including income, time or transport opportunities (Zenk et al., 2015, Feng et al., 2010, Powell and Han, 2011, Leal and Chaix, 2011). Disadvantaged population groups may therefore be more sensitive to proximal access to healthy food outlets.

Beauchamp and colleagues (2014) reviewed obesity prevention studies, finding that the effect on participants varied by socio-economic position. They suggested that interventions targeting environmental, social or structural change may be more effective because they rely less on individual-level factors such as income, health literacy and self-efficacy (Beauchamp et al., 2014). Similarly, other reviews have concluded that 'upstream' interventions that target policy and environmental determinants are more likely to reduce inequities in health outcomes than 'downstream' interventions that target individual-level factors (Lorenc et al., 2013, McGill et al., 2015).

Further, Leal and Chaix (2011) found weight-related outcomes varied by area-level socio-economic characteristics after adjusting for individual-level socio-economic factors. They suggested that both individual- and area-level socio-economic factors may be a source of bias in studies investigating environmental exposures and health outcomes, and that both should therefore be considered in analytic models (Leal and Chaix, 2011).

Considered together, these studies demonstrate the differential effects of food environments across population groups and socio-economic areas that may partly contribute to inconsistent findings in food environment research.

2.6.4. Food outlet data

The use of secondary food outlet data sourced from commercial and non-commercial sources is regularly noted as a possible source of measurement error in food environment studies, with concerns that such data are likely to misrepresent the true food environment (Black et al., 2014, Caspi et al., 2012b, Cobb et al., 2015). A limitation to secondary data sources is that they are not regularly updated and may include stores that have closed, or exclude stores that have recently opened (Lake et al., 2010, Liese et al., 2013). Accessing accurate and comprehensive food outlet spatial data across large geographic areas is frequently noted as a limitation in the food environment literature (Matthews et al., 2009, Lucan, 2015); indeed, it has been estimated that secondary data sources encompass only 52-68 per cent of the food outlets that exist in an area (Moore and Diez-Roux, 2014). In a U.K. study, Lake and colleagues (2010) combined three sources of food outlet data: a government listing, yellow pages, and an online commercial list. They found that, when used together, they achieved 93 per cent agreement between the combined dataset and field validation (Lake et al., 2010). Where field validation is not conducted, they recommend using multiple sources of food outlet data concurrently to achieve a robust food outlet dataset, (Lake et al., 2010).

2.6.5. Other limitations

Other limitations include the assumption that the nearest food outlets are where individuals shop for food, and the differences in perception of the local food environment versus actual food environments. While fully exploring such limitations is beyond the scope of this research (see delimitations section 1.4), a brief outline of these methodological challenges is presented.

Food environment research regularly assumes that individuals use the nearest food retail outlet (Cummins, 2007, Lucan, 2015). Known as 'the local trap', if an individual shops for food outside the immediate residential neighbourhood (for instance, by purchasing food on the way home from work or around the workplace), then only using small administrative areas to measure food exposure is likely to result in error (Cummins, 2007). Studies in the U.S. have used global positioning systems (GPS) and travel diaries to measure the space within which study participants moved throughout the day, discovering that their activity space is much larger than the neighbourhoods currently being used in food environment research (Zenk et al., 2011, Crawford et al., 2014).

Several studies have compared participant perceptions of local food environments with objective GIS measures. Barnes and colleagues (2015) found moderate agreement for urban residents between perceptions of the food environment at 1.6 km buffers and the presence of fast food chains and supermarkets. By contrast, Caspi and colleagues (2012a) revealed a high mismatch between perceived and objective measures, suggesting that perceived measures of the food environment may be more predictive of dietary behavior than objective measures.

In summary, while there is evidence that local food environments influence dietary intake and diet-related diseases including obesity, and health outcomes, that evidence is inconsistent. A range of limitations and methodological challenges have been identified that may contribute to the inconsistent findings across studies. As described in subsequent chapters, this study seeks to address these limitations to advance understanding of how access to food outlets affects dietary intake and health outcomes across geographic areas.

2.7. Policy and planning interventions to improve local food environments

The food environment literature includes a range of studies that investigate policy and environmental interventions to improve population health and health equity. This section reviews the literature on policy and planning interventions to create healthier local food environments.

The Global Burden of Disease Study identified high BMI as a leading risk for disease and death across low- and high-income countries (G.B.D. Risk Factors Collaborators, 2017). Low socio-economic groups have poorer diets and are at increased risk of non-communicable disease (Pescud et al., 2018). Increased availability, accessibility and affordability of energy-dense foods, and reduced opportunities for physical activity were identified as key drivers for increased high BMI risk (G.B.D. Risk Factors Collaborators, 2017). In response to high BMI risk and diet-related diseases, international and national health and urban planning agencies have recommended built environment interventions to improve dietary intake, and to reduce both obesity and non-communicable diseases (Butland et al., 2007, World Health Organization, 2013, Hodgson, 2012, Australian Medical Association, 2016). Urban planning and policy interventions have the potential to increase access to healthy food, improve health outcomes, and reduce health inequities (Marmot and Bell, 2012, Butland et al., 2007). While the literature across high-income countries in Europe, the U.K. and U.S. is emerging, little is known about the effects of urban planning and policy interventions in creating local food environments in an Australian context.

2.7.1. Interventions to restrict unhealthy food access

Although the evidence is still emerging, local authorities and researchers in the U.S., U.K. and Canada have recommended zoning and land use regulation to restrict fast food outlets (Local Government Association, 2016b, Chen and Florax, 2010, Cooksey-Stowers et al., 2017, Wooten et al., 2013, Nykiforuk et al., 2018). A U.S. study identified 100 proposed zoning and other land use policies to restrict fast food outlet access over a 12-year period to 2013 for aesthetic, economic, amenity and health reasons (Nixon et al., 2015). Only two-thirds of the policies were enacted, with nutrition-focused policies subject to most criticism in the news media, where it was claimed that they represented government intrusion on personal choice and that they would not be effective in reducing obesity (Nixon et al., 2015). The authors recommended that land use policies to restrict new fast food outlets be evaluated to strengthen health-focused arguments (Nixon et al., 2015). A Canadian study identified 27 municipalities that had adopted a ban on fast food drive-through services over a 13-year period to 2016; it represented less than one per cent of all municipalities (Nykiforuk et al., 2018). Again, these authors noted the importance of policy evaluation to determine whether land use policy is effective as a strategy for chronic disease prevention (Nykiforuk et al., 2018). In summary, few zoning and land use regulations to restrict fast food outlets have been implemented across these jurisdictions and even fewer have been evaluated. A notable exception, however, comes from the U.S.

In 2008, a zoning regulation was introduced in Los Angeles to restrict the opening or expansion of standalone fast food outlets as a public health measure in South Los Angeles, an area of 700,000 residents (Sturm and Hattori, 2015). An evaluation found that after five years there was little difference in the number of new fast food outlet openings compared with numbers in other parts of the city, little difference in fast food intake of residents, and an unexpectedly larger increase in overweight/obesity prevalence in South Los Angeles compared with other areas of the city or county (Sturm and Hattori, 2015). The authors concluded that this may be because of short evaluation timeframes or because of poor regulatory targeting which focused on large standalone fast food outlets rather than the far more common small food outlets in South Los Angeles (Sturm and Hattori, 2015).

In Australia, efforts to restrict new fast food outlets from opening by using zoning and land use regulations have been unsuccessful in Victoria and South Australia (Mills, 2014, Taylor, 2014). In 2013, the Victorian local government Yarra Ranges Shire Council refused a planning permit for a new McDonalds fast food chain outlet for public health and amenity reasons; however, this

was overturned by the planning tribunal (Mills, 2014). In a similar case in South Australia, the planning tribunal decided the evidence for negative public health impact was inconclusive (Mills, 2014).

2.7.2. Interventions to increase healthy food access

Zoning and land use regulations have also been used to increase access to healthy food outlets. New York City amended their local law to allow for 1,000 fruit and vegetable permits to be issued to 'green cart' vendors who would locate to neighbourhoods with limited fruit and vegetable access (Centers for Disease Control and Prevention, 2016). Evaluation of the initiative, however, found that only seven per cent of mobile vendors located themselves in food deserts where there were no healthy food outlets within 400 m (Li et al., 2014). Most green carts were positioned in areas where there was a large amount of foot traffic, with multiple other healthy food outlets nearby (Li et al., 2014), and not all green cart permits were active (Sisnowski et al., 2017).

Woodruff and colleagues (2018) reviewed studies that investigated the impact of new fruit and vegetable retailers on dietary intake (Woodruff et al., 2018). While there were small increases in the fruit and vegetable intake of adults who shopped at the new retailer, effects on the dietary intake of the broader community were inconclusive (Woodruff et al., 2018). The introduction of a government-subsidised supermarket in a low socio-economic area of New York elicited no change in the availability of healthy or unhealthy food in households or on children's dietary intake (Elbel et al., 2015). The authors recommended further research to determine distance and density thresholds at which poor supermarket access affects dietary intake (Elbel et al., 2015). Similarly, a study in Philadelphia that assessed the impact of a new supermarket opening in a food desert found no change in adult fruit and vegetable intake or BMI; however, the study did find that residents' perception of healthy food access improved (Cummins et al., 2014). The authors suggested that complementary in-store approaches such as price promotions, or food shopping and cooking skills programs may be needed to bridge the gap between perceptions of healthy food access and behaviour change (Cummins et al., 2014). They recommended further research in other locations and longer follow-up periods (Cummins et al., 2014).

Block and Subramanian (2015) argued that simply opening new supermarkets in disadvantaged areas may be an ineffective method of addressing dietary inequities, suggesting alternative strategies that focus on early childhood and school settings, point-of-sale nutrition information,

economic policies to incentivise healthy food purchase, and taxation of unhealthy foods (Block and Subramanian, 2015). In summary, they argued that eliminating food deserts alone is not enough, and recommended a range of interventions across settings and food environments to improve population dietary intake and reduce dietary inequities (Block and Subramanian, 2015).

2.8. Summary

This chapter reviewed the literature that forms the background for this research. It began with evidence for dietary intake, obesity and non-communicable disease, demonstrating that these behavioural and health outcomes are socio-economically patterned, with low socio-economic groups experiencing a greater burden. Improving population health outcomes and reducing the inequitable distribution of diet-related non-communicable disease provides the rationale for this research. Ecological models that describe the multiple influences on behavioural and health outcomes were presented, including several models that focused on food environments. Central to the ecological approach are depictions of the individual-, social-, environmental- and policy-level factors that influence behaviour; they therefore provide a framework for identifying upstream policy and environmental interventions to improve downstream population dietary and health outcomes.

In food environment ecological models, it is hypothesised that the built environment factors which influence dietary intake are the availability and accessibility of food outlets. These are potentially influenced in turn by the policy environment. While ecological models encompass policy and environmental factors that influence dietary and health outcomes, a key gap in the literature is guidance on metrics to inform spatial policy: the distances and thresholds that are required to create healthy local food environments.

This chapter reviewed the evidence on access to food outlets from an equity perspective and across levels of suburban development to identify gaps in current knowledge in an Australian context. Further, this chapter synthesised findings from several systematic reviews that summarise the extensive literature discussing how spatial access to food outlets influences dietary intake and weight status in high-income countries. The findings from these studies remain inconclusive. Several limitations were identified that need to be addressed to advance the field.

The chapter concluded with an overview of urban planning and policy interventions to improve local food environments by restricting access to unhealthy food outlets and increasing access to

healthy food outlets. In an Australian context, few studies have examined policy interventions to improve local food environments, and little is known about the relevant spatial metrics to inform urban planning policy interventions for healthy food environments.

The next chapter presents a conceptual framework for a health-promoting local food environment that depicts potential pathways from upstream urban planning and other government policies to downstream dietary and health outcomes. This framework provides the foundation for the quantitative analysis used in this research.

Chapter 3. A conceptual framework

3.1 Preface

This chapter presents a conceptual framework for the study that was published in the *Health Promotion Journal of Australia* (accepted 6 May 2016). Titled 'Indicators of a health-promoting local food environment: a conceptual framework to inform urban planning policy and practice' (Murphy et al., 2017a), the paper reviewed academic literature and urban planning policies to identify spatial measures of the food environment associated with adult dietary intake and obesity.

The framework conceptualises how urban planning and other government policies influence neighbourhood attributes relevant to the local food environment. Neighbourhood attributes in the framework include outdoor advertising, drinking fountains, food outlet availability and accessibility, transport opportunities, and land use mix. The pathways from these attributes, through dietary intake, physical activity and sedentary behaviour to weight status and health outcomes, are depicted in the framework; together they show how urban planning policy decisions influence built environment outcomes, which in turn influence diet-related diseases including obesity, and health outcomes

This conceptual framework, the foundation for this study's quantitative and spatial analyses, addresses the first research question presented in the Introduction (section 1.4):

1. How does the local food environment influence dietary intake and health outcomes in an urban adult population aged 18 years and over?

To investigate this research question, spatial measures of the local food environment that mapped to the conceptual framework were identified from the literature that had previously shown associations with dietary and health outcomes. Due to local contextual relevance, there was a focus on studies that targeted adults in urban settings in high-income countries. Spatial measures at the neighbourhood-level were selected, allowing for comparison within and across cities.

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Letter

Indicators of a health-promoting local food environment: a conceptual framework to inform urban planning policy and practice

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Global obesity prevalence has risen dramatically over the past 30 years in both adults and children.[1] This presents a major public health challenge because of its contribution to chronic disease and inequities in the distribution of obesity within populations.[1]

Obesity arises from the energy imbalance associated with dietary intake, physical activity and sedentary behaviours.[1] Built-environment attributes (land use, density, transport) appear to influence these behaviours.[2] While associations between built-environment attributes and physical activity are well established,[2] the relationship between the built environment and dietary behaviour is less well understood and evidence is inconsistent.[3]

Local food environments

A model developed by Glanz and colleagues[4] widely used to understand the food environment depicts the policy, environment and individual factors that influence dietary behaviour. It recognises the importance of the: 'community food environment' (type, location and accessibility of food outlets); 'organisational food environment' (food availability around workplace, home and school); and 'consumer food environment' (affordability, promotion and placement of food within the outlet).[4] Glanz's model has advanced our understanding of how food environments appear to influence dietary intake, but for this to inform the development of urban planning policy, spatial indicators to measure and monitor food environments are required. Local food environments (LFE) are small geographic areas where people shop for food within a walkable or short driving distance in urban areas.[5] We need to know which LFE spatial measures are most useful for assessing dietary and health outcomes in local areas, the most appropriate geographical scale to apply these measures, and how they can inform urban planning policy and practice.

The density of and proximity to food outlets[3] in a neighbourhood or around a household are examples of spatial measures commonly used to assess LFE. However, for these measures to be translated into policy and practice, more specific information is required to inform optimal outlet density or proximity. For example, evidence-informed spatial metrics (how many food outlets, how close to households) could assist local governments seeking to increase fresh food access in a local area through urban planning policy. Evidence suggests access to supermarkets may support dietary health[3] and access to fast-food outlets may be associated with obesity.[6] A recent study[7] found geographical scale to be an important factor in the association between these types of food outlets and obesity. For example, participants who lived within 1 km of a fast-food restaurant were more likely to be obese. However, a larger geographic scale (participant's postcode) was required to detect a protective effect of supermarkets on obesity. The study concluded that it is likely that people travel longer distances by car to the supermarket to purchase groceries. Therefore, optimal spatial

measures will vary depending on the food outlet type and travel mode used to access it (walking, cycling, car).

A conceptual framework to inform urban planning policy and practice

Evidence-based LFE indicators for the specific purpose of informing urban planning policy and practice in local areas have potential for identifying dietary and health inequities. Accordingly, we have devised a new conceptual framework (Fig. 1) that shows the hypothesised pathways through which built-environment attributes of the LFE may influence immediate behavioural outcomes (dietary intake, physical activity, sedentary behaviour) through to intermediate and long-term health outcomes. Upstream urban planning policies (towards the left of Fig. 1) provide the policy context that influences neighbourhood attributes associated with downstream behavioural and health outcomes.

Development of conceptual framework

A review of the literature was undertaken to first, develop the conceptual framework; and second, identify potential LFE spatial measures associated with dietary intake and weight. Well-established associations in the literature guided the development of the conceptual framework, which was then refined through an iterative process by the multi-disciplinary study team. To identify potential spatial measures, the electronic databases Medline, Embase, Web of Science and Scopus were searched for adult studies in English-language literature to the end-2014, using combinations of the terms 'local food environment', 'neighbo*hood food environment', 'indicators', 'index' or 'indices'. After removing duplicates, and studies with 'child*' in the title, 177 papers were reviewed. Previous reviews and their references were searched, as were Victorian planning documents to identify spatial measures currently applied in policy.[†] Criteria for selecting the measures were that they: mapped to the conceptual framework; could be spatially applied at the neighbourhood level; and came from

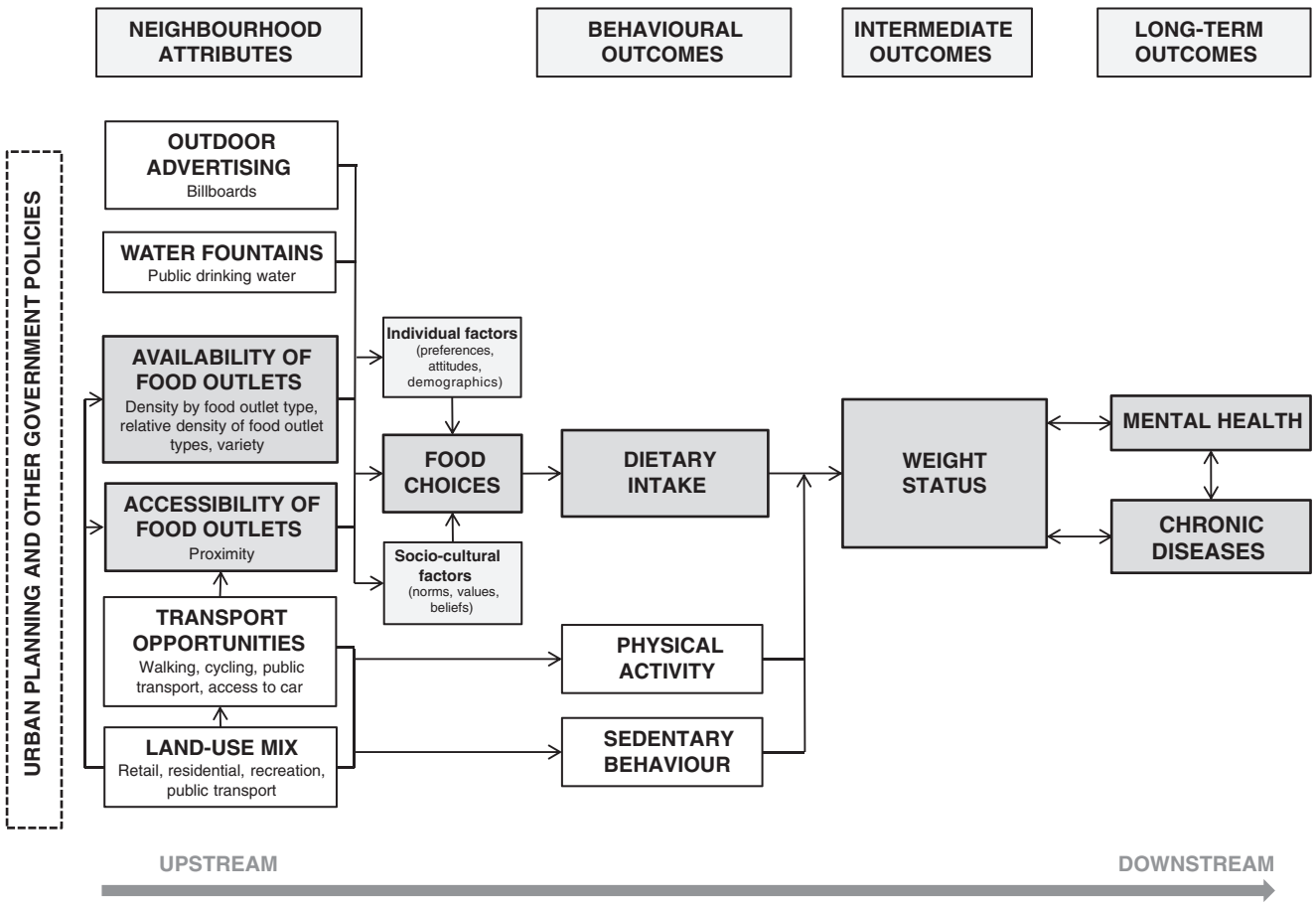

Fig. 1. A conceptual framework of the local food environment and health to inform urban planning policy and practice. Shaded boxes depict the hypothesised pathway from neighbourhood attributes of the local food environment though to long-term health outcomes.

[†]A list of academic and urban planning policy documents reviewed is available from the authors.

urban studies in high-income countries. Potential measures were assessed against each criterion. Studies focused on 'in-store' food environment indicators and regional/national-level indicators were excluded.

Neighbourhood-level attributes influencing dietary intake include food outlet availability (density, relative density, variety) and accessibility (proximity).[3] Other attributes (Fig. 1) such as land-use mix affect the availability and accessibility of food outlets;[2] and 'transport opportunities' influences how people travel to food outlets.[5] These attributes also influence physical activity and sedentary behaviours.[2] Individual factors (food preference, attitudes, demographics) and socio-cultural factors (norms, beliefs, values) are intermediary variables influencing food choice.[1,4] Together, dietary intake, physical activity and sedentary behaviour impact weight status, contributing to chronic disease and mental health conditions and vice versa,[1] downstream (towards the right) of the conceptual framework.

Spatial measures

Four LFE spatial measures showing significant associations with dietary intake, food purchasing or obesity risk were identified in the literature that met our criteria: density of supermarkets (associated with healthy diet);[6,8] density of fast-food outlets (associated with obesity);[7] relative density of supermarket to fast-food outlets (healthy food purchasing);[9] and proximity to supermarkets (associated with healthy diet and weight).[6,8] Victorian planning policies only contained one LFE spatial measure: residential development guidelines recommend households are located within 1 km of a town centre to allow for provision of a supermarket.[10] This paucity of spatial measures in Victorian planning policy underlines the importance of developing LFE indicators for urban planning policy and practice.

The conceptual framework and measures were developed in Victoria, Australia. Melbourne is Australia's fastest growing capital city[11] and faces challenges in common with other rapidly urbanising cities in high-income countries.

Next steps

In order to develop a set of LFE indicators to inform urban planning policy and practice, the spatial measures will be linked to existing health data and tested at appropriate geographical scales to examine associations with dietary behaviour and weight. Measures will be tested in Victoria and the most promising will be validated in other Australian cities using population health data. The findings will provide a set of validated LFE indicators to inform relevant Australian state and local government urban planning policy for improved dietary and health outcomes in local areas and to reduce inequities.

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3.2 Summary

An ecological view of health recognises that there are multiple determinants of health, including policy and built environment attributes, which influence health outcomes (Story et al., 2008). In this chapter, a conceptual framework depicting potential pathways from urban planning and other policies to dietary and health outcomes was outlined. Local food environment studies were reviewed for spatial measures of food availability and food accessibility, measures that could be assessed at the neighbourhood-level and which had shown at least one significant association with dietary and health outcomes, or were found in urban planning policy.

The spatial measures thus have potential as local food environment indicators to inform urban planning policy and practice, where an indicator comprises measures that describe conditions at a point in time (Organisation for Economic Co-operation and Development, 2008). They can be used for identifying trends, informing policy, and monitoring performance (Organisation for Economic Co-operation and Development, 2008). Local food environment indicators could provide a standardised approach for monitoring the food environment at the neighbourhood-level, and may assist in identifying opportunities for improving health outcomes and reducing inequities in local areas.

This new conceptual framework provides the foundation for the quantitative and spatial analyses in the following chapters that seek to identify, test and develop a policy-relevant and evidence-informed set of spatial measures for monitoring the food environment at the neighbourhood-level.

Chapter 4. Research design

4.1 Preface

This chapter introduces the overarching mixed methods study design applied in this research. It comprised both quantitative and qualitative approaches to answer the five research questions. The chapter presents the rationale for the sequential study design in which quantitative data collection and analysis informed the subsequent qualitative strand. The chapter concludes with details of the study area. Quantitative methods are presented in chapter five. And qualitative methods in chapter six.

4.2 Research aim and questions

The overall aims of this research were to conceptualise and develop local food environment indicators to inform urban planning policy and practice, and to identify governance actions to advance healthy, equitable local food environments within cities.

There were five research questions developed to investigate these aims:

1. How does the local food environment influence dietary intake and health outcomes in an urban adult population aged 18 years and over?
2. Is there spatial patterning of food outlet access, dietary intake and health outcomes across socio-economic areas, and across urban-growth and established areas of Melbourne, Australia?
3. What spatial measures of the local food environment are associated with individual-level dietary intake and health outcomes, and how can they guide urban planning policy and practice?
4. What contextual factors influence the availability and accessibility of food outlets in urban areas of Melbourne, a city experiencing rapid growth and suburban development?
5. What are the governance barriers and opportunities to support the development of a healthy, equitable local food environment?

4.3 Study design

This research used a mixed methods study design combining quantitative, spatial and qualitative research approaches. Many definitions for mixed methods research have been documented, evolving over time (Creswell and Plano Clark, 2011). In an effort to develop an agreed definition for mixed methods as a third research paradigm alongside quantitative and qualitative approaches, Johnson and colleagues (2007) synthesised a composite definition from 19 separate definitions from leading researchers in the field:

> Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration. (Johnson et al., 2007, p. 123)

Leech and Onwuegbuzie (2007) developed a typology of mixed method research designs that characterised studies as fully or partially mixed; as concurrent or sequential; and dominated by one research method or the other, or with both quantitative and qualitative research methods given equal status (Leech and Onwuegbuzie, 2007). In fully mixed methods studies, both quantitative and qualitative techniques are used in one or more stages of the research process or across these stages (Leech and Onwuegbuzie, 2007). While there is considerable debate about what constitutes mixed methods, core characteristics have been identified that incorporate diverse viewpoints. These include:

- collecting and analysing both quantitative and qualitative data based on a research question or set of research questions;
- concurrent mixing of the data to integrate or link the two forms of data, or sequential mixing where one data form builds upon the other, or embedded mixing where one form of data is within the other; and
- incorporating quantitative and qualitative approaches in a single study or in multiple stages of the same research program of study (Creswell and Plano Clark, 2011).

With reference to these characteristics, this PhD research used both quantitative and qualitative data to answer separate research questions contained within the overarching research aims outlined in section 4.2. In the sequential research design, the qualitative data collection followed

and was informed by quantitative analysis. Mixing of the data occurred both in the data collection and interpretation phases, as represented in Figure 4.1.

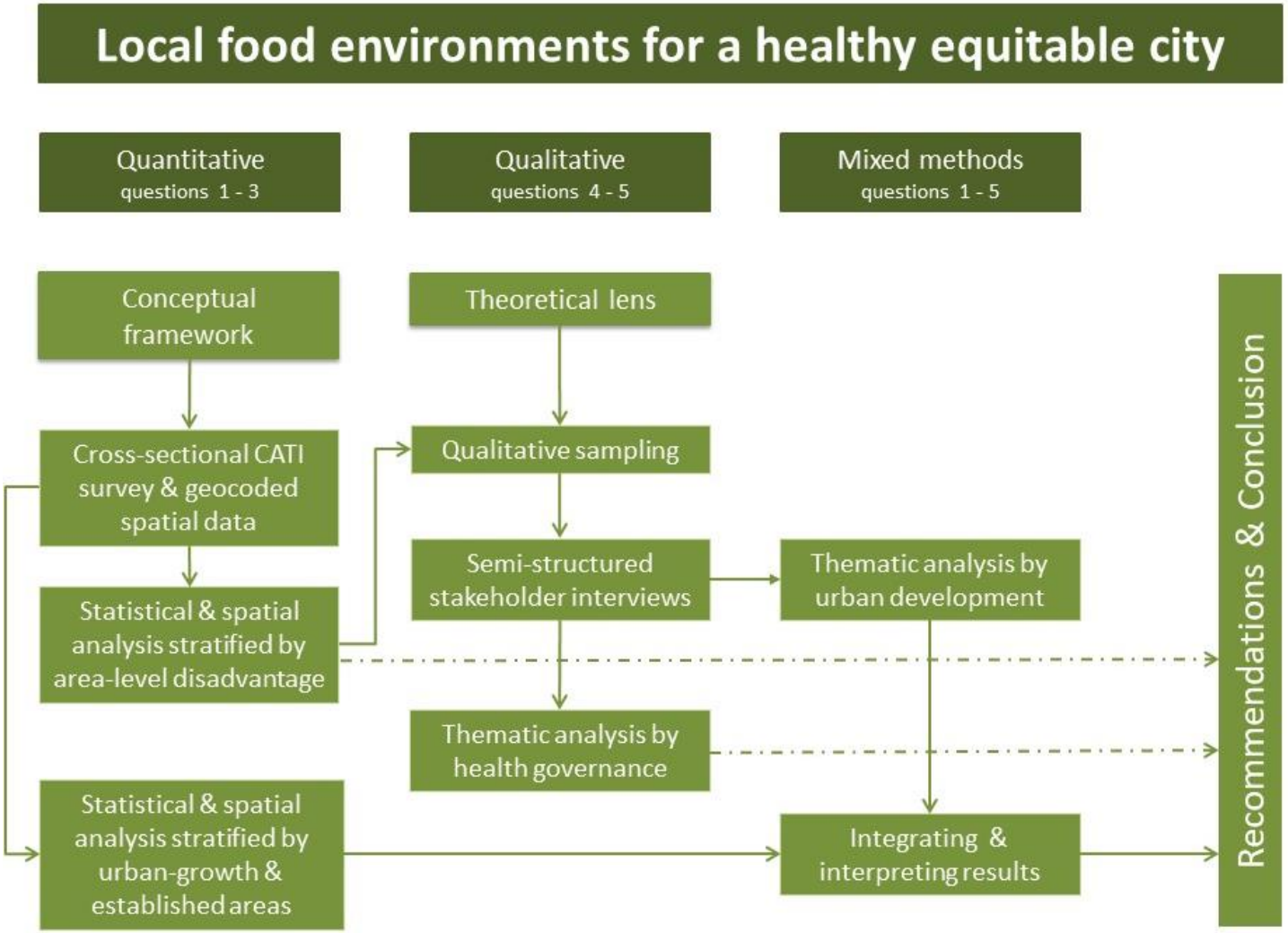

Figure 4.1. Mixed methods study design

4.3.1 Rationale for mixed methods study design

Public health researchers have argued that the complexity of public health problems requires research approaches that draw on both qualitative and quantitative methods (Baum, 1995, Grbich, 2013). Food environment researchers have echoed this call in recent years (Story et al., 2009, Dubowitz et al., 2007, Black et al., 2014), recommending use of both quantitative and qualitative approaches as a priority in future research.

A range of reasons has been identified for using mixed methods research designs, including:

- triangulation, where quantitative and qualitative findings are combined for corroboration;
- completeness, where the combining of methods provides a more comprehensive account of a phenomenon than a singular approach method;
- to answer different research questions; for explanation, where qualitative data can be used to explain quantitative findings;
- to provide contextual understanding;
- to enhance findings with a complementary approach; and
- for sampling, where one research approach is used to facilitate sampling for the second research approach (Bryman, 2016, Creswell and Plano Clark, 2011).

Mixed methods research design increases the usefulness of research findings in applied research, where, from a pragmatic viewpoint, the research is driven by practical aims and conducted for the purpose of offering a solution to an existing problem (du Toit, 2015, Creswell and Plano Clark, 2011).

The research questions, methods and rationale for selection of research method in this research are presented in Table 4.1.

Table 4.1: Research design and rationale

Research questions	Research method	Rationale
1-3	Quantitative: statistical and spatial data collection and analyses.	To test the hypothesis that food environments affect dietary and health outcomes. To empirically determine the spatial measures of food outlet access most appropriate for guiding urban planning policy to ensure equitable access and health outcomes. To inform the qualitative sampling strategy.
4-5	Qualitative: semi-structured interviewing and thematic analyses.	To increase understanding of factors that influence food environments and identify urban planning policy and governance opportunities to modify local food environments for more equitable access and improved health outcomes.
1-5	Quantitative followed by qualitative: statistical and spatial data collection and analyses; and semi-structured interviewing and thematic analyses.	To provide a comprehensive account and explanation of a little-known research area: local food environments and suburban development in an Australian context. To provide contextual understandings of factors that influence food environments across areas of varying suburban development.

4.4 Study area

Melbourne is the capital city of Victoria, with a population of 4.5 million across 31 LGAs (Department of Environment Land Water and Planning, 2016a). The Australian Bureau of Statistics (ABS) classifies Major Urban and Other Urban Sections of State as urban centres with a population of 1,000 persons to 100,000 or more (Australian Bureau of Statistics, 2011a). To address the research questions, which focus on local food environments in urban Melbourne, the study area comprised the Major Urban and Other Urban area and excluded both the less populated localities (i.e. < 1000 residents) and rural areas of metropolitan Melbourne's fringe (Figure 4.2).

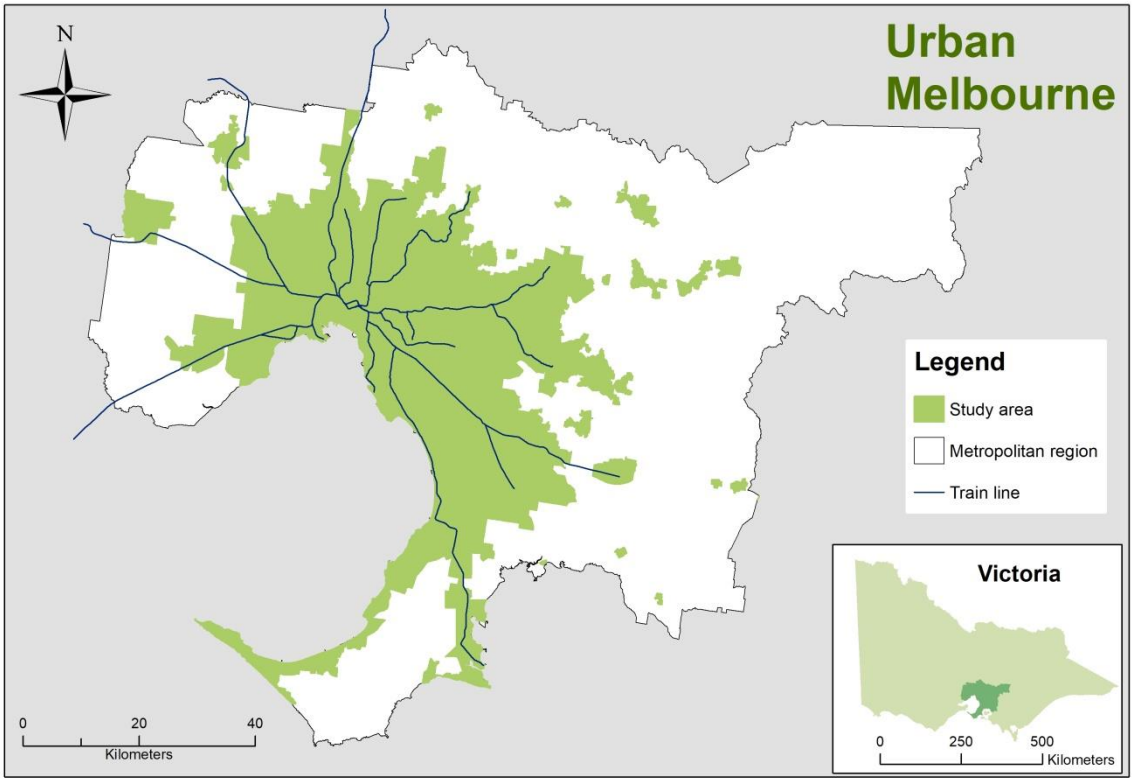

Figure 4.2. Study area - Melbourne, Victoria

4.5 Summary

This chapter described the mixed methods study design for the quantitative, qualitative and mixed methods studies. A mixed methods approach was adopted to facilitate a comprehensive investigation of each research question, and to not only provide an understanding of how food environments influence dietary and health outcomes, but to also understand and identify possible urban planning and policy responses to support healthy, equitable local food environments.

Chapter 5. Quantitative methods

5.1. Preface

This chapter presents the quantitative methods used to investigate how spatial measures of the local food environment affect dietary and health outcomes, according to the pathways depicted in the conceptual framework (chapter 3). In the conceptual framework, availability and accessibility of food outlets are neighbourhood attributes hypothesised to influence food choice.

The chapter begins with an overview of the population health survey and participant variables used in the analysis. Following the participant data description, the food outlet data and exposure variables used in the quantitative and spatial analyses are presented.

The statistical and spatial analyses were formulated to investigate measures of food access at a range of geographic scales to identify distances and densities associated with dietary intake and health outcomes. As discussed in the literature review (chapter 2), the MAUP describes the variation in results when analyses are undertaken at different spatial scales (Openshaw and Taylor, 1979). In food environment research, generating geographic buffers at different scales may influence associations between food environment exposure and dietary intake or health outcomes.

The quantitative strand of the study seeks to identify the optimal geographic scale to inform urban planning policy, and to explore whether there were differential associations between food outlet access and dietary and health outcomes across socio-economic areas. These results are reported in chapter 6. Additionally, the mixed methods study seeks to investigate measures of food access and associations with dietary intake and health outcomes across urban-growth and established urban areas. These results are reported in chapter 9.

5.2. Participant data

The Preventive Health Survey (PHS) is a self-report population health data set collected in 23 LGAs in Victoria in 2012-13 by the Victorian Department of Health and Human Services (DHHS). The aim of the PHS was to assess the prevalence of health risks among adults (≥ 18 years of age) in 12 intervention sites across Victoria where preventive health initiatives were being

implemented. Eleven non-intervention local government comparison areas were also included in the study design (Department of Health and Human Services, 2014). The PHS comprised self-reported questions on nutrition, physical activity, and smoking behaviours, and on the attitudes, beliefs and social norms that influence these behaviours. A cross-sectional, representative and randomly selected sample of 426 adults was cluster sampled from each of the 23 LGAs. The sample size was powered to detect change between the intervention sites and comparison LGAs. Primary approach letters for the PHS were mailed out on DHHS letterhead with a participant information sheet, followed up with a computer-assisted telephone interviewing (CATI) survey. The CATI was administered in English and nine community languages (Department of Health and Human Services, 2014).

The final PHS sample was 9806 respondents with an overall response rate of 62 per cent. Of the 9806 PHS respondents, 6707 (68.4%) could be geocoded to self-reported residential addresses. This enabled survey data to be linked to the spatial data. Geocoded residents who both lived within the metro Melbourne region and resided in the Major Urban and Other Urban Sections of State within the region were selected for this research, yielding a sample of 3141 participants from 12 LGAs. This focus on respondents who reside in metropolitan rather than rural or regional areas, will limit the generalisability of findings. Thirteen respondents lived in areas that did not have an Index of Relative Socio-economic Disadvantage (IRSD) score and therefore were removed from the analysis s across socio-economic areas, leaving a final sample of 3128 participants. IRSD provides an area-level score for variables associated with disadvantage, including low income, unemployment, disability, single parent households, low English-language proficiency and low levels of educational attainment, by aggregating the socio-economic census data of individuals within a geographic area (Australian Bureau of Statistics, 2013b).

5.2.1 Survey questions

The PHS questionnaire content was derived from surveys previously used for population health surveillance in Victoria and elsewhere. It comprised questions on demographics, on height and weight, on health behaviours including fruit and vegetable intake, physical activity, smoking and alcohol consumption, and on precursors to behaviour change such as knowledge, self-efficacy, habit strength and social norms (Department of Health and Human Services, 2014).

Self-reported dietary intake relies on accurate recall, placing an onerous burden on participants, and is therefore prone to error (Giskes et al., 2011, Schoeller, 1995). The under-reporting of

dietary intake has been documented in many studies (Macdiarmid and Blundell, 1998). Three commonly-used survey tools are the 24-hour dietary recall, the food frequency questionnaire (FFQ) and a brief screener. The 24-hour recall, where the participant reports everything consumed over the previous 24 hours, has the highest validity compared with other methods, and is often repeated over multiple days to estimate participants' usual dietary intake (Laraia et al., 2015). An alternate method is FFQ, which asks participants to report intake of a particular food over a specified period (Laraia et al., 2015). While less accurate, the FFQ is a pragmatic option for a survey in a large population, and was the approach adopted in the Australian National Nutrition Survey 1995 (Australian Bureau of Statistics, 2003, Australian Bureau of Statistics, 1998). A brief screener relies on several questions only, and is routinely used for surveillance purposes, however they do not reflect total or overall dietary intake (Miller and Miller, 2017).

The PHS used a self-reported brief screener for dietary intake over the previous period of two weeks. Body mass index (BMI) was assessed by calculating by weight/height^2 (kg/m^2) using self-reported weight and height data (National Health and Medical Research Council, 2013). Self-reported data are a potential source of error, where under-reporting of body weight has been noted in many studies (Nyholm et al., 2007, Rowland, 1990); however, a recent study suggested this bias has declined (Stommel and Osier, 2013).

The survey questions and variables relevant to this research are presented in Table 5.1

Table 5.1. Preventive Health Survey variables (DHHS, 2014)

Outcome variable	PHS survey question	Response scale/type
Height	How tall are you without shoes?	Numerical Continuous
Weight	Can you also please tell me what you currently weigh?	Numerical Continuous
Vegetable intake	Thinking about the last TWO WEEKS, how many serves of VEGETABLES did you typically eat PER DAY, where one serve is ½ cup of cooked vegetables or 1 cup of salad vegetables or 1 potato. Keep in mind that a meal like a vegetable stir-fry or curry might have more than 1 serve of vegetables. Please include potatoes but exclude potato crisps and vegetable juice.	Numerical Discrete
Fruit intake	Still thinking about the last TWO WEEKS, how many serves of FRUIT did you typically eat PER DAY, where one serve is 1 medium piece of fruit (like an apple, orange, banana) or 2 small pieces of fruit (like kiwi fruits, plums) or 1 cup of diced fruit or 1 and a half tablespoons of dried fruit (like sultanas). Please exclude fruit juice (even if freshly squeezed).	Numerical Discrete
Fast food intake	During the last TWO WEEKS, how often did you consume fast food, such as burgers, pizza, or hot chips from places like McDonalds, Kentucky Fried Chicken, or service stations?	Numerical Discrete
Covariates	**PHS survey question**	**Response scale/type**
Demographics	Sex, employment status	Categorical Nominal
	Age, education level, annual household income	Categorical Ordinal
Sweet drink intake	Thinking about the last TWO WEEKS, how often did you consume soft drinks, flavoured mineral water, energy or sports drinks, or cordial?	Numerical Discrete
Physical activity	In the last 7 DAYS, how many times have you walked continuously, for at least 10 minutes? This could have been for recreation, exercise, work, or as a means of transport. Each time you walked for at least 10 minutes during the last 7 days, on average, how long did you walk for each time? Now I want to ask about MODERATE physical activity that made you breathe somewhat harder than normal but did not make you puff and pant. For example, this would include housework, gardening, chopping wood, casual cycling, or carrying light loads. Thinking about these types of activities, in the last 7 DAYS, how many times did you do MODERATE physical activity for at least 10 minutes, including at work. Each time you did at least 10 minutes of moderate physical activity during the last 7 days, on average, how long was each session? Now I want to ask about VIGOROUS activity that made you breathe harder or puff and pant, such as jogging, tennis, cycling, or other types of exercise. During the past 7 DAYS, how many times	Numerical Discrete

	did you do vigorous activity for recreation, sport, work, or health and fitness purposes for at least 10 minutes? This can include work if your job is physical, such as a builder or bicycle courier, but do not include household chores in this one. Each time you did at least 10 minutes of vigorous physical activity during the last 7 days, on average, how long was each session?	
Knowledge of recommended vegetable/fruit intake	To maintain good health, at least how many serves of vegetables/fruit do health experts recommend you should eat per day?	Numerical Discrete
Self-efficacy vegetable/fruit	How confident are you that you could eat at least 5 serves of vegetables/2 serves of fruit on most days?	Five-point Likert scale
Habit strength vegetable/fruit	When you eat vegetables/fruit, it's usually in the same place and at the same time of day.	Five-point Likert scale
Social norms for vegetable/fruit/fast food	The people who are important to you think that: - you eat enough vegetables/fruit each day Just think about what you believe is the typical behaviour in your area. It doesn't matter that you won't know exactly, but just take your best guess. Most people in my local area: - eat enough vegetables/fruit each day - would eat fast food on most days of the week.	Five-point Likert scale

5.2.2 Outcome variables

The outcome variables considered were vegetable intake, fruit intake, fast food frequency and BMI. Participants were asked how many serves of vegetables/fruit they typically ate per day. A continuous variable for daily vegetable intake was created. Similarly, a continuous daily fruit intake variable was created. Participants were asked how often they consumed fast food, such as burgers, pizza, or hot chips, from places like McDonalds, Kentucky Fried Chicken, or service stations in the last two weeks. A continuous variable for frequency of fast food consumption was created. Self-reported height and weight data were collected. For the BMI analysis, a subset of the data was used; it excluded 240 participants with missing height and/or weight data, 16 participants who were pregnant, and 12 participants with extreme BMI, as applied in previous studies (Kim et al., 2006, Larson, 2006). Extreme BMI was calculated using the interquartile range (IQR) of observations where extreme outliers are defined at the lower and upper end respectively: quartile one – (3 x IQR); and quartile three +(3 x IQR) (Larson, 2006). Participants with BMI > 50kg/m^2 were therefore excluded. There were no extreme observations at the lower end. BMI was modelled as a continuous outcome, consistent with many previous food environment studies (for e.g. (Dubowitz et al., 2015b, Hirsch et al., 2014, Abbott et al., 2014, Adachi-Mejia et al., 2017)). Although categorising a continuous variable may result in loss of power in the statistical analysis (Altman and Royston, 2006), after the BMI continuous data analysis was complete in the socio-economic area analysis, BMI was modelled as a categorical

variable in a sensitivity analysis, comparing obese (≥ 30 kg/m^2) with normal-weight and overweight (18.50 – 29.99 kg/m^2) as the reference group.

5.2.3 Covariates

Socio-ecological models of health, which describe influences on health behaviour at the intrapersonal, interpersonal, community and environmental level, have been adopted by food environment researchers to depict the multiple influences on dietary intake (Story et al., 2008, Glanz et al., 2005). Demographics and psychosocial covariates (knowledge, self-efficacy, habit strength, social norms) which influence dietary intake were included in the analysis. All covariates were identified *a priori* from associations found in previous studies.

Demographics

Age, sex, education, and income are associated with dietary intake and BMI (Department of Health and Human Services, 2016a, National Health and Medical Research Council, 2013, Backholer et al., 2012, McLaren, 2007, El-Sayed et al., 2012) and are routinely adjusted for in studies. Lower fruit and vegetable intake has been associated with lower socio-economic position (Giskes et al., 2010), while higher fast food intake and purchasing have been associated with lower educational attainment (Miura and Turrell, 2014) and income (Thornton et al., 2011a).

Psychosocial

For the dietary intake analysis, knowledge, self-efficacy, habit and social norm covariates were included in the analysis. Evidence suggests that knowledge and self-efficacy are predictors of adult fruit and vegetable intake (Shaikh et al., 2008, Guillaumie et al., 2010). Participants were asked: 'to maintain good health, at least how many serves of vegetables (or fruit) do health experts recommend you should eat per day?' and 'how confident are you that you could eat at least 5 serves of vegetables (or 2 serves of fruit) on most days'. The responses were collapsed into correct knowledge/incorrect knowledge and confident/not confident. Habit is also a predictor of adult vegetable and fruit intake (Tak et al., 2013, Guillaumie et al., 2010, Brug et al., 2006). Participant responses to 'when you eat vegetables (or fruit), it's usually in the same place and at the same time of day' were collapsed into agree/not agree. Injunctive norms refer to an individual's beliefs about what is acceptable in their community, while descriptive norms refer to an individual's perception of the most usual behaviours of others (Ball et al., 2010). Vegetable, fruit and fast food intake are significantly associated with social norms for healthy eating and

fast food consumption (Ball et al., 2010). Participant responses to 'the people who are important to you think that you eat enough vegetables (or fruit) each day' and 'most people in my local area eat enough vegetables (or fruit) each day were collapsed into agree/not agree. Similarly, participant responses to 'most people in my local area would eat fast food on most days of the week' was collapsed into agree/not agree. Obesity is shown to spread in social networks. The psychosocial mechanisms by which this occurs are not known; however, it is hypothesised that they could be through social norm pathways (Christakis and Fowler, 2007).

Behavioural

For the BMI analysis, frequency of fast food intake, frequency of sweet drink intake, smoking status (current smoker/not a current smoker) and physical activity were included as covariates. Self-reported survey questions were used to assess physical activity. Participants were asked about the number of times a week they walked, engaged in moderate physical activity and vigorous physical activity, and the average session length for each. All responses were truncated at 180 minutes per day, following data truncation protocols of previous studies (IPAQ Group, 2005). Approximately 2.6 per cent of participants' walking data, 3.4 per cent of moderate physical activity data, and 0.3 per cent of vigorous physical activity data were truncated. A physical activity variable for total activity per week was created from the truncated data by summing the minutes per week of walking, moderate physical activity and vigorous physical activity (doubled prior to summing), then categorising into no activity (0 minutes), <150 minutes per week, and ≥150 minutes per week. In view of Australian government guidelines that physical activity should be accrued on most or all days of the week (Department of Health, 2014), a categorical variable was created for sedentary (0 mins/week), insufficient time and/or sessions (<150 mins or ≥ 150 mins and < 5 sessions), and sufficient time and sessions (≥150 mins and ≥ 5 sessions).

5.3. Food outlet data

Behavioural outcomes commonly found in the literature to assess healthy and unhealthy dietary intake are fruit and vegetable intake and fast food intake (Rahmanian et al., 2014, Caspi et al., 2012b, Black et al., 2014). Consistent with previous studies, access to supermarkets was used as a proxy for 'healthy food' access in the analysis. Supermarkets provide the range of foods required for a healthy and affordable diet (Bader et al., 2010, Block and Kouba, 2006), including a wide range of affordable and good quality fruit and vegetables (Laraia et al., 2015), so that

access to a supermarket has been shown to be associated with diet quality (Beaulac et al., 2009) and healthier weight (Zenk et al., 2015). In Australia, the top four major supermarket chains (Woolworths, Coles, IGA and Aldi) account for 90 per cent of market share (Tonkin, 2014). Combined with the smaller supermarket chain outlets included in this analysis (Foodworks, NQR, Costco, independents), market share is in excess of 93 per cent (Tonkin, 2014). In 2013, more than three quarters of fresh food retail distribution was through supermarkets, including independent supermarket retailers (Euromonitor International, 2017). While fresh food can be purchased through other retailers such as convenience stores and specialty retailers (including butchers and greengrocers), these only accounted for 2.5 and 15.3 per cent respectively. Further, the Australian Government estimated in 2012 that more than 72 per cent of fruit and vegetable retailing was though supermarkets, with the remainder retailed through greengrocers and markets (Spencer and Kneebone, 2012). Most people purchase fresh food in supermarkets; for this reason and other pragmatic ones, greengrocers and markets were not included in the analysis.

The top six fast food chains in Australia (McDonald's, Kentucky Fried Chicken, Subway, Hungry Jack's, Domino's Pizza, Red Rooster) were used as a proxy for 'unhealthy food' access. Together, the fast food restaurants (not including Domino's Pizza) account for more than 75 per cent of chained fast food value share (Euromonitor International, 2014). Access to unhealthy food outlets can adversely affect fruit and vegetable intake through: increased opportunity to purchase unhealthy foods; increased exposure to unhealthy food promotion; shifts in social norms and food preferences; and the lower cost of fast food per energy unit compared to fruit and vegetables (Laraia et al., 2015, Thornton et al., 2009). While fast food can be purchased in other outlets such as independent fish and chip and hamburger shops, for the pragmatic reason of the difficulty in obtaining an accurate fast food data set for the whole of Melbourne, only the major fast food chains were included.

Measures for both supermarket and fast food chain access were included in all models simultaneously to account for spatial co-occurrence of both outlet types (Lamichhane et al., 2013, Barnes et al., 2016b).

Supermarkets

A commercial dataset of geocoded supermarket outlets in metropolitan Melbourne was purchased (Pitney Bowes Ltd., 2014). Supermarket point data within 10 km of the metro

Melbourne boundary were included in the dataset. There were 708 supermarkets identified across all supermarket chains: Aldi, Coles, Costco, Foodworks, IGA (includes IGA, IGA Express, IGA Friendly and Supa IGA), NQR, and Woolworths (includes Safeway and Woolworths). The chain supermarkets were verified by cross-checking against the supermarket company website and/or with Google Maps Street View. There were also 44 Independent supermarkets in the dataset. After manual checking of the supermarket dataset, 22 of these supermarkets were found to be incorrectly located, while an additional 42 supermarkets were found on company websites that were not in the dataset. Five Thomas Dux supermarkets, owned by Woolworths Limited, were also added to the dataset. Supermarkets were included in the dataset if they were in existence in 2013, corresponding to the time when the PHS data were collected. During validation, images of the supermarket across a series of time points on Google Street View were used to determine when it was constructed; for example, two Woolworths supermarkets commenced construction in April-May 2014 in a new residential development in the growth area municipality of Wyndham in the west of metropolitan Melbourne. Prior to this time point, they did not appear on Street View as the land was undeveloped. These supermarkets were therefore not included in the analysis. All data were geocoded using ArcGIS 10.2 (ESRI, Redlands, CA, USA). After manual cleaning, checking and geocoding, the supermarket outlet dataset comprised 742 outlets within 10 km of the metropolitan Melbourne boundary (Table 5.2).

Table 5.2. Supermarkets within 10km of metro Melbourne boundary

Supermarket	Number of outlets
Aldi	85
Coles	157
Costco	2
Foodworks	81
IGA	192
Independents	43
NQR	16
Thomas Dux	5
Woolworths / Safeway	161
Total	**742**

Fast food chains

There were six fast food chains included in the fast food outlet dataset: Dominos, Hungry Jacks, Kentucky Fried Chicken, McDonalds, Red Rooster, and Subway. Geocoded fast food outlet data for McDonalds, Dominos and Subway were obtained from an open access directory of geocoded businesses (www.zenbu.org). When an address match was not found, the addresses were manually checked against company websites, White and Yellow pages listings for each fast food outlet, and/or with Google Maps Street View. Fast food outlet locations for Hungry Jacks, Red Rooster and Kentucky Fried Chicken were compiled from White and Yellow pages listings and company websites, then manually geocoded. Fast food restaurants located within 10 km of the metro Melbourne boundary were included in the dataset. After manual cleaning, checking and geocoding, the fast food chain dataset comprised 648 outlets within 10 km of the metropolitan Melbourne boundary, as presented in Table 5.3.

Table 5.3. Fast food chains within 10km of metro Melbourne boundary

Fast food chain	Number of outlets
Dominos	60
Hungry Jacks	73
KFC	116
McDonalds	174
Red Rooster	58
Subway	167
Total	**648**

5.3.1 Local food environment exposure variables

Supermarket and fast food chain outlet density and proximity measures were calculated for each participant using ArcGIS 10.2. The OD Matrix tool in the Network Analyst extension was used to calculate the density of supermarkets around each participant using road network buffers ranging from 800 m to 3000 m. The distance between the participant residence (origin) and the supermarket outlet (destination) along the road network was calculated. Road network data were sourced from VicMap Transport (Department of Sustainability and Environment, 2012), and a pedestrian road network was created by including walking and bike paths for the analyses from residential addresses at 800 m, 1000 m and 1600 m buffers, but removing freeways. Fast food outlets at freeway service-centres and at Melbourne Airport were excluded from these

analyses because they were not pedestrian-accessible. A car road network was used at the 2000 m and 3000 m buffers, which included freeway access.

Density and proximity from participant household

Density of supermarkets has been shown to be significantly associated with fruit and vegetable intake in previous studies at 2000 m, 3000 m and 4000 m buffers (Thornton et al., 2010a, Thornton et al., 2012), and protective of BMI at the 2000 m buffer (Bodor et al., 2010). Travel-mode survey data (Department of Economic Development Jobs Transport and Resources, 2016) showed that the median distance respondents in Melbourne walked to a supermarket was 660 m; the median distance they drove was 2.7 km; and the median distance they travelled by all modes including public transport was 2.2 km. Density of fast food outlets has shown positive associations with fast food intake in previous studies within 1000 m (Boone-Heinonen et al., 2011), 1600 m (Burgoine et al., 2014), and 1000 m to 2990 m buffers (Boone-Heinonen et al., 2011). Density of fast food outlets has shown positive associations with obesity risk at 1000 m (Fan et al., 2014) and 1600 m (Burgoine et al., 2014) buffers. The relative density of supermarket to fast food and supermarket chain outlet has been positively associated with healthier fruit and vegetable purchasing (Mason et al., 2013), and with fruit and vegetable intake in men (Clary et al., 2015). The median distance that survey respondents in Melbourne walked to a fast food outlet was 480 m; the median distance they drove was 3.9 km; and the median distance they travelled by all modes including public transport was 3.3 km (Department of Economic Development Jobs Transport and Resources, 2016). Informed by these studies, we selected 800 m, 1000 m, 1600 m, 2000 m and 3000 m as geographic scales to calculate food outlet density measures. Closer proximity to supermarkets has shown significant associations in previous studies for diet quality (Laraia et al., 2004), vegetable intake (Thornton et al., 2010b), fruit and vegetable intake and healthier weight outcomes (Michimi and Wimberly, 2010, Zenk et al., 2015). Proximity measures were calculated along both the pedestrian and car road networks.

Spatial distribution of supermarkets

Statistical areas level 1 (SA1) and mesh blocks (MB) are geographical areas defined by the Australian Bureau of Statistics. The SA1 administrative unit comprises approximately 400 persons (Australian Bureau of Statistics, 2011c) and a MB, the smallest geographical area, contains approximately 30 to 60 dwellings (Australian Bureau of Statistics, 2011b). (For further detail, refer to Appendix A). A spatial measure to model the proportion of all dwellings within 1

km of a supermarket was created to assess the implementation of a Victorian urban planning guideline for growth areas. The guideline specified that 80-90 per cent of households should be located within one kilometre of a town centre large enough to allow for provision of a supermarket (Growth Areas Authority, 2009. Revised 2013). Using the population-weighted centroid for each MB, being the geographic point where distance to all households is smallest (Thornton et al., 2011b), the proportion of all MBs within 1 km of a supermarket was calculated for SA1s across the study area. This was represented visually in ArcGIS to depict quintiles of access across urban Melbourne, and to calculate access in each LGA and across areas of socio-economic disadvantage.

Distances people travel to purchase food is influenced by their ability to access public or private transport (Morland, 2015a). A public transport sausage buffer layer was used that buffers 50 m either side of the street centre line. The proportion of all MBs within 400 m of a bus stop, or 600 m of a tram stop, or 800 m of a train station were calculated for each SA1 across the study area to model access to public transport. The three scales selected for each public transport mode (400, 600 and 800 m) were from Victorian urban planning policy designed to support walkable and compact neighbourhoods (Department of Environment Land Water and Planning, 2016b). The proportion of MBs achieving any of the public transport policy requirements in each SA1 was calculated across urban Melbourne. This was collapsed into tertiles, with the low access category used in the analysis. Spatial access to food outlets, differing across socio-economic areas, influences an individual's transport mode (Morland, 2015a). Private transport access was modelled using ABS vehicle ownership data at the SA1 administrative unit level (Australian Bureau of Statistics, 2016a). The proportion of dwellings with 2 or more cars was calculated and collapsed into tertiles, with the low ownership category used in the analysis.

Studies have shown that living proximally to healthy food outlets may be more important for people of low socio-economic status (Feng et al., 2010, Powell and Han, 2011). Areas of high disadvantage were identified using the IRSD (Australian Bureau of Statistics, 2013b). Using ArcGIS, areas of poor supermarket access (beyond 1 km), high area-level disadvantage (IRSD deciles 1-3), low public transport access, and low car ownership were mapped and visualised. The number of dwellings experiencing these multiple disadvantages was calculated as a percentage of the total number of dwellings in each LGA. A summary of the local food environments measures is presented in Table 5.4, with supporting references, intended scale for operationalisation, and data sources.

Table 5.4. Local food environment measures

Measure	Reference	Scale	Data source
Food outlet density			
Density of supermarket outlets	Thornton et al., 2010 Thornton et al., 2012 Bodor et al., 2010	800 m, 1000 m, 1600 m, 2000 m, 3000 m buffer	Road network: PSMA Administrative boundaries: ABS Zoning data: VicMap2012 Supermarkets: Pitney Bowes, White/Yellow pages, company websites
Density of fast food chain outlets	Boone-Heinonen et al., 2011 Burgoine et al., 2014 Fan et al., 2014	800 m, 1000 m, 1600 m, 2000 m, 3000 m buffer	Road network: PSMA Administrative boundaries: ABS Zoning data: VicMap2012 Fast food outlet: White/Yellow pages, company websites, Zenbu
Relative density of supermarket outlets: supermarket + fast food chain outlets	Mason et al., 2013 Clary et al., 2015	800 m, 1000 m, 1600 m, 2000 m, 3000 m buffer	Road network: PSMA Administrative boundaries: ABS Zoning data: VicMap2012 Fast food outlet: White/Yellow pages, company websites, Zenbu
Food outlet proximity			
Road network distance to nearest supermarket	Laraia, 2004 Thornton et al., 2010 Michimi et al., 2010		Road network: PSMA Administrative boundaries: ABS Zoning data: VicMap2012
% of dwellings within 1 km of a supermarket	Growth Areas Authority, 2009 (revised 2013)	1 km road network	Road network: PSMA Administrative boundaries: ABS Zoning data: VicMap2012
Key: ABS – Australian Bureau of Statistics; PSMA - Public Sector Mapping Agency; SA1 - statistical area level 1			

5.4. Statistical analysis

Population-weighted means and standard errors for participant demographics, outcome variables and covariates were calculated in Stata 13.0 (Stata Corp, College Station, Texas) using the population size of each sampled LGA and the number sampled in each LGA. Descriptives for local food environment access measures were calculated using means and standard deviations for density measures, and median and interquartile range for proximity measures. Generalised estimating equations were fitted to model associations between dietary intake, BMI and the food outlet access measures, adjusting for clustering at the LGA level. Separate models were fitted for each outcome (i.e. vegetable intake, fruit intake, BMI). This was a complete case analysis whereby participants with missing values on variables resulted in exclusion from the analysis. Complete case analysis by listwise deletion is the most commonly used method for dealing with missing data, however it may result in biased estimates (Acock, 2005, Schafer and

Graham, 2002). Missing data in the PHS data set ranged from <1 per cent (age) to 5 per cent (weight). Therefore, because the data set was large and the amount of missing data on each variable was relatively small, a listwise deletion was considered appropriate for the analysis. Further, other food environment studies have shown consistency in results using complete case analysis compared with other missing data handling methods such as multiple imputation (Jones-Smith et al., 2013, Thornton et al., 2011a, Lamb et al., 2017).

Analysis by area-level disadvantage

Socio-economic position negatively affects health behaviours and health outcomes at the individual level and area-level (Marmot, 2010). Accordingly, measurement of income, occupation, and educational attainment occurs at the individual level (compositional) and area level (contextual) (Lynch and Kaplan, 2000, Kawachi et al., 2002). Secondary analyses of studies in seven high-income countries found associations between area-level disadvantage and fruit and/or vegetable consumption in five of the seven countries (Ball et al., 2015). Area level disadvantage was associated with less vegetable consumption and greater fast food consumption in women in a Melbourne, Australia study (Thornton et al., 2010a). In another Melbourne study, individual-level education, occupation and household income were associated with fast food purchasing, while a trend toward association was found with area-level disadvantage (Thornton et al., 2011a). Area level disadvantage was associated with adult BMI in Melbourne, with those living in more disadvantaged areas having a higher BMI compared to those living in less disadvantaged areas (King et al., 2006). Results were stratified using the IRSD. When investigating area-level effects with an aggregated exposure such as IRSD, it is necessary to adjust for the corresponding individual-level socio-economic variables (Subramanian et al., 2007, Badland et al., 2013); therefore, the models also adjusted for educational attainment and household income. To achieve approximately even samples in each stratum, 'high disadvantage' comprised those living in IRSD deciles 1-3 (n=1079); 'mid-disadvantage' comprised those living in IRSD deciles 4-6 (n=1082); and 'low disadvantage' comprised those living in IRSD deciles 7-10 (n= 967). Stratified models were used to investigate effects over stratum of area-level disadvantage. Tests of statistical significance between strata were calculated to compare means and proportions.

Analysis by growth area-established area LGA

Melbourne is experiencing rapid population growth concentrated on the urban fringe. Six growth area LGAs on the urban fringe and a seventh outside the metropolitan boundary are expected to accommodate 42 per cent of future population growth between 2011 and 2031 (Victorian Auditor-General's Office, 2017). At the same time, the provision of infrastructure and services in new residential developments lags behind by many years (Victorian Auditor-General's Office, 2017). It is possible that uneven suburban development across Melbourne has an impact upon dietary and health outcomes; therefore, to investigate whether differential dietary and health outcomes exist for those residing in growth area LGAs compared with those residing in established areas, results were geographically stratified. Participants in the dataset lived in 12 LGAs across urban Melbourne. Six of these were growth area LGAs located on Melbourne's urban fringe, and six were located in the middle and outer ring LGAs in established urban areas. There was a similar quantum of participants in the growth areas (n=1648) and established areas (n=1493) strata. Tests of statistical significance between strata were calculated to compare means and proportions.

5.5. Ethics and data security

The Preventive Health Survey (Ethics ID: 1441599.1) was registered as approved by another Human Research Ethics Committee by The University of Melbourne Health Sciences Human Ethics Subcommittee on 27 March 2014. A data security plan to ensure confidentiality of participants in the Preventive Health Survey was developed and agreed upon following a meeting with representatives from the Victorian Department of Health and Human Services on 23 July 2014. The plan was finalised on 29 July 2014. It comprised technological security, staff security, and physical security measures to protect the identity of study participants.

5.6. Summary

The methods for the quantitative analysis, developed to investigate local food environments, dietary intake and health outcomes, are underpinned by the conceptual framework. The quantitative and spatial analyses aim to determine spatial measures of food outlet access most appropriate to inform urban planning policy to ensure equitable food access and health outcomes. The next chapter presents the results for the quantitative strand that investigated local food environments, dietary and health outcomes across socio-economic areas of urban Melbourne.

Chapter 6. Local food environments across socio-economic areas

6.1. Preface

This chapter presents the results for the quantitative and spatial analyses stratified by area-level disadvantage. The socio-economic analysis investigates food outlet access and associations from an equity perspective. It comprises two sections, one in the form of a published manuscript. Together, these address the research questions:

1. How does the local food environment influence dietary intake and health outcomes in an urban adult population aged 18 years and over?
2. Is there spatial patterning of food outlet access, dietary intake and health outcomes across socio-economic areas, and across urban-growth and established areas of Melbourne, Australia?
3. What spatial measures of the local food environment are associated with individual-level dietary intake and health outcomes, and how can they guide urban planning policy and practice?

In section 6.2, associations between supermarket access, dietary intake and BMI are reported, with the spatial distribution of supermarkets across Melbourne mapped and presented visually. These results were published in a paper titled 'Supermarket access, transport mode and BMI: the potential for urban design and planning policy across socio-economic areas' (Murphy et al., 2017b) in the journal *Public Health Nutrition* (accepted 24 July 2017).

While the focus of this publication was on supermarket outlet exposure, fast food chain exposure and a relative density measure were also investigated. The results are presented in sections 6.3 and 6.4. The analysis was informed by the conceptual framework (chapter 3) that depicted potential pathways from urban planning and other government policies to dietary intake, weight status and health outcomes. Together, four evidence-based spatial measures and a measure from urban planning policy (Table 5.4) were investigated.

6.2. Supermarket access, dietary intake and BMI

The published paper, entitled 'Supermarket access, transport mode and BMI: the potential for urban design and planning policy across socio-economic areas', investigated dietary intake, BMI and food outlet access at a range of geographic scales across areas of socio-economic disadvantage in urban Melbourne. Access measures for supermarkets and fast food chains were presented and stratified by area-level socio-economic disadvantage. Associations between supermarket access, dietary intake and BMI were reported in the paper. Geographic areas of high area-level disadvantage, poor supermarket access and transport disadvantage were represented visually in the published paper.

An analysis of the spatial distribution of supermarkets across Melbourne found that only 26 per cent of dwellings in growth areas were within 1 km of a supermarket, far less than the 80-90 per cent recommended in Victorian urban planning policy. Geographic areas that meet the urban planning policy guideline are depicted in Figure 6.1.

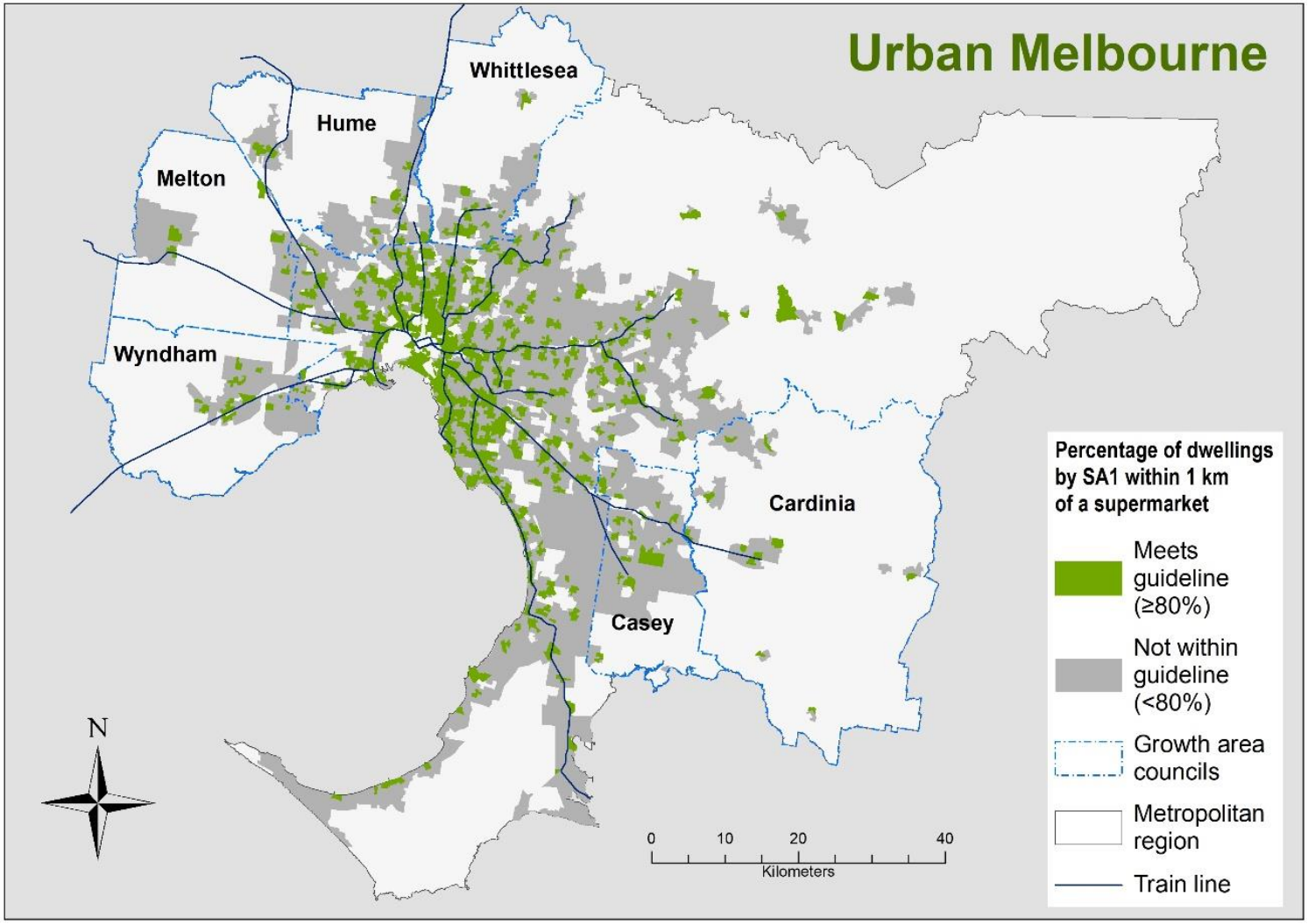

Figure 6.1. Spatial distribution of supermarket access by SA1 across urban Melbourne

Spatial data for each local government area of Melbourne (not reported in the published paper) are presented in Table 6.1. These data informed the sampling strategy for the qualitative study (section 7.3).

Table 6.1. Supermarket access in Melbourne

Local government area of Melbourne	% dwellings in high disadvantage area* and greater than 1 km to a supermarket
Greater Dandenong	50
Brimbank	48
Hume[I]	31
Darebin	22
Melton[I]	19
Casey[I]	18
Frankston	18
Maribyrnong	17
Mornington Peninsula	17
Whittlesea[I]	17
Wyndham[I]	16
Cardinia[I]	12
Hobsons Bay	11
Moreland	10
Yarra Ranges	8
Monash	7
Kingston	7
Knox	4
Maroondah	4
Whitehorse	4
Banyule	3
Port Phillip	2
Moonee Valley	1
Bayside	1
Boroondara	0
Glen Eira	0
Manningham	0
Melbourne	0
Nillumbik	0
Stonnington	0
Yarra	0

* High disadvantage area: Index of Relative Socioeconomic Disadvantage deciles 1 – 3

[I] Urban-growth local government area

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Supermarket access, transport mode and BMI: the potential for urban design and planning policy across socio-economic areas

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Abstract

Objective: To investigate dietary intake, BMI and supermarket access at varying geographic scales and transport modes across areas of socio-economic disadvantage, and to evaluate the implementation of an urban planning policy that provides guidance on spatial access to supermarkets.
Design: Cross-sectional study used generalised estimating equations to investigate associations between supermarket density and proximity, vegetable and fruit intake and BMI at five geographic scales representing distances people travel to purchase food by varying transport modes. A stratified analysis by area-level disadvantage was conducted to detect optimal distances to supermarkets across socio-economic areas. Spatial distribution of supermarket and transport access was analysed using a geographic information system.
Setting: Melbourne, Australia.
Subjects: Adults (*n* 3128) from twelve local government areas (LGA) across Melbourne.
Results: Supermarket access was protective of BMI for participants in high disadvantaged areas within 800 m ($P=0{\cdot}040$) and 1000 m ($P=0{\cdot}032$) road network buffers around the household but not for participants in less disadvantaged areas. In urban growth area LGA, only 26 % of dwellings were within 1 km of a supermarket, far less than 80–90 % of dwellings suggested in the local urban planning policy. Low public transport access compounded disadvantage.
Conclusions: Rapid urbanisation is a global health challenge linked to increases in dietary risk factors and BMI. Our findings highlight the importance of identifying the most appropriate geographic scale to inform urban planning policy for optimal health outcomes across socio-economic strata. Urban planning policy implementation in disadvantaged areas within cities has potential for reducing health inequities.

Keywords
Food environment
Urban planning policy
Obesity prevention
Health equity
Supermarket access

Dietary risk factors, including low vegetable and fruit intake, are among the leading risk factors for cardiovascular and circulatory disease, cancers, diabetes, and other non-communicable diseases[1]. The Global Burden of Diseases, Injuries and Risk Factors Study 2015 also singled out high BMI as presenting both a large and increasing risk for global disease burden[1].

Increases in dietary risk factors and BMI risk are linked to economic development and processes of urbanisation, accompanied by a shift in diets to include more fats, sugars, energy-dense and processed foods, and decreasing physical activity[1,2]. However, as cities grow and become more densely populated, recent evidence suggests that urban planning can play a protective role in reducing risk exposures and non-communicable diseases by supporting the development of health-promoting built environments[3,4]. Spatial access to food outlets, such as supermarkets and fast-food chains, is an aspect of the built environment hypothesised to influence dietary intake, BMI and non-communicable diseases[5,6]. Many studies have investigated how the location and number of food outlets in a local area influence people's health and whether spatial inequities in food outlet access contribute to dietary and health inequities[7]; however, the current evidence is limited in several ways.

First, a key challenge is the geographic scale around an individual's home at which the food environment may

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influence people's dietary and health outcomes. Few studies provide a rationale for choice of geographic scale[5,8] and it is often acknowledged as a study limitation[9]. It has been shown that associations of food outlet access with dietary and health outcomes vary depending on how an individual's local food environment is geographically defined[10,11]. Administrative boundaries, such as a census block or postcode, and circular or radial network buffers around a household[12] are commonly used to model an individual's local food environment, with buffer sizes typically ranging from 400 to 4000 m[5]. Road network buffers around the household[12] have also been applied, better representing the route an individual travels when shopping for food. A US study found that fast-food restaurants within a 1 km radial buffer of a household at census tract or postcode scale were detrimental to the BMI of men, however significant associations were not found at the smallest geographic scale (census block). Access to full-service restaurants, convenience stores and supermarkets was also investigated, finding significant associations with obesity risk at different levels of geographic scale for different food outlet types[11]. Another study examining the relationship between supermarket access and area-level socio-economic characteristics found that associations differed depending on the geographic scale used to define a neighbourhood[10]. Despite its importance for informing urban planning policy such as zoning regulations, geographic scale is understudied and not well understood in food environment research[10].

Second, spatial access to food outlets differs across socio-economic areas and is impacted by an individual's transport mode[13]. Distances people travel to purchase food is influenced by their ability to access public or private transport[13] and studies have shown that living proximally to healthy food outlets may be more important for people of low socio-economic status[14,15]. 'Food deserts', or local areas that have poor access to healthy and affordable food, may contribute to inequities in diet, BMI and non-communicable diseases[16]. In the USA, 'food deserts' in disadvantaged neighbourhoods are well documented[16,17] and access to a car is identified as a determinant of household access to healthy and affordable food[18]. In other high-income countries such as Australia and the UK, the evidence for food deserts is equivocal[16,19]. 'Deprivation amplification' describes individual or household disadvantage compounded by area-level or neighbourhood disadvantage[20]. When individuals of low socio-economic status are living in food deserts, they are exposed to a double disadvantage as their individual-level disadvantage is amplified by the area-level disadvantage of poor healthy food access[16]. If they also lack access to public transport, the area-level disadvantage is compounded further. Understanding where poor healthy food and low public transport access overlaps with area-level socio-economic disadvantage may inform efforts to reduce place-based inequities.

Several Australian studies have investigated spatial access to supermarkets across socio-economic areas[9,21]; however, these have not considered transport mode. A study conducted in forty-five suburbs in Melbourne, Australia found that participants in advantaged areas had more supermarkets within a 2 km road network buffer of their home and lived closer to the nearest supermarket than participants in disadvantaged areas[9]. In contrast, a Brisbane, Australia study found medium socio-economic areas had more supermarkets within a 2·5 km radial buffer of a census district centroid than advantaged or disadvantaged areas, and that disadvantaged areas had closest access to the nearest supermarket using a straight-line distance from centroid[21]. Another study in outer Melbourne modelled travel time to supermarkets by car, bus and walking, and estimated the proportion of residents with good access using census population data. The majority of residents (>80 %) were found to be within an 8–10 min car journey to a supermarket, considered to be good access; and advantaged areas had closer access to supermarkets[22]. While socio-economic areas and transport mode were considered, the study area was limited to one municipality and did not include supermarkets just outside the municipal boundary where residents are also likely to shop. Together, these studies highlight the considerable heterogeneity of food outlet access measures used to represent an individuals' food environment.

Third, there is limited evidence about the implementation of urban planning policy in relation to the food environment. Despite calls for policy evaluation to build the evidence base, few urban planning policies are evaluated for their impact on health risks and even fewer for their impact on health inequities[23,24].

Finally, few studies have assessed built environment attributes, dietary intake, physical activity and weight status simultaneously[25,26]. The current study was informed by a conceptual framework that hypothesises the pathway through which urban planning policies influence built environment attributes in local areas, which in turn impact individual and psychosocial factors that influence dietary intake through to weight status and long-term health outcomes[27].

The context for the study was Melbourne, Australia; however, the approach and findings have potential wider application for other cities. With 75 % of the world's population expected to be living in cities by 2050[3], it is important to understand how urban planning can support healthier food environments across diverse socio-economic areas within cities. Melbourne, the capital of Victoria, is experiencing rapid growth and urbanisation on its perimeter, with the population expected to increase from 4·5 million in 2015 to 8·0 million in 2051[28]. Victorian planning guidelines for urban growth areas specify that 80–90 % of households should be located within 1 km of a town centre large enough to allow for provision of a supermarket[29].

The aims of the current study were to: (i) investigate measures of supermarket access at a range of geographic scales to identify distances and food outlet densities most sensitive to optimal fruit and vegetable intake and BMI across strata of area-level socio-economic disadvantage; (ii) assess the spatial distribution of supermarkets across urban Melbourne by area-level socio-economic disadvantage and public and private transport access; and (iii) evaluate the implementation of an urban planning policy that provides guidance on spatial access to supermarkets.

Methods

The present study used cross-sectional data obtained from the Preventive Health Survey (PHS), a self-report population health data set with 9806 respondents collected in Victoria, Australia in 2012–13 by the Department of Health and Human Services. Data were cluster sampled from twenty-three local government areas (LGA) across Victoria. Primary approach letters for the PHS were mailed out on the Department of Health and Human Services' letterhead with a participant information sheet, followed up with a computer-assisted telephone interview survey. The aim of the PHS was to assess the prevalence of nutrition, physical activity and smoking behaviours among adults (≥18 years) and the attitudes, beliefs and social norms that influence these behaviours[30]. In the present study, data from the twelve LGA in metropolitan Melbourne were selected, specifically those participants who resided in the Major Urban and Other Urban Sections of State, an Australian Bureau of Statistics' classification that represents urban centres with a population of 1000 persons to 100 000 or more[31]. Of the 9806 PHS respondents, 6707 (68·4 %) could be geocoded to self-reported residential addresses. Of these, 3141 respondents lived in urban areas of the metropolitan Melbourne region. Thirteen respondents lived in areas that did not have an Index of Relative Socio-Economic Disadvantage (IRSD) score assigned and therefore were removed from the analysis, leaving a final sample of 3128 participants. The PHS received ethics approval from Department of Health and Human Services and the relevant university ethics committee.

Outcome variables

The outcome variables were self-reported vegetable intake, fruit intake and BMI. Participants were asked how many servings of vegetables and fruit they typically eat per day. Self-reported height and weight data were collected. For the BMI analysis, 239 participants with missing height and/or weight data, sixteen pregnant participants and twelve participants with extreme BMI (≥50 kg/m^2) were excluded, consistent with previous studies[32,33].

Covariates

All covariates were identified *a priori* from associations found in previous studies and the conceptual framework. These were age, gender, education and income[34], as well as the psychosocial and behavioural covariates detailed in the following sections. Participants with missing age and/or education data were removed from the dietary intake (*n* 57) and BMI (*n* 36) analyses.

Psychosocial covariates

For the dietary intake analysis, knowledge, self-efficacy, habit and social norm covariates were included in the models. Evidence suggests that knowledge and self-efficacy are predictors of adult fruit and vegetable intake[35,36]. Participants were asked, 'To maintain good health, at least how many serves of vegetables (or fruit) do health experts recommend you should eat per day?' and 'How confident are you that you could: eat at least 5 serves of vegetables (2 serves of fruit) on most days?' The responses were collapsed into correct knowledge/not correct knowledge and confident/not confident. Habit is also a predictor of adult vegetable and fruit intake[36,37]. Participant responses to 'When you eat vegetable (or fruit), it's usually in the same place and at the same time of day' were collapsed into agree/not agree. Vegetable and fruit intake are significantly associated with injunctive and descriptive social norms for healthy eating. Injunctive norms refer to an individual's beliefs about what is acceptable in his/her community and descriptive norms refer to an individual's perception of the most usual behaviours of others[38]. Participant responses to 'The people who are important to you think that you eat enough vegetable (or fruit) each day' and 'Most people in my local area eat enough vegetable (or fruit) each day' were collapsed into agree/not agree.

Behavioural covariates

For the BMI analysis, fast-food intake, sweet drink intake, smoking status and physical activity were treated as covariates in the models. Frequency of fast-food consumption, frequency of sweet drink consumption and smoking status (current smoker/not a current smoker) were included. Participants were asked about the number of times they did walking, moderate physical activity and vigorous physical activity, and the average session length for each. All responses were truncated at 180 min/d, following data truncation protocols of previous studies[39], and missing data were excluded (*n* 113). A physical activity variable for total activity per week was created from the truncated data by summing walking, moderate and vigorous physical activity (vigorous minutes were doubled prior to combining) minutes per week, then categorising into no activity, <150 min/week and ≥150 min/week. Following guidelines that physical activity should be accrued on most days of the week[40], a categorical variable was created: sedentary (0 min/week); insufficiently active (<150 min or ≥150 min and <5 sessions); and sufficiently active (≥150 min and ≥5 sessions).

Local food environment exposure variables

The primary exposure of interest was spatial access to supermarkets; however, measures for both supermarket and fast-food chain access were included in all models simultaneously to account for spatial co-occurrence of both outlet types[41,42]. Supermarkets provide a wide range of affordable and quality fruit and vegetables[43], foods for a healthy diet[44], and access to a supermarket is associated with healthier weight[6]. Access to unhealthy food outlets can adversely affect fruit and vegetable intake through increased opportunity to purchase unhealthy foods, increased exposure to unhealthy food promotion, shifts in social norms and food preferences, and lower cost of fast food per energy unit compared with fruit and vegetables[43,45].

Food outlet locations

A commercial data set of geocoded supermarket outlets in metropolitan Melbourne was purchased[46]. The branded supermarkets (Aldi, Coles, Costco, Foodworks, IGA, NQR and Woolworths) were verified by cross-checking against the supermarket company website and/or with Google Street View. Independent supermarkets were verified using Google Street View. Supermarket outlets were included in the data set if they existed in 2013, corresponding to the time when the PHS was collected, and comprised 742 outlets within 10 km of the metropolitan Melbourne boundary. Geocoded fast-food outlet data for McDonalds, Dominos, Subway, Hungry Jacks, Red Rooster and KFC were sourced from either www.zenbu.org or White/Yellow Pages listings and manually geocoded. All outlets were checked against company websites and/or with Google Street View. The fast-food chain data set comprised 648 outlets within 10 km of the metropolitan Melbourne boundary.

Previous studies have shown density of supermarkets to be significantly associated with fruit and vegetable intake at 2000, 3000 and 4000 m buffers[47,48] and protective of BMI at 2000 m buffer[49]. Density of fast-food outlets has shown significant associations with obesity risk at 1000 m buffer[11]. Travel-mode survey data[50] showed that the median distance respondents in Melbourne walked to a supermarket was 660 m, the median distance they drove was 2·7 km, and the median distance they travelled by all modes including public transport was 2·2 km. Informed by these studies, we selected 800, 1000, 1600, 2000 and 3000 m as geographical scales to calculate food outlet access measures.

Food outlet density, proximity and presence measures were calculated for each participant using GIS (geographic information system) software. The OD Matrix tool in the Network Analyst extension was used to calculate the distance to the closest supermarket and fast-food outlet, and the supermarket and fast-food density around each participant's home, using road network buffers ranging from 800 to 3000 m. These buffer sizes reflected the range of distances people may travel to purchase food by walking, public and private transport. Road network data were sourced from Vicmap Transport[51] and a pedestrian road network was created by including walking and bike paths for the analyses at 800, 1000 and 1600 m buffers but removing freeways. Fast-food outlets at freeway service centres and at Melbourne Airport were excluded from these analyses because they are not accessible by pedestrians. A car road network was used at the 2000 and 3000 m buffers. Proximity measures were calculated along both the pedestrian and car road networks.

Statistical analysis

Population-weighted means and SE for participant's demographics, outcome variables and covariates were reported. Data were stratified using the IRSD, which provides an area-level score for variables associated with disadvantage, including low income, unemployment, disability, single-parent households, low English-language proficiency and low levels of educational attainment. The IRSD aggregates the socio-economic census data of individuals within a geographic area[52]. When investigating area-level effects with an aggregated exposure such as IRSD, it is necessary to adjust for the corresponding individual-level socio-economic variables[53,54]; therefore, we adjusted for educational attainment and household income. To achieve an approximately even participant sample in each stratum, 'high disadvantage' comprised IRSD deciles 1–3 (n 1079); 'mid disadvantage' comprised IRSD deciles 4–6 (n 1082); and 'low disadvantage' comprised IRSD deciles 7–10 (n 967). Tests of statistical significance between strata were calculated to compare means and proportions.

Generalised estimating equations were used to model the associations between dietary intake, BMI and the food outlet access measures. The clustered nature of the data was taken into account by adjusting for clustering at the LGA level. Separate models were fitted for each outcome (i.e. vegetable intake, fruit intake, BMI). Univariate associations between each covariate and the outcome were assessed before final inclusion in the model. Following this analysis fruit intake was removed from the BMI model because it was not a significant predictor. Multicollinearity of covariates and exposure variables was assessed by calculating the variance inflation factor. No multicollinearity was present, with all variance inflation factors <2·00. Statistical significance was assessed at $\alpha < 0{\cdot}05$. Analyses were conducted using the statistical software package Stata version 13.0.

Spatial analysis

Statistical areas level 1 (SA1) and mesh blocks (MB) are geographical areas defined by the Australian Bureau of Statistics. The SA1 administrative unit comprises approximately 400 persons[55] and a MB, the smallest geographical area, contains approximately thirty to sixty dwellings[56]. Using the population-weighted centroid for

each MB, the point where distance to all households was smallest[57], the proportion of all MB within 1 km of a supermarket was calculated for all SA1 across the study area. This was represented visually in ArcGIS version 10.3.1 to depict quintiles of supermarket access across urban Melbourne. Public transport access was calculated as the proportion of MB in each SA1 within 400 m of a bus stop, or 600 m of a tram stop, or 800 m of a train station, distances found in Victorian urban planning policy to support compact and walkable neighbourhoods[58]. Private transport access was calculated using Australian Bureau of Statistics' vehicle ownership data at the SA1 level[59]. Both modes were collapsed into tertiles with the low access categories used in the analysis. Using GIS, supermarket access at 1 km was visualised with layers of area-level disadvantage[52], low public transport access and low car ownership.

Results

The majority of participants were female (61 %), secondary educated (75 %), employed (52 %) and with an annual household income less than $AU 50 000 (46 %; Table 1). The mean age was 54·1 (SE 0·31) years. Participants from high disadvantaged areas had a lower mean daily intake of vegetables ($P = 0·001$) and a higher mean BMI ($P = 0·003$) compared with those from less disadvantaged areas; however, there was no difference in fruit intake. Participants from high disadvantaged areas had a poorer knowledge of daily vegetable ($P = 0·002$) and fruit intake guidelines ($P < 0·001$); poorer self-efficacy for meeting daily vegetable intake ($P < 0·001$); less healthful habit strength for both vegetable and fruit intake ($P < 0·001$); and social norms related to poorer vegetable and fruit intake ($P < 0·001$). Trends were also found for sweet drink consumption ($P = 0·048$), physical activity ($P < 0·001$) and smoking status ($P < 0·001$) in the expected direction, with participants in high disadvantaged areas having less healthful behaviours.

Descriptions of geographic measures of supermarket and fast-food chain access by area-level disadvantage are presented in Table 2. Participants in high disadvantaged areas had better access ($P < 0·001$) to both supermarkets and fast-food outlets for all density measures compared with less disadvantaged areas. Participants in high disadvantaged areas also lived closer to the nearest supermarket ($P < 0·001$) and fast-food chain ($P < 0·001$) than those in less disadvantaged areas. Overall, 32 % of study participants had access to a supermarket within 1 km, ranging from 41 % in high disadvantaged areas to 23 % in low disadvantaged areas.

Associations of supermarket access with dietary intake and BMI across area-level disadvantage

Supermarket density and proximity were not associated with vegetable intake or fruit intake across most access measures and socio-economic areas. A statistically significant association was found for supermarket proximity and vegetable intake, and for supermarket density within the 800 m buffer and fruit intake; however, in both cases the effect size was too small (approximately 0·05 daily servings) to be of practical significance (see online supplementary material, Supplementary Table 1).

Supermarket access was protective of BMI for participants in the high disadvantaged areas within 800 m ($P = 0·040$) and 1000 m ($P = 0·032$) pedestrian road network buffers, but not for participants in mid or low disadvantaged areas. For each additional supermarket within the 800 m buffer, mean BMI decreased by 0·34 (95 % CI −0·66, −0·02) kg/m^2 and within the 1000 m buffer, mean BMI decreased by 0·30 (95 % CI −0·57, −0·03) kg/m^2. There were no significant associations within the 1600 m pedestrian road network buffer (Table 3). Associations between supermarket access and BMI along car road network buffers within 2000 and 3000 m were not significant across any stratum of disadvantage (see online supplementary material, Supplemental Table 1).

Spatial distribution of supermarkets and transport mode

Figure 1 depicts the percentage of dwellings within each SA1 of urban Melbourne that have access to a supermarket within 1 km. In urban Melbourne, 43 % of dwellings were within 1 km of a supermarket. In growth area LGA, only 26 % of dwellings were within 1 km of a supermarket. Figure 2 shows areas of high disadvantage in urban Melbourne that experience poor supermarket (beyond 1 km) and low public transport or car access. Overall, 12 % of dwellings across Melbourne were in areas of high disadvantage and beyond 1 km to a supermarket. For growth area LGA, 19 % of dwellings experienced this double disadvantage. Approximately half the dwellings in two of Melbourne's older outer-ring LGA had the double disadvantage of poor supermarket access and high area-level disadvantage (data not shown). When public transport access was considered, 2 % of all dwellings across urban Melbourne were in high disadvantaged areas and experienced poor supermarket and low public transport access, reaching a high of 12 % of dwellings in one outer-ring LGA. For growth areas, 4 % of dwellings were in geographic areas of multiple disadvantages with high area-level disadvantage, poor supermarket access and public transport access. In urban Melbourne, 2 % of all dwellings were in high disadvantaged areas and had poor supermarket and low car access.

Sensitivity analysis

Sensitivity analyses on significant results in the BMI model were conducted to explore: (i) whether significant associations within the 800 and 1000 m buffers persisted if BMI was modelled as a categorical variable, obese (≥30·00 kg/m^2) compared with normal-weight and overweight (18·50–29·99 kg/m^2); and (ii) whether significant

Table 1 Descriptive statistics of participants by area-level disadvantage; adults (*n* 3128) from twelve local government areas across Melbourne, Australia, Preventive Health Survey 2012–13

		Area-level disadvantage			
	Total	High (*n* 1079)	Mid (*n* 1082)	Low (*n* 967)	*P* value*
Demographic characteristics					
Age (years)					
Mean	54·15	56·36	53·98	51·31	<0·001
SE	0·31	0·53	0·53	0·56	
Sex (%)					
Male	38·6	37·8	39·6	38·3	
Female	61·4	62·2	60·4	61·7	0·679
Education (%)					
Primary	4·0	6·8	3·0	1·7	
Secondary	74·6	78·7	75·9	67·8	
Tertiary	21·4	14·5	21·1	30·5	<0·001
Employment status (%)					
Employed (including self-employed)	52·2	41·8	55·7	61·5	
Unemployed	4·1	5·2	3·5	3·5	
Not in labour force	43·7	53·0	40·8	35·0	<0·001
Annual household income (%)					
$AU 0–49 999	45·9	59·6	43·1	31·8	
$AU 50 000–79 999	18·1	14·7	21·7	18·1	
$AU 80 000–124 999	16·6	10·8	17·5	22·9	
≥ $AU 125 000	9·9	3·8	9·4	18·2	
Refused/don't know	9·5	11·1	8·4	9·1	<0·001
Outcome variables					
Vegetable consumption (servings/d)					
Mean	2·26	2·13	2·29	2·40	0·001
SE	0·03	0·05	0·05	0·05	
Fruit consumption (servings/d)					
Mean	1·74	1·75	1·73	1·74	0·911
SE	0·02	0·04	0·04	0·04	
BMI (kg/m^2)					
Mean	27·34	27·58	27·55	26·80	0·003
SE	0·10	0·18	0·18	0·18	
BMI category (%)					
Underweight (<18·50 kg/m^2)	1·3	1·7	1·0	1·1	
Normal weight (18·50–24·99 kg/m^2)	36·4	33·1	36·1	40·7	
Overweight (25·00–29·99 kg/m^2)	35·3	37·1	34·4	34·6	
Obese (≥30·00 kg/m^2)	27·0	28·1	28·5	23·6	0·017
Covariates: psychosocial					
Knowledge of RDI (%)					
Correct knowledge, vegetable	27·8	24·0	28·6	31·3	0·002
Correct knowledge, fruit	72·5	67·1	73·5	78·0	<0·001
Self-efficacy (%)					
Eating RDI vegetable	73·3	68·3	75·0	77·6	<0·001
Eating RDI fruit	92·8	92·1	92·5	93·8	0·336
Habit strength (%)					
Vegetable consumption	83·0	78·7	84·8	86·4	<0·001
Fruit consumption	58·2	53·8	58·9	62·8	<0·001
Social norms: injunctive (%)					
Vegetable consumption	69·5	66·7	70·6	71·9	0·033
Fruit consumption	65·0	62·5	66·4	66·7	0·082
Social norms: descriptive (%)					
Vegetable consumption	33·9	32·1	31·1	39·4	<0·001
Fruit consumption	33·4	29·3	31·0	41·1	<0·001
Covariates: behavioural					
Fast-food consumption (frequency/fortnight)					
Mean	1·12	1·15	1·08	1·14	0·709
SE	0·04	0·08	0·05	0·07	
Sweet drink consumption (frequency/fortnight)					
Mean	6·12	6·66	6·13	5·51	0·048
SE	0·20	0·35	0·36	0·31	
Physical activity (%)					
Inactive	6·8	8·4	6·3	5·6	
Insufficient activity (frequency & duration)	25·0	27·5	26·3	20·0	
Sufficient activity (frequency & duration)	68·2	64·1	67·4	74·4	<0·001
Smoking status (%)					
Current smoker	14·7	17·4	15·1	11·0	
Not a current smoker	85·3	82·6	84·9	89·0	<0·001

RDI, recommended daily intake.
*P values determined by the adjusted Wald test for continuous variables and by the χ^2 test for categorical variables.

Table 2 Geographic measures of supermarket and fast-food chain access by area-level disadvantage among adults (*n* 3128) from twelve local government areas across Melbourne, Australia, Preventive Health Survey 2012–13

	Total		Area-level disadvantage						
			High (*n* 1079)		Mid (*n* 1082)		Low (*n* 967)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* value*
Supermarket density (pedestrian road network)									
≤800 m	0·30	0·67	0·41	0·78	0·26	0·60	0·22	0·59	<0·001
≤1000 m	0·49	0·86	0·68	1·02	0·43	0·75	0·36	0·76	<0·001
≤1600 m	1·39	1·44	1·74	1·63	1·32	1·31	1·08	1·27	<0·001
Supermarket density (car road network)									
≤2000 m	2·11	1·79	2·55	1·90	2·02	1·67	1·71	1·69	<0·001
≤3000 m	4·57	2·91	5·31	2·63	4·46	2·75	3·85	3·19	<0·001
Fast-food chain density (pedestrian road network)									
≤800 m	0·24	0·68	0·36	0·85	0·23	0·65	0·12	0·45	<0·001
≤1000 m	0·43	0·94	0·62	1·13	0·39	0·87	0·24	0·71	<0·001
≤1600 m	1·29	1·67	1·74	1·90	1·24	1·56	0·85	1·35	<0·001
Fast-food chain density (car road network)									
≤2000 m	2·00	2·03	2·57	2·15	1·93	1·98	1·43	1·76	<0·001
≤3000 m	4·49	2·82	5·31	2·70	4·41	2·80	3·66	2·73	<0·001
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	
Distance to closest supermarket (pedestrian road network) (km)	1·30	0·88–1·80	1·12	0·78–1·61	1·33	0·91–1·83	1·46	1·04–1·99	<0·001
Distance to closest fast-food chain (pedestrian road network) (km)	1·55	1·03–2·19	1·29	0·89–1·87	1·58	1·06–2·22	1·74	1·26–2·47	<0·001

IQR, interquartile range.
**P* values determined by ANOVA for food outlet density and Kruskal–Wallis test for food outlet proximity.

results within the 1000 m buffer were due to the influence of supermarkets within the 800 m buffer. First, when BMI was modelled as a categorical variable, supermarket density was associated with an approximately 15 % lower odds of obesity within both 800 m (OR = 0·86; 95 % CI 0·78, 0·95) and 1000 m (OR = 0·85; 95 % CI 0·76, 0·96) pedestrian road network buffers for participants living in high disadvantaged areas. Second, a 'donut-buffer' exposure measure was created that counted the supermarkets within 801–1000 m of participants' address, following the method described in a previous study[60]. The protective effect of supermarkets for people in disadvantaged areas persisted for participants within the 800 m pedestrian road network buffer of a supermarket but was not found for the 801–1000 m donut-buffer (see online supplementary material, Supplemental Table 2).

Discussion

The current study examined dietary intake, BMI and supermarket access at a range of geographic scales across areas of socio-economic disadvantage in urban Melbourne, Australia. Participants in high disadvantaged areas had lower vegetable intake and higher BMI compared with those in less disadvantaged areas, consistent with previous studies that find a social gradient in health risks and outcomes[61]. Participants in high disadvantaged areas had better access to supermarkets and fast-food outlets than those in less disadvantaged areas, a result that contrasts with the two earlier Melbourne studies where participants in disadvantaged areas had poorer supermarket access[9,22]. However, given the present study was conducted across a larger study area and comprised 742 supermarkets, compared with fifteen and seventy-four supermarkets in the previous studies[9,22], our findings may more comprehensively and accurately represent supermarket access in urban Melbourne.

Supermarket density at 800 and 1000 m was protective of BMI for participants in high disadvantaged areas but not for those in mid or low disadvantaged areas. These results highlight the importance of investigating geographic scale and considering its differential impact across communities of socio-economic disadvantage. The effect size was greatest at the 800 m network buffer, which approximates a walkable distance of 10 min for adults[62] and is close to the median distance we identified *a priori* that people in Melbourne walk to supermarkets[50]. Sensitivity analysis suggests that supermarkets within the 800 m buffer may also be responsible for the significant association between supermarkets and BMI at the larger 1000 m buffer. Other studies have noted that proximal access to supermarkets may be more important for people in disadvantaged areas because they are less mobile and have access to fewer resources, including income, transport[15] and time[63]. Our findings support the hypothesis that close access to supermarkets in disadvantaged areas provides opportunities to regularly purchase affordable fresh foods while reducing reliance on transport modes other than walking.

Table 3 Generalised estimating equations models of associations between BMI and measures of supermarket access among adults (*n* 2712) from twelve local government areas across Melbourne, Australia, Preventive Health Survey 2012–13

BMI (kg/m²)*	Total			Area-level disadvantage: High (*n* 923)			Mid (*n* 937)			Low (*n* 852)		
	β	95 % CI	*P* value	β	95 % CI	*P* value	β	95 % CI	*P* value	β	95 % CI	*P* value
Supermarket density												
≤800 m (pedestrian road network)	−0·032	−0·367, 0·303	0·852	−0·337	−0·660, −0·015	0·040	0·014	−0·767, 0·796	0·971	0·292	−0·306, 0·890	0·339
≤1000 m (pedestrian road network)	−0·012	−0·242, 0·218	0·919	−0·296	−0·566, −0·025	0·032	0·034	−0·712, 0·780	0·929	0·273	−0·220, 0·766	0·278
≤1600 m (pedestrian road network)	0·082	−0·126, 0·290	0·441	0·006	−0·345, 0·356	0·974	0·151	−0·116, 0·419	0·267	0·071	−0·153, 0·295	0·537

*Adjusted for age, sex, education level, income, vegetable intake, frequency of sweet drink consumption, frequency of fast-food consumption, physical activity, smoking, fast-food chain access and clustering at the local government area level.

Counterintuitively, supermarket access was not associated with vegetable and fruit intake at a level of practical significance at any geographic scale or stratum of disadvantage. These results are consistent with a previous review that found supermarket access was consistently associated with lower BMI but not dietary intake[25]. It is possible that the null findings may be explained by the complexities in measuring dietary intake when it relies on participants' accurate recall[25,43]. Further, a larger sample and more comprehensive measures of a healthy diet may be required to detect associations. For example, a recent study of more than 9000 adults found significant associations between supermarket access and diet quality[64]. Future research could also include additional measures of dietary intake consistent with dietary guidelines including grains, lean meat and dairy[65]. However, the BMI analysis produced an expected result, possibly because the model comprehensively captured and adjusted for multiple influences impacting weight status, including intakes of fast foods and sweet drinks, smoking status and physical activity[25]. While the present study was concerned primarily with the influence of supermarket access on dietary intake and BMI, the gradient in the knowledge and self-efficacy (vegetables) covariates across socio-economic strata is important to note (Table 1), representing an opportunity for targeted public health interventions in disadvantaged areas, such as skill development and social marketing, to reduce inequities. Additionally, while knowledge, self-efficacy, habit strength (vegetable) and injunctive norms were consistently associated with dietary intake across socio-economic strata, habit strength (fruit) and descriptive norms were weak predictors of dietary intake (data not shown). In summary, the current investigation of supermarket access found that BMI was sensitive to both geographic scale and socio-economic disadvantage, and identified walkable distances of 800 and 1000 m as protective of BMI for participants in disadvantaged areas. Notably, the 1000 m buffer corresponds to the distance to supermarkets recommended in Victorian urban planning policy[29]. This threshold informed subsequent analysis of supermarket access.

Spatial analysis of the distribution of supermarket access across Melbourne using a 1 km distance threshold was investigated and small geographic areas of double disadvantage were identified where high area-level disadvantage was compounded by poor supermarket access. While most households were not vulnerable, a sizeable proportion of dwellings – 12 % or 187 000 households across urban Melbourne, and more than 60 000 households in growth area LGA – were in high disadvantaged areas and experienced poor supermarket access. When public transport opportunities were considered, most striking was the multiple disadvantages observed in older outer-ring municipalities. In addition, if frequency of public transport (particularly bus services) had been included, actual access to supermarkets would likely be

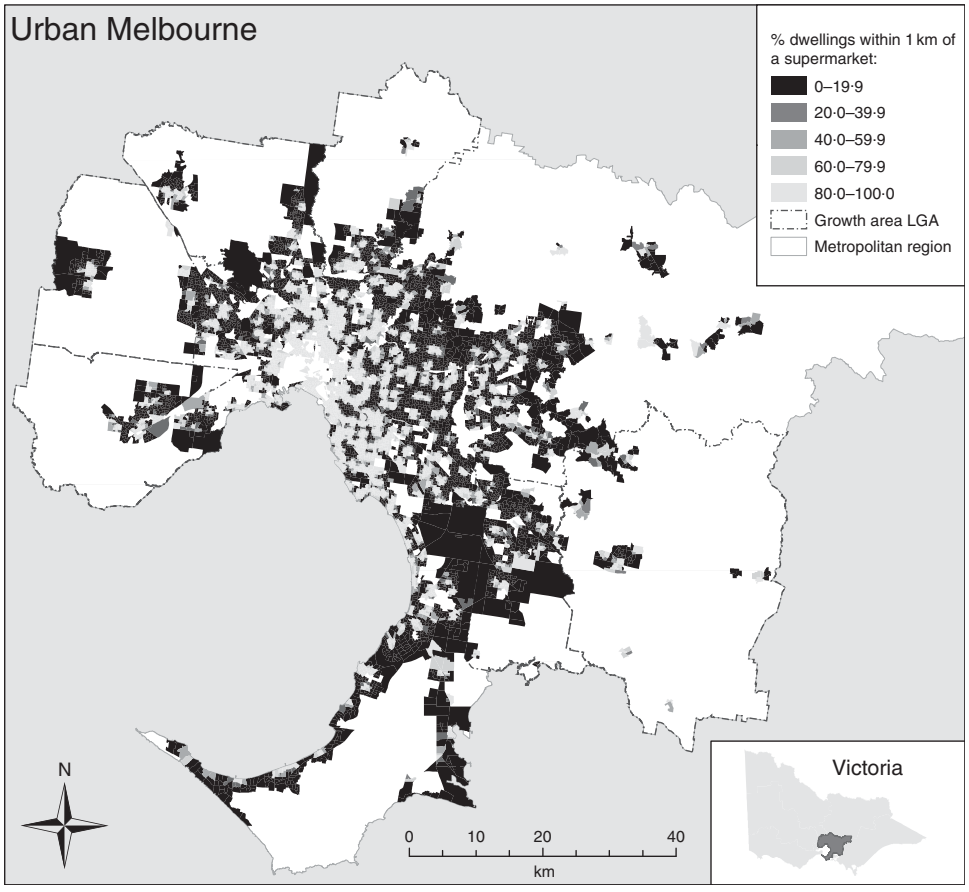

Fig. 1 Spatial distribution of supermarket access at SA1 level across urban Melbourne, Australia: percentage of dwellings within 1 km road network distance to the nearest supermarket (SA1, statistical areas level 1; LGA, local government area)

worse[66] given low public transport service levels in outer areas of Melbourne[67].

The WHO calls on policy makers to understand and assess determinants of health inequities within cities, of global importance as cities experience rapid urbanisation and growth on urban fringes[68]. Our study evaluated the implementation of an urban planning policy providing guidance on supermarket access. In growth area LGA, only 26 % of dwellings were within 1 km of a supermarket, far less than the 80–90 % of dwellings suggested in the policy guideline[29]. We showed that access to health-promoting resources such as supermarkets and public transport was not evenly distributed across Melbourne, and identified geographic areas of disadvantage where inequities in access overlap. The socio-spatial patterning suggests that policy implementation should be prioritised in high disadvantaged areas across urban Melbourne, not just those within growth areas. The study highlights the utility of spatial research for identifying areas of multiple disadvantages where communities are most vulnerable and provides fine-grained data to inform urban planning policy and practice for healthier food environments.

We offer two key recommendations based on our study. First, we highlighted the importance of geographic scale in food environment research. The heterogeneity of food access measures in the literature is vast and few are theoretically or conceptually informed. It is important to identify the most appropriate geographic scale for optimal health outcomes that also considers transport mode and socio-economic areas. Second, our study showed that supermarket access had a differential impact on BMI across socio-economic strata, suggesting the importance of equity analyses in future food environment studies. The present study makes an important and timely contribution to the evidence on urban health, equity and food environments and demonstrates the potential of urban planning policy to improve health and reduce health inequities.

Our analysis had several strengths. First, we considered access to both supermarkets and fast-food chains simultaneously to account for spatial co-occurrence or clustering of fast-food outlets around supermarkets[41,42]. Second, a rigorous approach to food outlet verification was adopted; validating commercial business lists with comprehensive cross-checking against company websites, White/Yellow Pages listings and Google Street View. Sourcing accurate and comprehensive spatial data across large geographic areas is noted as a limitation in

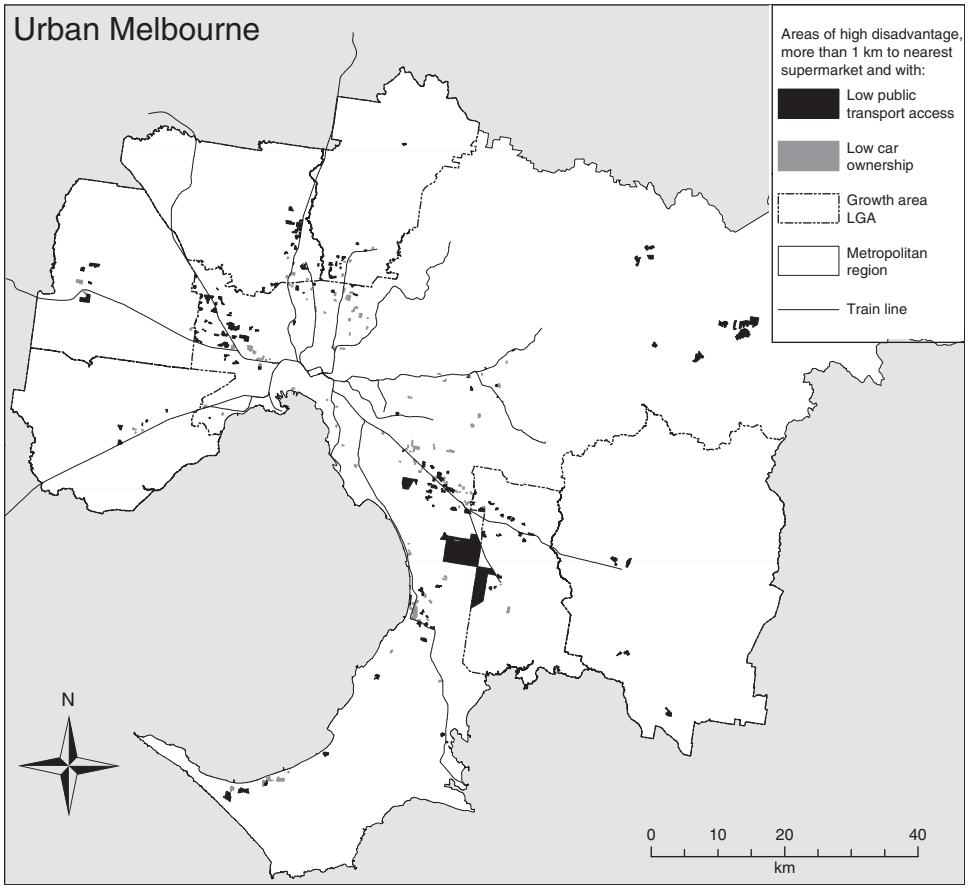

Fig. 2 Geographic areas of high disadvantage across urban Melbourne, Australia where distance to the nearest supermarket by road network is more than 1 km and with low public transport access or low car ownership

many studies[69]. Third, food outlet exposure data and health outcome data were contemporaneous[70]. However, there were limitations to the data used in our study. The food environment exposure variables did not include greengrocers, therefore underestimating the true food environment where people purchase vegetables and fruit; and supermarkets were used as a proxy of healthy food access even though unhealthy foods can be purchased there. Neither did we analyse in-store food environments (e.g. price, promotion of food) and other food environment exposures (e.g. near workplaces or outdoor advertising) that are also likely to influence dietary intake and BMI. Third, MB population-weighted centroids were used to calculate the spatial distribution of supermarkets and public transport access. While variation in MB size is reduced by considering only urban areas in the metropolitan region, spatial uncertainly exists. Using the interquartile range as the measure of spread, the variation in the spatial extent of the MB area was 2·09 ha. The mean and median MB area were 4·72 and 2·94 ha, respectively (data not shown). Other data limitations include self-reported rather than objectively measured health data, and cross-sectional survey data that are unable to determine causality.

Conclusion

The current study found that the local food environment differentially impacted BMI of people living in disadvantaged areas. Replication of these findings in other rapidly growing cities could assist in developing urban planning guidelines aimed at improving access to healthy food outlets across socio-economic areas. The importance of the study is that it provides evidence to guide policy interventions and suggests a way forward to reduce inequities by prioritising implementation of healthy food and public transport access policies in disadvantaged areas. The study offers useful insights into methodology and findings for other food environments studies in urban settings.

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Supplementary material

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Supplementary Table 1 and Table 2 from the published paper are provided in Appendix B.

6.3. Fast food chain access, dietary intake and BMI

In this section, associations between fast food chain access, dietary intake and BMI are reported.

Fast food chain outlet density within buffers ranging from 800 m to 3000 m was not associated with frequency of fast food intake across any strata of disadvantage (Table 6.2). Fast food chain density within 2000 m was associated with lower BMI for people living in high disadvantage areas (*P* = 0.040) (Table 6.3). For each additional fast food chain outlet within 2000 m buffer along the car road network, mean BMI decreased by 0.18 kg/m^2 (95% CI -0.35, -0.01). There were no significant associations within the 800 - 1600 m pedestrian road network buffer or within the 3000 m buffer. Correlation between the fast food chain outlet density and supermarket density was investigated, with a moderate positive relationship (r=0.56) found within the 2000 m buffer in high disadvantage areas.

Table 6.2. GEE models of associations between frequency of fast food intake and fast food chain density for urban PHS participants

	Area-level disadvantage											
	Total			High (*n* 1059)			Mid (*n* 1058)			Low (*n* 954)		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI	
Fast food intake (frequency/fortnight) *												
Fast food chain density												
≤ 800 m (pedestrian road network)	-0.013	-0.097,	0.070	0.001	-0.112,	0.114	-0.052	-0.152,	0.048	0.026	-0.377,	0.429
≤ 1000 m (pedestrian road network)	-0.036	-0.101,	0.029	-0.041	-0.166,	0.084	-0.028	-0.100,	0.044	-0.029	-0.168,	0.109
≤ 1600 m (pedestrian road network)	-0.029	-0.068,	0.011	-0.060	-0.122,	0.003	-0.031	-0.070,	0.007	0.023	-0.055,	0.101
≤ 2000 m (car road network)	0.015	-0.050,	0.080	0.025	-0.076,	0.125	0.016	-0.048,	0.079	-0.002	-0.055,	0.051
≤ 3000 m (car road network)	0.005	-0.026,	0.036	0.000	-0.072,	0.072	0.018	-0.015,	0.051	0.018	-0.025,	0.060

BMI = body mass index; CI = confidence interval; m = metre
* Adjusted for age, sex, education level, income, social norm (descriptive), supermarket access and clustering at the LGA level

Table 6.3. GEE models of associations between BMI and fast food chain density for urban PHS participants

	Area-level disadvantage											
	Total			High (*n* = 923)			Mid (*n = 937*)			Low (*n* = 852)		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI	
BMI (kg/m^2) *												
Fast food chain density												
≤ 800 m (pedestrian road network)	0.019	-0.245,	0.284	0.081	-0.355,	0.516	-0.017	-0.596,	0.562	-0.275	-0.992,	0.442
≤ 1000 m (pedestrian road network)	0.120	-0.061,	0.301	0.150	-0.204,	0.505	0.144	-0.372,	0.661	-0.055	-0.488,	0.378
≤ 1600 m (pedestrian road network)	-0.124	-0.253,	0.005	-0.216	-0.528,	0.096	-0.032	-0.307,	0.243	-0.167	-0.397,	0.064
≤ 2000 m (car road network)	-0.027	-0.111,	0.058	-0.177	-0.346,	-0.008‡	0.039	-0.132,	0.209	-0.011	-0.226,	0.203
≤ 3000 m (car road network)	-0.067	-0.148,	0.015	-0.160	-0.346,	0.026	-0.050	-0.231,	0.130	-0.067	-0.163,	0.030

BMI = body mass index; CI = confidence interval; kg = kilogram m = metre
* Adjusted for age, sex, education level, income, vegetable intake, frequency of sweet drink intake, frequency of fast food intake, physical activity, smoking status, supermarket access & clustering at the LGA level; ‡ $P < 0.05$

6.4. Relative density of supermarkets and fast food chains and BMI

In this section, associations between the relative density of supermarkets to fast food chains and BMI are reported. A relative density exposure measure for supermarket and fast food chain access was created in which 1 was added to both the numerator and denominator to avoid null values:

[supermarket outlet + 1] ÷ [supermarket outlet + fast food chain outlet + 1].

The range of supermarket and fast food chain outlets within each buffer is presented in Table 6.4.

Table 6.4. Range of supermarket and fast food chain outlets within each buffer by area-level disadvantage

		Area-level disadvantage		
	Total	High (*n* = 1079)	Mid (*n* = 1082)	Low (*n* = 967)
	Range	Range	Range	Range
Supermarket outlets				
≤ 800 m	0-4	0-4	0-4	0-4
≤ 1000 m	0-7	0-7	0-5	0-6
≤ 1600 m	0-9	0-9	0-6	0-8
≤ 2000 m	0-10	0-10	0-9	0-9
≤ 3000 m	0-20	0-19	0-19	0-20
Fast food chain outlets				
≤ 800 m	0-6	0-6	0-5	0-5
≤ 1000 m	0-8	0-7	0-5	0-8
≤ 1600 m	0-10	0-10	0-9	0-8
≤ 2000 m	0-10	0-10	0-10	0-9
≤ 3000 m	0-13	0-13	0-13	0-12

m; metre
Range; smallest count of outlets - largest count of outlets

For the relative density exposure measure, significant positive associations were detected within 2000 m and 3000 m buffers for people living in high disadvantage areas: BMI increased as relative density increased. Among participants in high disadvantage areas, for each 10 per cent increase in the relative density measure, mean BMI increased by 0.13 kg/m^2 (95% CI 0.01, 0.24) within 2000 m buffer and by 0.31 kg/m^2 (95% CI 0.09, 0.53) within 3000 m buffer (Table 6.5).

Table 6.5: GEE models of associations between BMI and measures of food outlet exposure for urban PHS participants

	Area-level disadvantage											
	Total			High (*n* = 923)			Mid (*n* = 937)			Low (*n* = 852)		
	β^	95% CI		β^	95% CI		β^	95% CI		β^	95% CI	
BMI (kg/m²) *												
Relative density [l]												
≤ 800m (pedestrian road network)	-0.033	-0.136,	0.069	-0.027	-0.193,	0.139	-0.003	-0.178,	0.173	-0.015	-0.245,	0.214
≤ 1000m (pedestrian road network)	-0.065	-0.159,	0.028	-0.019	-0.177,	0.138	-0.118	-0.280,	0.044	0.015	-0.148,	0.178
≤ 1600m (pedestrian road network)	0.057	-0.036,	0.149	0.167	-0.002,	0.336	0.004	-0.163,	0.172	0.082	-0.050,	0.214
≤ 2000m (car road network)	0.026	-0.052,	0.103	0.128	0.014,	0.242‡	0.037	-0.091,	0.164	-0.002	-0.172,	0.169
≤ 3000m (car road network)	0.040	-0.068,	0.148	0.310	0.089,	0.530†	-0.043	-0.240,	0.154	0.033	-0.057,	0.122

BMI = body mass index; CI = confidence interval; kg = kilogram m = metre

* Adjusted for age, sex, education level, income, vegetable intake, frequency of sweet drink intake, frequency of fast food intake, physical activity, smoking status & clustering at the LGA level

[l] [supermarket outlet + 1] : [supermarket outlet + fast food chain outlet + 1] x 100 %

^ β coefficients were estimated for ten per cent increase in relative density

‡ $P < 0.05$; † $P < 0.01$

6.5. Summary

This chapter presented the results of the quantitative and spatial analysis for access to food outlets across socio-economic areas. The results showed that there were few significant associations between dietary intake and food outlet access, and any statistical associations present were not of practical significance. Supermarket density within 800 m and 1000 m, however, was associated with BMI for participants residing in high disadvantage areas, such that BMI decreased as supermarket density increased. Unexpectedly, fast food density within 2000 m of a residence was associated with lower BMI for participants in high disadvantage areas. Also, unexpectedly, the relative density measure was positively associated with obesity in high disadvantage areas, suggesting that an increase in the number of supermarkets as a proportion of all outlets is associated with increases in BMI.

The findings indicate that geographic and socio-economic differences in the local food environment exist, and that they have implications for urban planning policy and practice. In responding to the first three research questions (section 6.1) therefore, the results provide guidance on spatial thresholds for urban planning policies to improve food environments and health outcomes. Additionally, they provide insights that suggest tailoring or prioritising policy implementation and interventions to specific geographic areas by food outlet type. The implications of these findings will be discussed in Chapter 10.

Chapter 7. Qualitative methods

7.1. Preface

This chapter presents methods for the qualitative study, which addresses the research questions:

4. What contextual factors influence the availability and accessibility of food outlets in urban areas of Melbourne, a city experiencing rapid growth and suburban development?
5. What are the governance barriers and opportunities to support the development of a healthy, equitable local food environment?

Health governance and accountability frameworks were used to develop the interview guide and to analyse data. The chapter begins with a review of the theoretical frameworks that underpinned the qualitative study. Next, the methods for the data collection and thematic analysis are described, followed by a section on ethics.

As previously noted, the overarching research aims (section 1.3) of this thesis were to conceptualise and develop local food environment indicators to inform urban planning policy and practice, and to identify governance actions to advance healthy, equitable local food environments within cities. By addressing research questions four and five, the qualitative data and analysis supports translation of the spatial indicators identified in the quantitative and spatial analysis into urban planning policy and practice.

7.2. Theoretical lens

This study is informed by health governance and accountability frameworks. Governance for health is defined as 'the attempts of governments or other actors to steer communities, countries or groups of countries in the pursuit of health as integral to well-being through both whole-of-government and whole-of society approaches' (Kickbusch and Gleicher, 2012). Actions and processes of health governance, defined by Barbazza and Tello (2014), included enabling partnerships, policy development, generating information and intelligence, system design, participation and consensus, regulation, transparency and accountability. A similar typology of governance actions was conceptualised for World Health Organization member states, with nine categories of action: evidence support, setting goals and targets, coordination, advocacy, evaluation, policy guidance, financial support, legal mandates, and implementation (McQueen

et al., 2012b). Ruger's (2011) shared health governance model emphasised the interdependent roles of public, civic and private sector actors, with government at the centre, and a joint commitment, shared goals and shared responsibility for health and healthy equity (Ruger, 2011). Kickbusch and Gleicher's (2012) governance for health approach requires policies and joint action from both within and outside the health sector and government, drawing upon collaboration, engaged citizens, regulation and persuasion, and adaptive policies (Kickbusch and Gleicher, 2012).

Health governance frameworks were adopted as a theoretical lens. These theoretical frameworks recognise the range of government and non-government actors that have a role in influencing health and health equity and that can assist in identifying the governance actions required to move forward to improve health and health equity. These frameworks were used to inform and guide stakeholder interviews, and in subsequent analysis to identify the roles, responsibilities and accountabilities of individual stakeholders as well as the potential for shared goals and commitments. The health governance frameworks were suited to the applied research focus of the study, which aimed to offer a practical solution to an existing problem (du Toit, 2015).

Stakeholder interviewing was also guided by Kraak and colleagues' (2014) four-step accountability framework to promote healthy food environments . This framework involves: assessing evidence, policies and practices that impact upon food environments; communicating evidence among stakeholders; identifying opportunities and barriers to advance healthy food environments; and establishing monitoring and accountability structures (Kraak et al., 2014). It was used as a tool to assist in the structuring of the interview guide (see section 7.4)

7.3. Sampling strategy

Purposive sampling is a qualitative research sampling method that selects information-rich cases for in-depth study (Liamputtong, 2013). Unlike random and statistically representative sampling used in quantitative studies, purposive sampling is aimed at seeking an in-depth understanding of the phenomena of interest (Patton, 2002).

State and local government participants were approached if they had a role in influencing the development of local food environments through urban planning or public health regulation or policy. Non-government and private sector participants were approached if they had a role in urban planning or public health policy that influenced the development of local food

environments, or for their advocacy/coordination on local food environments. Table 7.1 depicts the regulatory, policy and advocacy/coordination roles of potential key stakeholder participants.

Table 7.1. Key stakeholders: roles and responsibilities that influence the development of local food environments

Stakeholder	Regulatory	Policy	Advocacy/coordination
State government			
Urban planning	*Planning and Environment Act 1987* Sets the statewide planning scheme and policy. Develops strategic urban planning policy. *Victorian Civil and Administrative Tribunal Act 1998* Decides applications by permit applicants, permit holders, objectors, and responsible authorities involving disputes over the use and/or development of land.	State Planning Policy Framework	Establish coordinating structures that bring together key stakeholders from public and private sector during the development of large-scale urban planning strategies such as precinct structure plans.
Health	*Public Health and Wellbeing Act 2008* Identify public health and wellbeing needs of people in the state and establish priorities to promote and protect health	Victorian public health and wellbeing plan: statewide plan developed every four years	Statewide coordination of public and private sector stakeholders on healthy food environments within in settings (e.g. schools) and within the community.

Stakeholder	Regulatory	Policy	Advocacy/coordination
Local government			
Urban planning	*Planning and Environment Act 1987* Planning authority: sets local strategic policy framework and initiates amendments to the planning scheme, which are subject to Planning Minister approval; and Responsible authority: administers the planning scheme (including zones and overlays)	Prepare a municipal strategic statement that sets the key strategic planning, land use and development objectives for the municipality, and the strategies and actions for achieving those. Adopts other local policies and strategies to include in the planning scheme (e.g. transport plans).	Establish coordinating structures that bring together key stakeholders from public and private sector during the development of local urban planning and other policies. Advocates on behalf of community.
Health	*Public Health and Wellbeing Act 2008* Identify public health and wellbeing needs of people in the municipality and establish priorities to promote and protect health	Prepare a municipal public health and wellbeing plan every four years with strategies and actions for achieving these. Must be consistent with municipal strategic statement. Adopts other policies and strategies, as required, to address health issues (e.g. food security plan).	Local coordination of public and private sectors stakeholders on health priorities, food access and food security.
Non-government organisations & peak bodies			
		Provide policy guidance. Documenting and disseminating best practice.	Advocates and lobbies government on behalf of members, the community, or in pursuit of organisational priorities. Facilitating and bringing together stakeholders across sectors and portfolios.
Private sector urban planners, designers & architects			
		Provide expertise to government, developers, supermarket chains and others on urban and retail planning during strategic planning, design and implementation.	

Note: Table data compiled from web searches, stakeholder interviews and Land use planning in Victoria: Councillor Guide 2016 (Municipal Association of Victoria, 2016b)

7.3.1. Purposive sampling

The qualitative study used two purposive sampling strategies to select participants, plus criterion sampling and snowball sampling. Criterion sampling identifies and selects those cases that meet a predetermined criterion, while snowball sampling uses existing participants to

identify additional information-rich cases (Palinkas et al., 2015, Patton, 2002). A two-stage purposive criterion sampling strategy was used to select local government participants.

First, criterion sampling was used to select three established area and two growth area LGAs that had a high proportion of dwellings experiencing poor supermarket access in areas of high disadvantage (data from the quantitative and spatial analysis, see Table 6.1). These geographic areas pertain to the findings of the quantitative strand where proximal supermarket access within 1 km was shown to be protective of BMI for people who live in areas of high socio-economic disadvantage. Sampling extreme cases of poor access provides insights or lessons that can be used to guide remedial policy and other interventions (Creswell and Plano Clark, 2011). Figure 7.1 depicts the first stage of the sampling strategy.

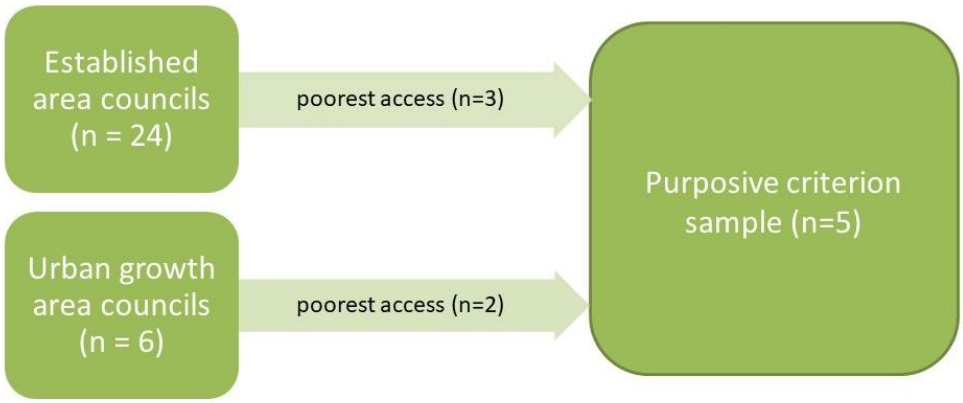

Figure 7.1 Purposive criterion sampling of local government areas

In the second stage, potential participants at the executive or managerial level within these selected councils were identified from the local government websites, a social media networking website (www.LinkedIn.com), and the researcher's networks. For local government participant recruitment, while the urban planning directorate within Council was identified as a key point of contact, food environment responsibilities were dispersed across portfolios of local government and were also within the remit of economic development and the health and community service portfolios. If the sampling was not successful - that is, if the council declined to participate or did not respond - the criteria were used to identify other councils from either the established or growth areas with poor supermarket access.

Snowball sampling was also used to identify potential participants. At the end of key informant interviews, participants were asked to suggest other people within their Council or organisation who could be meaningfully interviewed.

7.3.2. Recruitment

Using the aforementioned sampling methods, policy elites were recruited for the qualitative study, that is, those individuals with influence over the policy development process and institutional decision-making (Baker, 2013). Participant recruitment occurred via email with a Plain Language Statement and consent form attached to the invitation (see Appendix C). Prior to interview, signed consent forms were received from all participants.

7.4. Key stakeholder interviews

Semi-structured interviews were considered appropriate to gain an in-depth understanding of key stakeholder perceptions of the development and planning of local food environments (Silverman, 2015).

From December 2016 to August 2017, semi-structured interviews with 27 participants were conducted in Melbourne (response rate of 75 %). All interviews, except one, were conducted face-to-face. The interview were guided by a thematic question schedule, but also adapted in response to comments made by interviewees (Silverman, 2015). The interview guide was informed by the theoretical frameworks, specifically Ruger's (2011) shared health governance model and Kraak and colleagues' (2014) accountability framework (Table 7.2). For further detail, refer to Appendix G.

The interviews sought to collect information about: the roles and responsibilities of actors across government and other sectors in the development of local food environments; relevant urban planning and other policy mechanisms; influences on decision-making; and governance opportunities and barriers to advancing healthy food environments. Prior to interviewing stakeholders, the interview guide was pilot-tested with a local government urban planner and a private sector one to refine questions (Creswell, 2013). A two-page report summarising research findings from the quantitative strand (Chapter 6) with maps depicting supermarket and transport access by area-level disadvantage was sent to each participant before the interview (see Appendices C and D). These documents were referred to during the interview to prompt discussion about roles and responsibilities for the development of local food environments.

Table 7.2. Interview Guide

Introduction	*Local food environments are defined as the places in an urban area or neighbourhood where people shop for food within a 20-minute walking or short driving distance from home.* Role of interviewee.
Policies and practice	Role of interviewee's organisation and other stakeholders that influence food environments in local area. Urban planning policies and guidelines that influence local food environments. Barriers to and facilitators of healthy food environments in local area.
Data and evidence	*Quantitative and spatial data for local government area or urban Melbourne presented.* Stakeholder responsibilities for acting on healthy food access. Accessing, utilising and acting on quantitative and spatial data and food environments. Influences on decision-making about food environments
Responsibilities and collaboration	Assessing existing partnerships on local food environments Opportunities for intersectoral collaboration to advance local food environment.
Leadership and governance	Developing a shared commitment. Policies, practice and governance structures. Critical success factors for healthy food environments. Prospects for the future.

7.4.1. Transcription

All interviews were audio-recorded and transcribed using a transcription service provider (www.rev.com). Transcripts were checked by reading through the transcript while listening to the audio-recording. Participants were provided with the opportunity to review and amend the transcript.

7.4.2. Analysis

Participants were coded according to their level of government or sector, and portfolio. Transcriptions and initial data analysis were undertaken during the interview period. Open coding and focused coding were used to assign data into categories, with constant comparison across categories to develop and synthesise broad, overarching themes from the data (Silverman, 2015, Skeat, 2013). Qualitative data were examined and re-examined, according to the iterative process of qualitative data analysis (Silverman, 2015). Memos were created to summarise emerging themes under nodes and coding categories (Silverman, 2015). Through this iterative process, recurring patterns or themes emerged from the data consistent with a thematic analysis approach (Skeat, 2013, Liamputtong and Serry, 2013). Transcription and initial

data analysis were undertaken during the interview period. Transcription and initial data analysis were undertaken during the interview period. The collecting and concurrent analysis of data are verification strategies to ensure reliability and validity during the conduct of the qualitative study (Morse et al., 2002). The 'information power' approach guided the sample size (Malterud et al., 2015), such that the specificity of the study aim, selection of participants with knowledge and experiences relevant to the study aim, and the high-quality interview data suggested that the sample had sufficient information power to address the research questions. The governance frameworks (Kickbusch and Gleicher, 2012, McQueen et al., 2012a, Ruger, 2011) were applied as an analytic lens across emergent themes. Data analysis was undertaken using NVivo 11 (QSR International, Melbourne, Australia). The coding framework is available in Appendix F.

7.5. Ethics and data security

Ethics approval for the qualitative strand of the study was granted by The University of Melbourne Human Ethics Advisory Group (HEAG) (Ethics ID 1648132.1) on 25 November 2016. Transcribed interviews were stored electronically on a password-protected computer system. Participants were referred to with descriptors where 'LG' denotes local government participant, 'SG' denotes state government participant, 'NG' denotes non-government participant, and 'PS' for private sector participants. The link between participant name and the descriptor was kept in a separate password-protected file. While interview data was kept confidential and participants de-identified, there was only a small number of interviews conducted, so it is possible that a participant may be identified by the nature of their responses and point of view.

7.6. Summary

This chapter presented the methods for the qualitative strand which was informed by health governance and accountability frameworks. The qualitative methods were developed to facilitate data collection that responds to research questions four and five. The selection of the local government areas in the two-stage purposive sampling strategy for the qualitative data collection was guided by the results of the quantitative and spatial analysis. Semi-structured interviews with 27 participants from state and local government, non-government and private sector organisations were conducted, with the data coded and analysed using health governance frameworks. The next chapter presents the results of the qualitative analysis.

Chapter 8. Local food environments, urban planning policy & governance

8.1. Preface

This chapter presents the findings from qualitative interviewing and analysis that was used to understand the urban planning and governance opportunities to advance healthy equitable local food environments. The qualitative strand investigated government, non-government and private sector perspectives on their roles and responsibilities in the development of local food environments and identified urban planning policy and governance actions and processes to support healthy and equitable food access.

The results have been published in a paper, 'Local food environments: Australian stakeholder perspectives on urban planning and governance to advance health and equity within cities' (Murphy et al., 2018b) in the journal *Cities & Health* (accepted 16 August 2018).

The study identified a range of stakeholders across government and the private sector that potentially have a role to play in creating healthy food environments. However, responsibilities and accountabilities are not clear and, in some cases, contested across sectors (Eckert and Shetty, 2011), across health and urban planning disciplines (Kent and Thompson, 2012), and across levels of government (Shill et al., 2012). The study identified urban planning and policy levers available to stakeholders to influence food environments, demonstrating the potential of governance and collaboration among stakeholder for meeting emerging urban health challenges, including equitable access to healthy food environments.

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Local food environments: Australian stakeholder perspectives on urban planning and governance to advance health and equity within cities

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ABSTRACT

Urban planning policy has the potential to improve population health outcomes and reduce health inequities within cities. In Australia, however, the pathways for implementing policy approaches are unclear, and responsibilities are contested and dispersed across sectors, portfolios and levels of government. This study investigated government, non-government and private sector perspectives on spatial planning for local food environments and aimed to identify governance opportunities to advance healthy equitable food access. Informed by health governance frameworks, 27 key informant interviews with policymakers and practitioners from urban planning, public health, urban economic and partnership development were conducted in Melbourne, Australia, a city experiencing rapid growth. Stakeholders identified regulation, urban planning policy, finance, coordination and partnerships as key governance processes for the creation of healthy food environments; political leadership as a driver for action; and distributed leadership as essential for implementation. Urban health is a recurring theme in the UN Sustainable Development Goals with targets for health and wellbeing, and sustainable urbanisation. Our study contributes to an understanding of the governance actions required to deliver healthy equitable urban food environments, and demonstrates the importance of comprehensive action, particularly when two of the potentially most powerful levers, regulation and finance, are weak.

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Introduction

Rapid urban growth within cities is a global health challenge, linked to decreased physical activity and increases in dietary risk factors, obesity and non-communicable diseases (NCDs) (Commission on Social Determinants of Health 2008). Major risk factors for obesity and NCDs include poor diet and low physical activity (G.B.D. Risk Factors Collaborators 2017), and there is strong evidence that targeting these risk factors at the population level through policy interventions is more cost-effective and equitable than targeting at the individual level (Backholer *et al.* 2014, Capewell and Capewell 2017). Ecological models that describe the individual-level, socio-cultural, environmental, and policy influences on health behaviour have been applied to dietary intake (Glanz *et al.* 2005, Story *et al.* 2008). Evidence-based urban planning and design policy has potential to improve dietary and health outcomes and reduce inequities within cities (Commission on Social Determinants of Health 2008, Rossen and Pollack 2012). Consequently, the World Health Organization (WHO) calls for urban planning approaches to reduce NCDs (World Health Organization 2013). National health and urban planning organisations such as the American Planning Association (2007), Public Health England (Pinto 2017) and the Australian Medical Association (2016) are converging on similar urban planning recommendations targeting healthy food access for obesity prevention (Sallis *et al.* 2012). In Australia, a 2012 parliamentary *Inquiry into Environmental Design and Public Health in Victoria* recommended that health be incorporated into urban planning regulatory and policy frameworks (Parliament of Victoria 2012). Furthermore, the inquiry recommended state government support spatial mapping of food outlets at the municipal level, and the development of a planning mechanism to limit the oversupply of fast food outlets in communities (Parliament of Victoria 2012).

Local food environments are small geographic areas where people shop for food within a walkable or short driving distance from home (Morland 2015). Evidence suggests that spatial access to food outlets may be associated with diet and diet-related health outcomes; however, research findings are inconclusive (Caspi *et al.* 2012, Zenk *et al.* 2015). Key methodological challenges relating to the measurement of food environments and dietary intake may account for inconsistent findings (Caspi *et al.* 2012, Black *et al.* 2014, Cobb *et al.* 2015). Nevertheless, trends

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have emerged that suggest access to supermarkets is associated with healthier dietary intake and lower body weight, whereas access to fast food outlets may be associated with unhealthy dietary intake and higher body weight (Black *et al.* 2014, Lake 2018). Proximal access to supermarkets may be more important for population sub-groups with access to fewer socio-economic resources or for those that live in disadvantaged areas (Feng *et al.* 2010, Burgoine *et al.* 2017, Murphy *et al.* 2017b). Despite recommendations for urban planning interventions, studies involving Australian local government policy-makers in the Australian states of Victoria and Queensland found little support for action on food environments beyond nutrition education and food safety regulation (Allender *et al.* 2012, Good *et al.* 2010). Another study explored the views of state government policy-makers across Australia about regulatory interventions for healthy food environment (Shill *et al.* 2012). It noted that participants proposed interventions that were the responsibility of local and federal government rather than state government, suggesting a deflection of responsibility to other levels of government (Shill *et al.* 2012). The study also found government silos were a barrier to policy action on healthy food environments (Shill *et al.* 2012), a finding echoed in other studies (Cullerton *et al.* 2016). Hence, urban planning policy has potential to improve access to healthy food outlets and limit access to unhealthy outlets; however, pathways in Australia for implementing these policy approaches are unclear, and responsibilities are contested and dispersed across portfolios and levels of government.

Governance frameworks provide insight into policy development processes and draw attention to a range of 'actors' – those individuals, organisations, groups and institutions that influence the process (Buse *et al.* 2012). Kickbusch and Gleicher (2012, p. 4) define governance for health as 'the attempts of governments or other actors to steer communities, countries or groups of countries in the pursuit of health as integral to well-being through both whole-of-government and whole-of society approaches'. They contend that wicked problems such as obesity require a diffusion of governance away from state-centred models, and towards multiple levels of governance co-produced by government, non-government, private sector actors, and citizens (Kickbusch and Gleicher 2012). Similarly, health governance literature argues for a move toward horizontal, networked or shared governance, which have multiple sources of power and activity across a diverse range of actors (Ruger 2011, Barbazza and Tello 2014). The 'Health in All Policies' (HiAP) approach is one such governance for health strategy that is grounded in intersectoral, whole-of-government, whole-of-society action to promote health (Kickbusch and Gleicher 2012). The literature suggests that governance is a determinant of urban health and healthy equity (Vlahov *et al.* 2007, Barten *et al.* 2011, Corburn and Cohen 2012). To assist WHO member states in achieving health and health equity, an analytic framework was developed describing the nine key actions and processes underpinning governance, including goal-setting, coordination, advocacy, policy guidance, evidence, legal mandate and finance (Mcqueen *et al.* 2012). A review of health governance literature identified a similar typology of governance processes including participation and consensus, partnerships, policy development, information and intelligence, system design, regulation and accountability (Barbazza and Tello 2014).

A range of policy actors from government, non-government and private sectors have a role in influencing the development of local food environments. In the United States (U.S.), Canada and the United Kingdom (U.K.) local food policy councils and coalitions have emerged that bring together diverse stakeholders to influence government food policy and improve healthy food access at the local and regional level (Broad Leib 2013, Caraher *et al.* 2013, Clayton *et al.* 2015). In the United States, there are more than 280 food policy councils (Calancie *et al.* 2018), and in the United Kingdom, there are more than 50 sustainable food cities (King 2017). However, in an Australian context, food policy coordinating platforms are relatively new (Department of Health and Human Services 2014, Mccartan and Palermo 2017). The aims of this study were to explore stakeholder perspectives on urban planning policies and other factors that influence the development of local food environments, and to identify governance opportunities to advance healthy equitable local food environments. The focus of the study was on the availability and accessibility of supermarkets and fast food chain outlets in Melbourne, in the state of Victoria, Australia. The Melbourne metropolitan region is experiencing rapid population growth and densification, with a population of 4.5 million across 31 local government areas, including six growth area councils on the urban boundary (Department of Environment Land Water and Planning 2016). It is projected that Melbourne's population will almost double to 8.0 million by 2051 (Department of Environment Land Water and Planning 2016).

Methods

Theoretical framework

This study is informed by governance frameworks. Ruger's (2011) shared health governance model emphasises the interdependent and shifting roles of public,

civic and private sector actors with government or a designated agency at the centre. Furthermore, joint commitment, shared goals and shared responsibility for health and healthy equity are key elements of the model (Ruger 2011). Similarly, Kickbusch and Gleicher (2012) governance for health approach requires policies and joint action from both within and outside the health sector and government, which draw upon collaboration, engaged citizens, regulation and persuasion, and adaptive policies. These frameworks informed the interview guide and were applied as a theoretical lens to themes arising from the study data.

Study background

This study draws upon previous research undertaken on the associations between supermarket access, transport mode and BMI in urban Melbourne. Briefly, this research found that supermarket access within 800 m and 1000 m of participant household was protective of BMI for people living in high disadvantaged areas, and suggested that urban planning policy interventions to prioritise supermarket access in disadvantaged areas may have potential for reducing health inequities (Murphy *et al.* 2017b). A two-page report with research findings and maps depicting supermarket and transport access by area-level disadvantage across Melbourne was sent to participants in the current study prior to interview. The results of the previous research were referred to during the interview.

Participants

A two-stage purposive sampling strategy was used to select participants. Purposive sampling is a qualitative research sampling method that selects information-rich cases for in-depth study and covers a range of sampling strategies including criterion sampling and snowball sampling (Patton 2002, Palinkas *et al.* 2015). First, criterion sampling was used to select municipalities in metropolitan Melbourne with high area-level disadvantage and poor supermarket access beyond 1 km (data not shown). Second, potential participants at the executive or managerial level who worked for the local government authority in selected municipalities were identified from Council websites and the authors' networks. Similarly, participants from state government, non-government and the private sector who had a role in influencing the development of healthy equitable food environments in Melbourne were identified through websites and authors' networks. They were invited to participate via an initial approach email with a plain language statement and consent form attached to the invitation. Informed consent was gained from all participants prior to interview. Using a snowball sampling approach, all recruited interviewees were asked to identify other people to interview from local or state government or the non-government and private sector that had a relevant role.

Data collection

Semi-structured interviews were considered appropriate to gain an in-depth understanding of key stakeholders perspectives on the development of local food environments (Silverman 2015). From December 2016 to August 2017, semi-structured interviews with 27 participants were conducted in Melbourne. All interviews, except one, were conducted face-to-face; and all interviews, except one, were conducted one-on-one. The interview guide sought to collect data on: the roles and responsibilities of actors across government and sectors in the development of local food environments; urban planning policy and other mechanisms that have an influential role; influences on decision-making; and governance opportunities and barriers to advance healthy food environments. Prior to the data-collection period, the interview guide was pilot-tested with a local government and private sector urban planner to refine questions (Creswell 2013). All interviews were audio-recorded and transcribed, and participants were provided the opportunity to review and amend the transcript.

Analysis

Transcriptions and initial data analysis were undertaken during the interview period. Open coding and focused coding were used to assign data into categories, with constant comparison across categories to develop and synthesise broad, overarching themes from the data (Skeat 2013, Silverman 2015). Memos were created to summarise emerging themes under nodes and coding categories (Silverman 2015). The governance frameworks (Ruger 2011, Kickbusch and Gleicher 2012, Mcqueen *et al.* 2012) were applied as an analytic lens. Data analysis was undertaken using NVivo 11 (QSR International). Ethics approval for this study was granted by The University of Melbourne (Ethics ID 1648132.1).

Results

There were 27 participants from local government (LG), state government (SG), non-government (NG) and private sector (PS) organisations across portfolios of: urban planning and design; health and community services; urban economics and economic development; partnerships and coordination (Table 1). Several participants had worked in multiple sectors,

bringing perspectives from both government and private sectors. The average interview length was 50 min.

Influences on local food environments

Participants reported a range of factors that influence the development of local food environments, from the proximal influences at the individual and socio-cultural level to the more distal macro-environment influences that include urban planning, economic and other government policies.

Individual-level and socio-cultural factors

Participants perceived that the demographics, socio-economic position, food preferences and shopping behaviours of residents influenced the availability of food outlet types in local areas. For example, local government stakeholders from culturally diverse municipalities reported that culturally diverse grocery stores and takeaway food outlets established in their municipalities to meet local demand and preference for foods. Furthermore, one stakeholder noted that 95 per cent of food premises in their municipality were multicultural, and explained that:

> At the retail level, food remains very easy, no barriers to entry, business for any new arrival to get into. It's easy to go, "What am I going to do here in Australia now that I've arrived? I'll just begin by doing what I know, [which] is cooking food for my own culture." LG6

Local government, state government and private sector participants described how the socioeconomic position of residents influenced the type and size of food outlets in a neighbourhood. In more affluent established residential areas, there was a demand for regular food purchasing opportunities on the way home from work where people were 'running smaller kitchens, smaller fridges and more frequent shops' (LG13). Consequently, smaller supermarkets with higher prices had emerged in these areas. In contrast, large supermarkets with extensive car parking dominated the food environment in outer suburban areas where 'people will go do their full trolley shop less frequently' (PS1). In these areas, a stakeholder noted that 'a larger format [supermarket] can deliver that critical mass and keep their prices relatively low' (SG2).

Table 1. Participant characteristics.

	Portfolio				
Sector	Urban planning and design	Health and community	Economics	Partnerships and coordination	Total
Local government	9	3	1	-	**13**
State government	4	3	1	1	**9**
Non-government	-	2	-	1	**3**
Private sector	2	-	-	-	**2**
Total	**15**	**8**	**2**	**2**	**27**

Macro-level factors

According to participants from across state and local government and the private sector, land availability and ownership were macro-level environmental factors that influenced the availability and accessibility of food outlets. Local government stakeholders reported that the size and configuration of available land parcels was a constraint on food outlet access:

> They'll [supermarket chain] only pay so much for a piece of land, they want a particular sized piece of land, it can't be bigger or smaller, they'll only have one template. We've shown them heaps of sites and . . .they don't want the site because it's too skinny or it's this or it's that. LG1

Land availability was also perceived to affect the accessibility and connectivity of food outlets with local walking and cycling paths. One local government had a policy to support active transport to shops and services 'but it's not always possible to get a piece of land that will be allowing us to make those connections' (LG8). Population size also influenced the availability of food outlets, with participants reporting that population catchments of between 8000 and 10,000 residents were required for a major supermarket to establish. Local government authorities can 'work with developers and often with a supermarket, however they're going to need a population base to support the development of a supermarket' (LG5).

Urban planning policies for land use, housing density, urban design and transport planning were identified by participants from all sectors and levels of government as mechanisms that influence food outlet access. By using these policy levers in tandem, local and state government stakeholders described how they were able to influence local food environments. For example, one participant reported that local government improved food access by re-zoning land to increase housing density within a walkable distance of existing retail outlets and services:

> We've just re-zoned huge amounts of land throughout the municipality. . . with the intention of how to get more people closer to the services, to your shops, to your community facilities. . . . whether that's shops, community centres, medical, whatever it might be. LG7

Stakeholders noted that the provision of public transport was important for food access in socioeconomically disadvantaged areas, and that local government played a key role in 'making sure that there's advocacy for really good public transport. . .. having the

awareness of the existing socioeconomically disadvantaged areas' (LG3).

While land use zoning was an urban planning policy lever that could influence local food environments, there were also limitations noted by stakeholders. It was described as a 'blunt tool' (SG3) by a state government participant, and a local government participant described how it offered 'limited control at a planning, local government planning perspective'(LG7). For example, 'we'll zone something, say Commercial 1 Zone, that allows for a supermarket but that also then doesn't prevent a fast food takeaway establishment going on that same site – they're all supported within those zones' (LG7).

The urban planning legislation was described as 'the head of power for the policy and the planning schemes' (SG8) and provided the objectives that 'cascade down into the land uses' (SG8). Hence, local government were limited in their capacity to influence local food environments through urban planning policy because the regulatory framework and planning scheme did not provide an authorising environment 'to control the food offering' (LG9). The planning scheme was described by a state government participant as one which 'minimises prohibitions' and 'much more of a discretionary system' (SG8). Local government participants commented on 'poor integration between health and planning' (LG1) and noted the case for a 'stronger objective in terms of health' (LG3) in the legislation. Further, a private sector participant described a 'planning system and a planning ethos in Victoria, which was very much market-led, rather than public interest-led' (PS2).

In summary, participants identified factors in the individual, socio-cultural and macro-level environments that influenced the development of local food environments. Urban planning policy and legislation were among the macro-environment factors that both enabled and limited healthy food access. These are considered further in the following sections as processes of governance.

Governance for healthy equitable local food environments

Participants described the barriers and opportunities for advancing healthy equitable local food environments, which have been analysed through the lens of governance frameworks (Ruger 2011, Kickbusch and Gleicher 2012, Mcqueen *et al.* 2012). The governance actions and processes identified were: regulatory frameworks; urban planning policy; finance; coordination and partnerships; political leadership activated by data and evidence; and distributed leadership with shared goals for implementation. A summary of the key barriers and opportunities with illustrative quotes for each of the governance processes is presented in Table 2.

Regulation

The regulatory framework was identified as a governance process that offered limited potential for supporting healthy food access. For example, a local government participant described that:

> Our health area was looking at trying to restrict takeaway outlets so that people will have a preference to go and eat fresh food. You can't do that under the planning scheme …there's been no attempt to try and make a differentiation between takeaway, unhealthy and something else, that's not available in the scheme as a concept. LG1

Another local government participant noted the 'fundamental disconnect between health promotion and land use planning' (LG9). There was agreement among stakeholders that the planning system lacked controls or provisions to support healthy food access or to limit unhealthy food access. The deregulated nature of the planning framework was identified as a key concern by one local government participant, 'less red tape, less red tape, that's the mantra, isn't it? Less red tape. In fact, what the evidence is saying is that we need more red tape. You know what I mean? It means more regulation at different levels, not less' (LG2). Without a strong regulatory framework, participants identified the free market as a key determinant of food access.

Several participants raised a high-profile case where a Melbourne community objected to a planning permit for a fast food chain but were unsuccessful despite community activism, wide publicity and 'hundreds and hundreds of objections' (NG3). Until there was regulatory reform, participants from state government, local government and non-government organisations emphasised the importance of utilising other governance levers:

> At the end of the day, we decided the best thing to help communities is let them know that at this point in time, they can't change that [state regulation and legislation]. To stop people burning up energy on that…..that's not doable just now. It doesn't mean you don't keep advocating for it, but this is what you can control. SG9

Finance

According to local government participants, the allocation of funding and investment to support the development of healthy food access was critical. When asked about the barriers they confronted, one local government respondent reported that in a 'rate-capped environment' (LG8), the ability of local government to raise revenue through property tax was

Table 2. Governance for healthy equitable local food environments: summary of key barriers and opportunities.

Governance action	Barriers	Illustrative quotes	Opportunities
Regulation			
	Lack of integration between urban planning and health	*We can't say specifically that restricted retail, that food and drink premises must not be a McDonald's.… we can't get to pick and choose as planners, which one it is. We can make the area available for commercial, and we just don't get to pick and choose what goes in there. LG9*	Integrate urban planning and public health legislative frameworks.
	Neoliberal regulatory framework	*Because the Planning and Environment Act and the planning scheme is privileged toward the market, what that means is at a local government level, the capacity for us to embed social justice and health principles in that becomes really at the margins at best.…it [the Act] is about facilitating investment and developers, and private investment, not necessarily public investment. LG2*	Advocate to state government for legislative change.
	Local government has limited control over municipal planning scheme	*The planning scheme is centralised, so you can't get anything through unless the [state] government agrees to it and that's become even worse now it's more centralised… the local policy must be consistent with what the zone can actually allow you to do. LG1*	Advocate to state government for legislative change.
Finance			
	Funding deficit for active transport infrastructure to improve access to retail centres.	*What we can do is that we can improve the parts of the transport system which we control, so we can improve footpaths, we can improve bicycle lanes. What we can do too, is work in the area of advocacy. One area which we're advocating for currently is to establish a high frequency bus network which would link the train station with the shopping centre…we're advocating that there should be a 10-minute service, which does that loop. LG5*	Advocate to state government for funding for public and active transport infrastructure.
	Funding deficit for public transport infrastructure and services in growth areas.	*[Outer growth areas will] keep growing and getting more and more car dependent, as much as we might profess to say that's not a great thing or that we're going to support them with good public transport, the reality is it's not going to happen. There's not the money at the state level to support these new suburbs with really good public transport – I see things getting worse out there. SG8*	Implement a comprehensive value capture scheme to finance major infrastructure works and services.
Urban planning policy			
	Healthy food access, by itself, is not a priority within urban planning	*There is more of a focus on the walkability…. through the planning process, in terms of access to strictly speaking healthy food; it's probably not something we look at. But in terms of access to services, it's something we look at, community facilities, those type of things, whether they're all within that 20-minute range, to be able to get to local shops or to the local library, those type of things. LG7*	Housing, land use and urban design policy used together can influence local food environments.
Coordination and partnerships			
	Responsibilities for healthy food access is dispersed across many stakeholders, and no one agency is accountable.	*I think the issue about food, it's so multi-dimensional, and it works across government in many different facets. There's the export part, there's the innovation, there's the business part that's looking at getting companies to have technology to make products that sell overseas. There's the horticulture, the agriculture, there's … water and land and urban planning. It's that bringing it together for the whole and understanding that the views across government come from perspectives, but at some point, that pulling it together is quite challenging. SG9*	Harness on-going statewide and regional food and place-based coordinating platforms to create healthy local food environments.
Leadership			
	Competing priorities	*At some point, it's going to hit through and the stars will align. Unfortunately, I think as we've seen with family violence, which is terrible, that we've got to get to the point where it's a crisis. We know the data from population health; we're heading towards very unhappy places with the* [obesity] *data. SG9*	Political leadership at state and federal government level activated by worsening health outcomes. Political leadership at local government level influenced by local fine-grained local data
	Siloed approaches	*It's been the trajectory of where communities faced with traditional siloed approaches being relatively ineffective against these emergent challenging wicked problems. Climate would be a good one, health might be another. In reforming that, people are now much less concerned with big 'G' government and they're more interested in governance and how groups of institutions particularly, spatially organised in a region or a place, work together collaboratively to produce outcomes. SG7*	Distributed leadership and shared goals across multiple levels of government and sectors. Civil society advocating for and driving change.

limited, creating a reliance on federal and state government investment. Several participants referred to previous federal government obesity prevention funding that had been used to support spatial mapping and urban planning policy initiatives that targeted food environments. In one instance, an urban planner was funded to sit within a public health team of local government to build capacity and strengthen coordination across urban planning and health.

Participants from all sectors identified walking, cycling and public transport infrastructure as a funding priority, in recognition that access to food outlets and access to transport were interdependent. Public transport infrastructure funding was considered to be 'the least controllable element' (PS1), however private sector participants pointed to land value capture as a way forward. Described as a 'new governance instrument that integrates transit, land use and finance' (Newman *et al.* 2016), it hinges on the proposition that land values increase after the provision of infrastructure such as urban rail. Therefore, participants argued that governments should recover some of this increase from private landowners 'for building the infrastructure in a timely way' (PS2). There was concern that the lack of public infrastructure and services in new residential areas would lead to poorer health outcomes for people living in these areas compared with the well-serviced and less affordable inner-city areas. The implications of this uneven access to infrastructure and services was noted by one state government participant:

> The proximity that you will have in a 20-minute neighbourhood to a whole variety of services will in fact lead to a lot of people wanting to live there. What we do notice is that those suburbs then become very unaffordable for people who really would benefit from having all that proximity. SG6

Participants described how the lack of government investment in preventive health was impeding efforts to reduce obesity through food environments, 'the [state government] budget was a perfect example of putting the ambulance at the bottom of the cliff. . ..all that money going in to emergency wards, building bigger emergency services . . ..and very little into prevention' (NG3). Moreover, the 'shift away from government funding advocacy organisations' (NG3) was impacting their capacity to advocate and mobilise stakeholders around healthy food environments.

Urban planning policy

The development of urban planning policy was identified by state and local government participants as a governance process that brought stakeholders together in time-limited or on-going coordinating platforms and partnerships. Several participants from urban planning portfolios reported that healthy food access was not a standalone priority; rather it was encased within broader objectives important for health such as access to services, public open space and walkability. One participant argued, 'I don't think we'd only sell health issues focused around just the food part, it's critical of course, but in my mind it goes hand in hand with a whole series of other pieces in terms of walkability, in terms of the quality of place' (PS1). Similarly, a local government participant reported that 'through the planning process, in terms of access to healthy food, it's probably not something we look at. But in terms of access to services, it's something we look at' (LG7). The Melbourne metropolitan urban planning strategy (Department of Environment Land Water and Planning 2017a) had adopted a 20-min neighbourhood policy that brought these multiple elements together under a key direction for 'living locally'. A state government participant described it as a policy that supported healthy food access through 'a range of local services provided in a neighbourhood, which would include food, either through supermarket, small supermarket or shop' (SG3).

Participants reported that urban planning policy was an important governance lever, particularly in the absence of a strong regulatory framework for urban planning.

Coordination and partnerships

Participants identified multiple stakeholders and agencies with responsibilities that intersected with healthy food access, however there was no one level of government, sector or portfolio that had a mandate to address spatial access to food outlets. Therefore, coordination and partnership structures were important to overcome professional silos and poor communication across stakeholders. One stakeholder noted:

> One of the challenges we find is we often feel like we're sitting in the middle at the moment. We'll talk to developers and they'll say, "Local government doesn't allow this or doesn't allow that" and then you talk to local government and they say, "Oh, the developers won't do this and they won't do that." From where we're sit . . . it's very much a case of everyone seems to want [healthy food access] but the mechanisms to put in place aren't always as clear cut. NG2

In several councils, food security and food access initiatives had been established that brought together environmental health, community development and health planning practitioners in local government with food relief and community organisations. Participants most commonly reported time-limited coordinating platforms that brought together government, non-government and private sectors stakeholders during the development of a specific place-based strategy or plan where 'we gather together the stakeholders and have those conversations based on locations' (LG8). The examples provided were led by either state or local government:

> Council in those instances would be very proactive in talking to the developer about, or the supermarket chain about what we're wanting, about being proactive in setting up the pre-application meetings and getting as many of council staff there at the initial meetings. . .it's one of the first things which we try

> and bed down, the location of retail and activity centres. LG5

Two multi-stakeholder, multi-sectoral partnership structures were identified by participants that offered potential for coordinating action on local food environments. The first had been established by the state government health department with a focus on healthy food availability in schools, hospitals, workplaces and recreation centres (Department of Health 2012). Multiple stakeholders across government, non-government and private sector organisations were involved and it was suggested as a coordinating platform for spatial access to health food outlets by a non-government participant. However, an opposing view was that the health department could not lead action on local food environments because 'then it gets marginalised back to health. . ..whilst it's a health outcome that we need to achieve, the actions that need to happen are not in the responsibility of health – we can't change the planning, the transport, the eco dev' (SG9).

The second partnership structure had been established by state government to provide a platform for communities to advise government on local and regional priorities to improve social, economic and environmental outcomes (Department of Environment Land Water and Planning 2017b). According to a state government participant, these partnerships offered potential for healthy food access as part of a broader consideration around 'liveability':

> We have a general mandate, which is essentially to assist, coordinate, and link across governments and across sectors with the focus on regional, or place-based management of investment and delivery of outcomes. . .. they could look at liveability through a variety of different lenses. One of them could be on early intervention and prevention in relation to health issues. SG7

Partnerships and coordination opportunities were identified as governance processes that must be in place to support the development of healthy local food environments, however leadership to activate and drive change was seen to be essential.

Leadership

Participants identified two types of leadership that were necessary to drive action on healthy food access: political leadership by government informed by data and evidence; and distributed leadership with shared goals across multiple levels of government and sectors.

Political leadership, data and evidence. First, political leadership was required to create a mandate for action and drive change at the ministerial or cabinet level. Participants across sectors consistently argued that the catalyst for change would be worsening diet-related health outcomes linked to food environments. Several participants drew parallels with the response to family violence, when after incremental action over many years, this 'compelling problem' came to the fore of the political agenda leading to significant new investment, new policy frameworks, new legislation and new institutional arrangements across government (Family Safety Victoria 2017). Participants identified competing priorities and multiple 'wicked problems' (SG7) as barriers to gaining traction on healthy food environments, however one participant reflected on previous experience working on tobacco control:

> The economics are going to be what tips this. It will be when people are getting overweight or obese younger and younger, particularly men. Men of working age. . .. it's when that not having a healthy, productive workforce impacts. . ..that's when rubber will hit the road. NG3

Fine-grained local data were identified as a powerful tool for gaining traction at the local government level. Several participants gave examples of how mapping fresh food access had been used powerfully to draw attention to the issue, and to identify local pockets of disadvantage. Participants agreed that spatial data at the local level linked to health outcomes had potential for influencing local urban planning policy and was a powerful advocacy tool to address inequities:

> In our work with councils on obesity prevention, when you can present data to government, whether it be at the state or local, to highlight a problem area and what's influencing it, it can really jolt action. SG6

Distributed leadership and shared goals. The second type of leadership identified by participants was distributed leadership across government and other sectors, as described by this participant:

> I think that you will need a form of network governance to both design a solution and then to implement and deliver a solution. It's going to require multiple actors, across multiple portfolios in state government, across multiple local governments and their own internal silos and structures. Then there's a role of civil society, there's a role of business here, they're all important. SG7

While several participants proposed distributed or shared leadership across government and other sectors, there was a diversity of views about whether it was feasible to develop shared goals with private sector stakeholders such as the developers and supermarket chains. Despite their central role in the development of food environments, participants spoke of the political influence that developers wield, of donations to both major political parties and that 'it's an income stream that they're [the political parties] reluctant to cut off' (PS2). Supermarkets were described such that 'they pretty much run whatever

they want' (LG7). However, there were developers, one participant reported, that had a 'broader vision than just pure commerciality' (PS1), and hence it would be possible to align goals for a healthy food environment with their commercial imperatives. Further, the participant argued that architects and urban designers were an important bridge between sectors and were able to 'balance the ideals of councils, the commercial reality of developers and the needs and understanding of people in the community' (PS1).

In summary, participants described the actions and processes of governance that were critical for supporting the development of healthy equitable local food environments. Despite a lack of finance and a weak regulatory environment, participants noted that other governance levers presented opportunities to make progress.

Discussion

Through analysis of stakeholder perspectives, this study identified key factors that influence spatial access to food outlets in local areas and opportunities to advance healthy equitable food environments through governance actions and processes. Ecological models can be used to represent the policy and food environment influences on dietary and health outcomes, and the individual-level factors such as food preference, socioeconomic position and demographics that influence food choice and dietary behaviour (Glanz *et al.* 2005, Story *et al.* 2008, Murphy *et al.* 2017a). However, stakeholders perceived that the socio-economic position and socio-cultural background of residents influenced the size and types of food outlets that were established in local areas.

Consistent with other research that investigated factors influencing supermarket location (Hawkes 2008), stakeholders in the present study perceived that land availability and population catchments placed constraints on supermarket availability and accessibility. Therefore, local government urban planners used land use, housing, urban design and transport policies in tandem to increase population densities to influence the location of supermarkets and retail centres, and to provide physical access to the outlet by various transport modes. By contrast, a U.K. study found that few urban planners reported that delivering healthy food environments was a priority (Lake *et al.* 2017). The authors suggested there may be insufficient understanding among urban planners of the potential for urban planning to contribute to obesity prevention (Lake *et al.* 2017). Further, a U.S. study found the prevailing belief among urban planners was that food outlet access was the responsibility of the private market (Eckert and Shetty, 2011). However, recent studies have shown that urban planning policies that improve supermarket access have potential for healthy and equitable weight outcomes (Burgoine *et al.* 2017, Murphy *et al.* 2017b).

Stakeholders in the present study noted a number of interdependent and overlapping challenges to the development of healthy local food environments. Consistent with previous research these included: a weak regulatory environment and the absence of health objectives within urban planning legislation; a lack of finance and investment to support healthy food access; poor collaboration across portfolios and sectors; and competing policy priorities (Kent and Thompson 2012, Carmichael *et al.* 2013, Carey and Crammond 2015).

Governance for health requires action extending from 'hard' regulatory interventions, policy and partnership approaches, to 'soft' education-based and persuasive approaches (Kickbusch and Gleicher 2012). While hard governance mechanisms are considered to be more effective and equitable with population-wide impact (Swinburn *et al.* 2015, Capewell and Capewell 2017), in this study, regulatory levers were weak. Therefore, with pragmatism, stakeholders focused efforts on other governance mechanisms 'in the absence of getting legislative change' (NG2). The study highlighted the limited capacity that local government authorities have to consider public health issues in urban planning decision-making. Where conflict arises, a planning tribunal reviews and makes decisions on disputes over the use and development of land (Municipal Association of Victoria 2016). A tribunal decision in 2013 demonstrates how the regulatory framework does not support the public health objectives of local government:

> Town planning is not a panacea for all perceived social ills, nor is planning decision-making a forum for addressing all issues of social or community concern. At its heart, planning is about the use, development and protection of land.... it is not the role of town planning to address all issues of public health, nor to regulate the pricing or general availability of a product to manage the health and well-being of a society (Victorian Civil and Administrative Tribunal 2013).

Although past efforts to bring health considerations into urban planning in Victoria had been stymied, there was a view among some stakeholders that this would change. In recent years, other Australian jurisdictions have succeeded in placing health onto the urban planning legislative agenda. For example, in the Australian state of New South Wales, public health advocates were successful in including objectives pertaining to health in draft legislation (Kent *et al.* 2017).

Finance and investment were identified as a governance action that could help bridge the gap between urban planning and public health to support healthy food access. Obesity prevention funding had been used to place a local government urban planner in a public health team, and in another example, an urban planner described being 'the connector between the various elements of Council and the agencies, and the private sector, to pull all this [healthy urban design] together' (PS2). These stakeholder views resonate with outcomes from the U.K. Healthy Towns program, which aimed to tackle obesity through the built environment and policy interventions. The three-year initiative provided opportunities for urban planners and public health practitioners to develop reciprocal working relations and an 'open channel' that might not have been otherwise possible, it accelerated 'the integration of planning into public health (including obesity prevention)' (May Goodwin *et al.* 2014, p. 124). The literature is replete with calls to break down professional silos between urban planning and health (for example, Kent and Thompson 2012, Barton and Grant 2013, Carmichael *et al.* 2013, Carey and Crammond 2015, Sreedhara *et al.* 2017). Consistent with U.K. research, the present study showed that a focus on a broader conception of health gained traction rather than a standalone focus on access to food outlets for obesity prevention (May Goodwin *et al.* 2014).

The present study found there were time-limited partnerships that addressed spatial access to food outlets as part of broader urban strategic planning processes, however there was a notable lack of *on-going* coordination structures across government, portfolios and sectors. Similar to other studies, responsibilities for food environments were found to be dispersed across many sectors, portfolios and levels of government (James *et al.* 2017). One participant noted that a Victorian government inter-departmental committee on food had been established in 2009 that brought together six government departments from primary industry, environment, transport, planning, health and central agency portfolios. It had included a 'theme' to reduce obesity and diet-related disease, and hence, had considered food environments (Regional Development Victoria 2010, p. 33). However, a participant reported that this was disbanded shortly afterwards following a change in government. Consistent with the literature, the study found that on-going and enduring coordinating platforms, such as food policy coalitions, are required to bring together diverse stakeholders to focus attention on the food system, including spatial access to food outlets (Caraher *et al.* 2013, Mccartan and Palermo 2017).

Governance is a dynamic process where governments are one actor among many in policy-making (Barten *et al.* 2011). Multi-sectoral and multi-faceted obesity prevention initiatives under the leadership of New York City Mayor Michael Bloomberg, demonstrated how political leadership can drive policy innovation and significant action on food environments (Kelly *et al.* 2016). The present study found agreement among stakeholders that political leadership on local food environments at a state or federal would emerge as the health and economic impact of obesity prevalence and diet-related NCDs worsened. This was noted in another Australian jurisdiction, when the South Australian government adopted a HiAP governance approach, partly in response to rising healthcare system costs (Oneka *et al.* 2017). Similar to previous local government research (Allender *et al.* 2009), the findings pointed to data and evidence as important drivers for political leadership at the local government level, but qualified these needing to be local and fine-grained. A recent case before a Victorian planning panel on the location of alcohol outlets adds weight to this perspective. The panel noted evidence on associations between alcohol outlet density and domestic violence, however it stated that 'research specific to this locality that would justify a particular planning response has not been presented' (Planning Panels Victoria 2017). In addition to satisfying an evidentiary purpose, local fine-grained data can be used to identify geographic areas of urban health inequities within cities (World Health Organization 2010).

This study builds an understanding of the integrated governance actions required to deliver healthy equitable local food environments. Therefore, we offer three recommendations. First, the study highlights the importance of concerted action across multiple governance processes, even when two of the potentially most powerful levers, regulation and finance, are weak. Second, a multi-pronged approach to coordination and partnerships is recommended, harnessing opportunities to bring healthy food access to time-limited and on-going coordinating platforms, as a standalone priority or as part of a broader focus on healthy built environments or liveable communities. Partnerships help overcome narrow sectoral interests and provide a platform for collaborations and coordinated action, however leadership is required to facilitate change (Kickbusch and Gleicher 2012, Lin *et al.* 2012). Therefore, the third recommendation is about generating local fine-grained data of food outlet distribution and associations with health outcomes. Stakeholders noted it was an important driver of political leadership at the local level, and engages civil society as advocates for change. Additionally, it contributes to the evidence of potential location-specific health risks and inequities. Urban health is a recurring theme in the UN Sustainable Development Goals with targets for health and wellbeing, and inclusive and sustainable urbanisation (United Nations 2015). Although these

perspectives come from the specific urban context of Melbourne, Australia, they provide insights for many other rapidly growing cities, which have shared characteristics.

This study had a number of strengths. It adopted a methodology whereby participants were provided with local data that showed the variation in supermarket and public transport access by area-level disadvantage, and provided them the opportunity to reflect on factors that inform decision-making about the availability and accessibility of food outlets. Second, the study brought together a wide range of perspectives from urban planning, health, and economic portfolios, and from multiple government, non-government and private sector participants. The study adopted the 'information power' (Malterud *et al.* 2015) approach to guide sample size. The specificity of the study aim, selection of participants holding knowledge and experiences highly relevant to the study aim, and the high-quality interview data suggests the sample had sufficient information power to address the research questions. The study is not without limitations. First, there were 27 participants from a range of portfolios across state and local government, non-government and private sectors, however it did not include participants representing the major supermarket chains or from the urban developers. Representatives of these organisations were invited to participate, but they declined or did not respond. However, we were successful in recruiting participants that were currently or had previously worked for these organisations in a consultancy role. Second, the specific context of the Victorian urban planning framework means the generalisability of some of the findings may be limited. Third, the study only focused on spatial access to food outlets and did not consider other food environment exposures such as the non-residential food environment around schools and workplaces or the 'in-store' food environment (Glanz *et al.* 2005). Fourth, limitations to the governance for health (including HiAP) theoretical frameworks have been noted, including: the lack of attention to complexity (Burns 2015, Labonte 2018); lack of attention to national and global contexts (Labonte 2018); health imperialism (Kemm 2001, Oneka *et al.* 2017); and limited conceptions of intersectoral action to break down government silos (Holt *et al.* 2018). Similarly, ecological models have also been critiqued for their inattention to complex systems science, which offers utility for understanding the interactions and feedback loops between factors that influence dietary behaviour and inequities (Butland *et al.* 2007, Diez Roux 2011, Friel *et al.* 2017, Rutter *et al.* 2017). Hence, future research could explore Australian policy and governance opportunities to create healthy local food environment within a global political and economic context, and could incorporate a systems analysis of the factors that support dietary health and health equity.

Conclusions

In a global context of rapid urbanisation, population growth and widening health inequities within cities, it is important to understand how governance actions and processes can support the development of healthy and equitable local food environments. This study found weak legislative imprimatur for urban health, where local action was frequently stymied. However, urban design, land use, housing and transport planning policies were being harnessed by local authorities to influence spatial access to supermarkets. A range of stakeholders across government, industry and the community have a role in influencing food environments, however responsibilities and accountabilities are dispersed. Despite this, new forms of network governance and collaboration among stakeholders are emerging that offer potential for meeting urban health challenges, including equitable access to healthy food.

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8.2. Summary

This chapter presented the results of the qualitative strand of the research that investigated government, non-government and private sector stakeholder perspectives on the roles and responsibilities of key stakeholders in relation to the development of local food environments, identifying factors that influenced decision-making. This chapter highlighted urban planning policy and governance opportunities that have the potential to advance healthy and equitable local food environments. The findings showed that, while government, non-government and private sector stakeholders have a role in influencing food environments, responsibilities are dispersed. Urban health governance processes offer potential for equitable healthy food access.

Chapter nine presents the mixed methods study that focused on local food environments in the urban-growth and established areas of Melbourne. This chapter combines quantitative and qualitative approaches to build an understanding of how food environments vary across levels of urbanisation and how they impact upon health, and it identifies salient contextual factors. It builds on the preceding chapters by illuminating the impact of food environments at small-scale within cities, not only across socio-economic areas but also across areas with varying degrees of suburban development and residential density.

Chapter 9. Local food environments and suburban development

9.1. Preface

In this chapter, the local food environment is investigated in the context of rapid population growth and suburban development. The findings reported in this chapter respond to research questions one to five.

1. How does the local food environment influence dietary intake and health outcomes in an urban adult population aged 18 years and over?
2. Is there spatial patterning of food outlet access, dietary intake and health outcomes across socio-economic areas, and across urban-growth and established areas of Melbourne, Australia?
3. What spatial measures of the local food environment are associated with individual-level dietary intake and health outcomes, and how can they guide urban planning policy and practice?
4. What contextual factors influence the availability and accessibility of food outlets in urban areas of Melbourne, a city experiencing rapid growth and suburban development?
5. What are the governance barriers and opportunities to support the development of a healthy, equitable local food environment?

The chapter is underpinned by a mixed methods approach that brings together quantitative and qualitative data and analysis. The methods and results were published in a paper titled 'Local food environments, suburban development and BMI: a mixed-methods study' in the *International Journal of Environmental Research and Public Health* (accepted 22 June 2018).

Referring to the conceptual framework (chapter 3) and local food environment exposure measures (Table 5.4), supermarket and fast food chain access was assessed across established and urban-growth areas in Melbourne, then associations with BMI investigated. The paper fills a research gap on local food environments and BMI across municipal areas of varying suburban development in Melbourne, using qualitative data to contextualise and explain the results.

Following the paper, additional analysis using a relative density exposure measure of supermarket and fast food chain access and associations with BMI are reported (section 9.3). The chapter concludes with a methodological contribution arising from the mixed methods study (section 9.4), and a summary of mixed methods findings (section 9.5).

9.2. Supermarkets, fast food chain access and BMI

The quantitative analysis investigated access to supermarkets and fast food chains across urban-growth and established LGAs of Melbourne. The qualitative strand of the mixed methods study analysed interview data described in chapter 7 through an urban-growth versus established area lens, therefore providing insights that contextualise and interpret the quantitative results.

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Local Food Environments, Suburban Development, and BMI: A Mixed Methods Study

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Abstract: More than half the world's population now live in urban settlements. Worldwide, cities are expanding at their fringe to accommodate population growth. Low-density residential development, urban sprawl, and car dependency are common, contributing to physical inactivity and obesity. However, urban design and planning can modify urban form and enhance health by improving access to healthy food, public transport, and services. This study used a sequential mixed methods approach to investigate associations between food outlet access and body mass index (BMI) across urban-growth and established areas of Melbourne, Australia, and identify factors that influence local food environments. Population survey data for 3141 adults were analyzed to examine associations, and 27 interviews with government, non-government, and private sector stakeholders were conducted to contextualize results. Fast food density was positively associated with BMI in established areas and negatively associated in urban-growth areas. Interrelated challenges of car dependency, poor public transport, and low-density development hampered healthy food access. This study showed how patterns of suburban development influence local food environments and health outcomes in an urbanized city context and provides insights for other rapidly growing cities. More nuanced understandings of the differential effect of food environments within cities have potential to guide intra-city planning for improving health and reducing inequities.

Keywords: food environment; urban planning policy; obesity; mixed methods; cities; urban health

1. Introduction

More than one half the world's population live in urban settlements [1] and this number is set to almost double by 2050 [2]. Worldwide, cities are expanding at their urban fringe to accommodate population growth, while also becoming more densely populated within [1]. The United Nations' New Urban Agenda recognizes that population growth concentrated in cities is placing significant pressure on housing, infrastructure, food systems, the natural environment, and services [2]. However, the World Health Organization suggests that these challenges also bring opportunities to achieve good health through sustainable urban development [1].

Urban design and planning policies can enhance population health by: improving access to healthy affordable food; prioritizing public transport, walking, and cycling as travel modes; and supporting compact higher-density residential development [1,3]. While there is potential

to improve population health through such policies, low-density residential development, urban sprawl, and car dependency are common and have contributed to increases in physical inactivity, overweightness, and obesity [4,5]. For example, a review found that urban sprawl and less land use mix in North America were positively associated with increased body weight [4]; and in Australia, more sprawling suburbs were positively associated with insufficient physical activity, overweightness, and obesity [6]. Furthermore, a UK study of 420,000 adults found that high residential density was associated with lower body mass index (BMI), waist circumference, and body fat [7]. Therefore, increasing residential density and minimizing urban sprawl may have a protective effect on overweightness and obesity [5,7].

Many studies have investigated how the location of food outlets influences dietary intake and diet-related health outcomes, hypothesizing that a high level of access to supermarkets is protective of health and that a high level of access to fast food outlets is detrimental to health [8,9]. Indeed, evidence exists that supermarket access is negatively associated with body weight [9,10] and that fast food outlet access is positively associated with body weight [11,12]. Researchers have also investigated whether access to food outlets impacts dietary and health outcomes differently across urban, suburban, and rural environments [13,14]. For example, a U.S. study found varying associations between food environments and obesity depending on metro or nonmetro location, with fast food access positively associated with obesity in metro areas, but inversely associated in nonmetro areas [15]. A study from Denmark found that fast food proximity was positively associated with fast food intake; however, the magnitude of the association varied by urban, suburban, or rural location [13].

In Australia, many studies have investigated associations between food outlet access and dietary or health outcomes in urban [16] and regional areas [17]; however, little is known about food environments across established residential and urban-growth areas within cities. In the context of rapid urban growth, it is important to understand how patterns of suburban development influence local food environments and health outcomes. In the decade up to June 2016, more than three-quarters of Australia's population growth was concentrated in capital cities, with Melbourne in the state of Victoria accounting for the largest growth [18]. Within Melbourne, local government areas on the fringe experienced some of the largest and fastest growth, and this trend is projected to continue [18]. At the same time, the delivery of infrastructure and services in new residential developments lags behind population settlement by many years [19]. Uneven suburban development across established and urban-growth areas of Melbourne may influence food environments and health outcomes; however, this is an understudied research area in an Australian context. A more nuanced understanding at the intra-city level has potential to guide and target urban design and planning policy interventions to specific geographic areas where health and access inequities exist [20].

Therefore, a mixed methods approach was used to investigate this relatively unknown research area. Mixed methods can be used to bring together a more comprehensive account of a research area and can improve the usefulness of findings for practitioners [21]. While focused on an Australian city, this research has relevance for other cities experiencing rapid population growth and suburban development and contributes to the food environment evidence base utilizing mixed methods approaches. Accordingly, the aims of this study were to: (i) investigate associations between measures of supermarket and fast food chain access and BMI across established and urban-growth areas; (ii) understand the contextual factors that influence food environments in established and urban-growth areas; and (iii) identify challenges to the development of healthy equitable local food environments.

2. Materials and Methods

A sequential mixed methods research design was applied to investigate the research aims [22]. First, quantitative and spatial analytical methods were used to investigate access to food outlets across established and urban-growth areas and associations with BMI. Second, key informant interviews were conducted to contextualize, explain, and triangulate findings [21,22]. Mixing of the approaches occurred during data collection and at interpretation [22], whereby the quantitative and spatial

analyses guided the sampling strategy for the qualitative strand, and the qualitative strand assisted in interpreting and contextualizing the quantitative results.

2.1. Quantitative Strand

Data were obtained from the preventive health survey (PHS) 2012/13, a self-report population health dataset collected by the Victorian Department of Health and Human Services. Full details of the survey have been reported elsewhere [23]. Briefly, the aim of the PHS was to assess the prevalence of health risks among adults who were cluster-sampled from 23 municipalities across Victoria. Of the 9806 adult respondents, 6707 (68.4%) were successfully geocoded at the residential address level. In the present study, the sample drawn from the PHS comprised 3141 respondents from the Melbourne metropolitan region. With a focus on urban food environments, the study was delimited to urban areas of greater Melbourne. Two categories of suburban development were created: established area and urban-growth area municipalities. There were 1648 respondents residing in six established area municipalities in the middle-outer ring of Melbourne, and 1493 residing in six urban-growth area municipalities on the fringe (Figure 1). It is estimated that 42% of population growth from 2011–2031 will occur in the six urban-growth area municipalities of greater Melbourne and a seventh growth area outside the metropolitan region [19]. The PHS received ethics approval from the Victorian Department of Health and Human Services (02/12) and University of Melbourne (1441599.1).

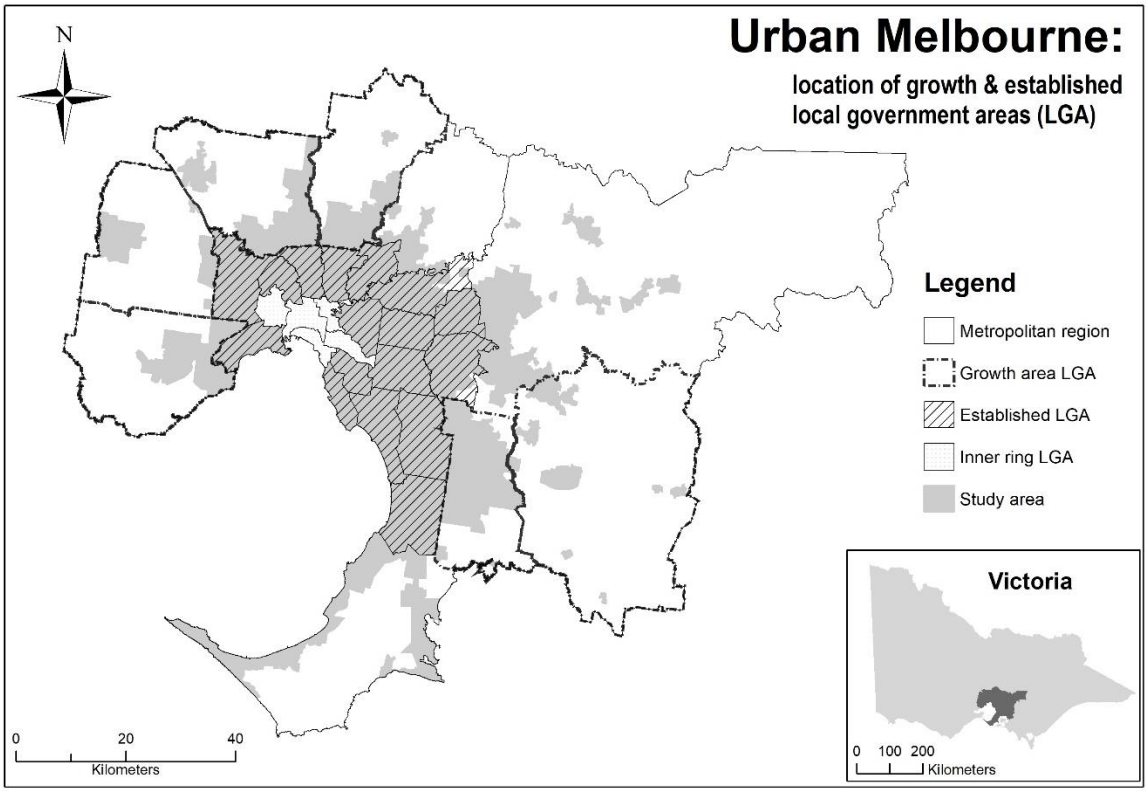

Figure 1. Study area.

2.1.1. Outcome Variable

The outcome variable was BMI (kg/m^2), calculated using self-reported height (m) and weight (kg). Consistent with previous studies [24], 16 pregnant respondents and 12 respondents with extreme BMI values ($\geq$50 kg/m^2) were excluded from the analysis. Additionally, 239 respondents with missing height and/or weight data were removed prior to analysis.

2.1.2. Covariates

Individual-level covariates comprised age, gender, education, and household income. Behavioural covariates comprised self-reported vegetable intake (serves/day), fruit intake (serves/day), fast food (such as burgers, pizza, hot chips) intake (frequency/fortnight), soft drink intake (frequency/fortnight), smoking status (current smoker/not a smoker), and physical activity. A physical activity variable for total activity per week was created by summing minutes per week of walking and moderate and vigorous physical activity (doubled prior to summing), then categorizing into: no activity (0 min); <150 min per week; and ≥150 min per week. All data were truncated at 180 m per day [25]. In accordance with guidelines recommending that physical activity is accrued on most days of the week [26], a categorical variable was created for sedentary (0 min/week); insufficient time and/or sessions (<150 min or ≥150 min and <5 sessions); and sufficient time and sessions (≥150 min and ≥5 sessions). Respondents with missing physical activity (n = 113) and/or age and education (n = 36) data were excluded from the analysis.

The Index of Relative Socio-Economic Disadvantage (IRSD) was included as an area-level covariate. The Index of Relative Socio-Economic Disadvantage aggregates the socio-economic census data of individuals within a geographic area, including variables such as low income, educational attainment, unemployment, disability, single-parent households, and low English-language proficiency [27]. Thirteen respondents lived in areas without an IRSD score and were excluded from the analysis.

2.1.3. Exposure Variables

The exposure variables were supermarket access and fast food chain access. Consistent with previous studies, access to supermarkets was used as a proxy for "healthy food" access in the analysis. Supermarkets provide the range of foods required for a healthy diet [28,29], including affordable fruit and vegetables [30], and access to a supermarket has been shown to be associated with diet quality [31] and healthier weight [9]. In Australia, the top four major supermarket chains (i.e., Woolworths, Coles, IGA, and Aldi) account for almost 90% of the market share [32]. A commercial supermarket dataset was purchased [33] and extensively cross-checked and verified against company websites, the White/Yellow pages, and Google Street View. The top six fast food chains in Australia (i.e., McDonald's, Kentucky Fried Chicken, Subway, Hungry Jack's, Domino's Pizza, and Red Rooster) were used as a proxy for "unhealthy food" access. Fast foods are energy-dense and nutrient-poor, and eating at least one fast food meal a week is associated with weight gain, overweightness, and obesity [34]. Together, these fast food restaurants (not including Domino's Pizza) account for more than 75% of chained fast food value share [35]. Fast food chain data were sourced from an open access directory of geocoded businesses (www.zenbu.org) [36], company websites, and the White/Yellow pages and extensively cross-checked and verified. There were 742 supermarkets and 648 fast food chain outlets in the datasets within 10 km of the metropolitan Melbourne boundary.

Food outlet density and proximity measures were created using geographic information systems software (ESRI, Redlands, CA, USA). The origin-destination (OD) Matrix tool in the Network Analyst extension was used to calculate the density of outlets around each participant's geocoded address using network-based buffers ranging from 800 m to 3000 m. Road network data were sourced from VicMap Transport [37]. A "pedestrian road network" was created to model a walkable distance of between 10 and 20 min by including walking and bike paths and removing tollways/freeways. Fast food outlets at tollway/freeway service centres and at Melbourne airport were excluded because they were not pedestrian-accessible. The pedestrian road network was used in analyses at 800 m, 1000 m, and 1600 m buffers, and the unmodified "car road network" used at the 2000 m and 3000 m buffers. The selection of buffers has been described in full elsewhere [23]. In brief, the density of supermarkets has been found to be associated with lower BMI within 800 m, 1000 m, and 2000 m buffers [23,38]. The density of fast food outlets has shown significant associations with higher odds of obesity within 1000 m and higher BMI within 1600 m buffers [39,40]. In addition, travel-mode survey data for 2013

in Melbourne showed the median distance travelled from home to a supermarket was 0.7 km by walking, 2.7 km by car, and 2.2 km by all modes including public transport; and the median distance travelled to a fast food outlet was 0.5 km by walking, 3.9 km by car, and 3.3 km by all modes [41]. Proximity measures for supermarket access and fast food chain access were created along both road networks. Closer proximity to supermarkets has shown significant associations with decreased obesity prevalence [42], and increased distance to fast food outlets has shown significant associations with decreased BMI in women [43].

2.1.4. Statistical Analysis

Population-weighted means and standard errors for individual-level and behavioural covariates and outcome variables were calculated using the population size and the number sampled in each sampled municipality. Descriptive statistics for local food environment access measures were calculated using means and standard deviations for density measures and the median and interquartile range for proximity measures. Data were stratified by established versus urban-growth municipality location. Tests of statistical significance across strata were calculated to compare means and proportions. Generalized estimating equations were fitted to model associations between BMI and food outlet density and proximity, adjusting for clustering at the municipality level. All analysis was conducted in Stata version 13.0 (StataCorp, College Station, TX, USA), and the level of statistical significance was $\alpha < 0.05$.

2.2. Qualitative Strand

2.2.1. Sampling and Recruitment

Qualitative interviews were conducted from December 2016 to August 2017. Purposive criterion sampling was used to select three middle-outer established area municipalities and two urban-growth area municipalities as information-rich cases for in-depth study [22]. The quantitative and spatial results guided the selection of municipalities for the qualitative strand, focusing on those that had a high proportion of dwellings with poor supermarket access (more than 1 km) in areas of high disadvantage (data not shown). Previous research has shown that supermarket access within 1 km was protective of BMI for people residing in high-disadvantage areas of Melbourne [23]. Purposive sampling of extreme cases can provide insights that can be used to guide remedial policy and other interventions [22].

Local government participants at the executive or managerial level were identified from Council websites, a social networking website (www.linkedin.com), and the authors' networks. Urban planning, economic development, and public health portfolios were targeted for participant recruitment because these stakeholders have potential to influence local food environments. State government, non-government, and private sector participants were identified through websites and the authors' networks. Snowball sampling was also used, whereby participants were asked to identify other people who would be meaningful to interview [44]. Participant recruitment occurred via email with a plain language statement and consent form attached. Ethics approval for the qualitative strand was granted by the University of Melbourne (1648132.1).

2.2.2. Key Stakeholder Interviews

Semi structured interviews were conducted to gain stakeholder perspectives on the factors that influence the development of local food environments across established and urban-growth areas. All interviews, except one, were conducted face-to-face by the first author (Maureen Murphy). Participants were provided with a two-page report on the quantitative findings and maps that visualized the spatial distribution of supermarkets and transport access across metropolitan Melbourne. The interview was guided by thematic questions to explore roles, responsibilities, and factors that influence decision-making on food outlet access [45]. The interview guide is available in Table S1.

2.2.3. Data Analysis

Participants were coded according to the level of government, sector, and portfolio. Transcriptions and initial data analysis were undertaken during the interview period by the first author (Maureen Murphy). The initial analysis was discussed by three coauthors (Helen Jordan, Hannah Badland and Billie Giles-Corti). Open coding and focused coding were used to assign data into categories [45,46]. In the present study, the data were interrogated using thematic coding and content analysis relating to established and urban-growth areas [46]. The coding framework and themes were revised and agreed by four co-authors (Maureen Murphy, Helen Jordan, Hannah Badland and Billie Giles-Corti). Excerpts from the interviews are presented to illustrate the contextual factors and challenges identified by the denoted state government (SG), local government (LG), non-government (NG), and private sector (PS) participants. Data analysis was undertaken using NVivo 11 (QSR International, Melbourne, Australia).

3. Results

3.1. Quantitative Strand

3.1.1. Descriptive Analysis

Descriptive statistics of PHS survey respondents are presented in Table 1. Respondents living in urban-growth areas were younger ($p < 0.001$) and less well-educated ($p < 0.001$) than respondents in established areas; however, more were employed ($p < 0.001$), and their household incomes were higher ($p < 0.001$). Mean BMI for urban-growth area respondents was higher ($p = 0.030$) and they had lower daily fruit consumption than respondents in established areas ($p = 0.032$). Fewer growth area respondents resided in either high- or low-disadvantage areas ($p < 0.001$), with 40% residing in mid-disadvantage areas, compared with 28% of established area respondents.

Table 1. Descriptive statistics of the preventive health survey (PHS) respondents by location: established versus urban-growth local government area.

		Location		
	Total	**Established Area (*n* = 1648)**	**Growth Area (*n* = 1493)**	***p*-Value ***
Demographic Characteristics				
Age (years)				
Mean (SE)	54.15 (0.31)	56.10 (0.43)	52.48 (0.45)	<0.001
Gender (%)				
Male	38.6	38.1	38.9	
Female	61.4	61.9	61.1	0.667
Education (%)				
Primary	4.0	4.6	3.4	
Secondary	74.6	71.7	77.1	
Tertiary	21.4	23.7	19.5	<0.001
Employment status (%)				
Employed (Include self-employed)	52.2	48.6	55.2	
Unemployed	4.1	3.9	4.3	
Not in labour force	43.7	47.5	40.5	<0.001
Household income (AUD) (%)				
$0–$49,999	45.9	49.0	43.2	
$50,000–$79,999	18.1	16.8	19.3	
$80,000–$124,999	16.6	14.1	18.7	
≥$125,000	9.9	9.9	9.9	
Refused/Don't know	9.5	10.2	8.9	<0.001

Table 1. *Cont.*

	Location			
	Total	**Established Area (*n* = 1648)**	**Growth Area (*n* = 1493)**	***p*-Value ***
Outcome Variable				
BMI (kg/m^2)				
Mean (SE)	27.34 (0.10)	27.10 (0.14)	27.55 (0.15)	0.030
Covariates: Behavioural				
Vegetable consumption (serves/day)				
Mean (SE)	2.26 (0.03)	2.28 (0.05)	2.24 (0.05)	0.439
Fruit Consumption (serves/day)				
Mean (SE)	1.74 (0.02)	1.79 (0.04)	1.70 (0.04)	0.032
Fast food consumption (frequency/fortnight)				
Mean (SE)	1.12 (0.04)	1.04(0.06)	1.20 (0.06)	0.053
Soft drink consumption (frequency/fortnight)				
Mean (SE)	6.12 (0.20)	5.85 (0.30)	6.35 (0.27)	0.209
Physical activity (%)				
Inactive	6.8	7.0	6.7	
Insufficient activity (Frequency & duration)	25.0	24.0	25.7	
Sufficient activity (frequency & duration)	68.2	69.0	67.6	0.602
Smoking Status (%)				
Current smoker	14.7	13.6	15.5	
Not a current smoker	85.3	86.4	84.5	0.137
Covariate: Area Level				
Area level disadvantage (IRSD)				
High disadvantage (IRSD deciles 1–3)	36.2	40.6	32.4	
Mid disadvantage (IRSD deciles 4–6)	34.6	27.9	40.3	
Low disadvantage (IRSD deciles 7–10)	29.2	31.5	27.3	<0.001

* *p*-values determined by adjusted Wald test for continuous variables and by X^2 test for categorical variables. IRSD: Index of Relative Socio-Economic Disadvantage; BMI: body mass index; AUD: Australian dollar; SE: standard error.

Compared with urban-growth area respondents, those residing in established areas had significantly greater access to supermarkets for all density measures, except within the 1000 m buffer, and were in closer proximity to supermarkets. Those residing in established areas had significantly greater access to fast food chains for all density measures and were in closer proximity than those residing in urban-growth areas (Table 2).

Table 2. Geographic measures of supermarket and fast food chain access by location: established versus urban-growth local government area.

	Location						
	Total		Established Area (n = 1648)		Growth Area (n = 1493)		p-Value *
	Mean	SD	Mean	SD	Mean	SD	
Supermarket Density (Pedestrian Road Network)							
≤800 m	0.30	0.67	0.32	0.69	0.27	0.64	0.022
≤1000 m	0.49	0.86	0.52	0.86	0.47	0.86	0.128
≤1600 m	1.39	1.44	1.49	1.43	1.27	1.44	<0.001
Supermarket Density (Car Road Network)							
≤2000 m	2.11	1.79	2.30	1.84	1.89	1.72	<0.001
≤3000 m	4.57	2.91	5.13	3.20	3.96	2.42	<0.001
Fast Food Chain Density (Pedestrian Road Network)							
≤800 m	0.24	0.68	0.29	0.74	0.19	0.60	<0.001
≤1000 m	0.43	0.94	0.50	1.01	0.35	0.86	<0.001
≤1600 m	1.29	1.67	1.45	1.68	1.12	1.63	<0.001
Fast Food Chain Density (Car Road Network)							
≤2000 m	2.00	2.03	2.24	2.06	1.74	1.97	<0.001
≤3000 m	4.49	2.82	5.00	2.81	3.93	2.73	<0.001
	Median	IQR	Median	IQR	Median	IQR	
Distance to Closest Supermarket (Pedestrian Road Network) (km)	1.30	0.88–1.80	1.24	0.85–1.69	1.37	0.91–1.92	<0.001
Distance to Closest Fast Food Chain (Pedestrian Road Network) (km)	1.55	1.03–2.19	1.40	0.96–1.98	1.69	1.16–2.46	<0.001

* p-values determined by Analysis of Variance (ANOVA) for food outlet density and Kruskal–Wallis test for food outlet proximity. IQR: interquartile range; SD: standard deviation.

3.1.2. Associations with BMI

Supermarket density and proximity were not associated with BMI for any access measures across established and urban-growth area location (Table S2). Fast food chain density within 800 m (p = 0.047) and 1000 m ($p < 0.001$) buffers was associated with higher BMI for respondents in established areas. For each additional fast food chain, mean BMI increased by 0.20 kg/m^2 (95% CI, confidence interval (0.00, 0.40)) and 0.27 kg/m^2 (95% CI (0.14, 0.40;), respectively. In contrast, fast food chain density was associated with lower BMI for respondents in growth area municipalities within 800 m (p = 0.043) and 1600 m (p = 0.002) buffers (Table 3). Significant associations were found at 1600 m in unstratified analysis such that mean BMI decreased by 0.15 kg/m^2 (95% CI (-0.27, -0.02)) for each additional fast food chain outlet. Significant associations were also found within the 3000 m buffer for all respondents; however, the effect size was too small (-0.08 kg/m^2) to be of practical significance. Fast food chain proximity was not significantly associated with BMI in either established or urban-growth areas.

Table 3. Generalized estimating equations (GEE) models of associations between BMI and measures of fast food access for urban PHS respondents (n = 2712) by location.

BMI (kg/m^2) *	Location											
	Total				Established Area (n = 1406)				Growth Area (n = 1306)			
	β	95% CI		p-Value	β	95% CI		p-Value	β	95% CI		p-Value
Fast Food Chain Density												
≤800 m (Pedestrian road network)	−0.019	−0.292	0.255	0.894	0.198	0.002	0.395	0.047	−0.367	−0.722	−0.012	0.043
≤1000 m (Pedestrian road network)	0.095	−0.097	0.287	0.332	0.270	0.137	0.404	0.000	−0.158	−0.443	0.127	0.278
≤1600 m (Pedestrian road network)	−0.147	−0.270	−0.024	0.019	−0.045	−0.189	0.098	0.533	−0.262	−0.431	−0.093	0.002
≤2000 m (Car road network)	-0.049	−0.125	0.027	0.205	−0.039	−0.163	0.084	0.532	-0.032	−0.150	0.086	0.593
≤3000 m (Car road network)	−0.082	−0.163	−0.001	0.046	−0.056	−0.156	0.045	0.279	−0.097	−0.258	0.065	0.241
Fast Food Chain Proximity												
(Pedestrian Road Network)	−0.016	−0.115	0.084	0.759	−0.112	−0.344	0.121	0.346	−0.053	−0.152	0.046	0.297

*Adjusted for age, gender, education level, income, vegetable intake, fruit intake, soft drink consumption, fast food consumption, physical activity, smoking, supermarket access, IRSD, and clustering at the municipality level. CI: confidence interval.

3.2. Qualitative Strand

Twenty-seven participants from state, local, and non-government and private sector organisations were interviewed. More than half of the participants (n = 15) had expertise in urban planning, followed by participants with public health and community planning (n = 8), urban economics/economic development (n = 2), and coordination/partnership development (n = 2) expertise. The average duration of interviews was 50 min.

Data from the qualitative interviews provided insights that assisted in understanding and interpreting the results of the quantitative and spatial analyses, specifically: (i) contextual factors that influence food outlet access in established and urban-growth areas; and (ii) urban planning and design challenges to the development of healthy local food environments.

3.2.1. The Context

Participants provided contextual information about the development of food environments in urban Melbourne and how this differed across geographic areas. Melbourne was described as a city experiencing rapid population growth "higher than [in] London and matching New York in absolute numbers" (PS2), and that this population growth was accommodated by both urban expansion and densification. Participants reported population growth expanding outward in low-density residential developments in urban-growth areas, alongside increased residential density with "infill development" (SG4) in established areas. Both patterns of suburban development were regarded as key factors that influenced local food environments.

In low-density residential areas, a state government participant described the "old model" of retail development that involved "placing your big shopping centre here . . . and some piddly little centres five or eight kilometres away that service the local catchment but never really thrive . . . so people just keep driving to the big sub-regional centre all the time" (SG8). Under this model, large retail centres were surrounded by extensive car parking where "the old-school line of thought is always cars front and centre, 100% about the car" (PS1).

In contrast, in residential areas where infill development was occurring, the local food environment developed differently. When presented with spatial data from the quantitative strand, an

established area stakeholder noted how increasing residential density can lead to improvements in food access:

> *Twenty years ago, it* [middle-ring suburb] *was struggling, it had a fairly underperforming main street, it probably didn't feel safe, it certainly didn't look vibrant. The only thing that's changed in that street or around it is that there has been a lot more one and two-bedroom apartments built that's brought a new population in . . . [increasing density] brings opportunities: there's now two or three thousand additional people that have much better access to public transport, much better access to food, restaurants and places to meet. LG13*

However, increasing residential density was described as "a really hard sell" despite evidence that "if you move from 17.5 households per hectare up to 21 or 25, you get this burst of services appearing within your local fabric" (SG7). Another state government participant concurred:

> *You've got to have a decent density—15 or 18 dwellings per hectare I don't think cuts it— you've got to have 20 to 25* [dwellings per hectare] *. . . in the vast majority of your conventional, residential areas. Then you've got to build it up as you get closer to your activity centres. SG8*

In summary, rapid population growth has been accommodated by low-density residential development and expansion in the urban-growth areas and increasing residential densities in established areas. These patterns of suburban development provided the context for the development of local food environments within Melbourne. Urban planning and design policies were identified as critical elements that can influence and modify food outlet access and potentially improve diet-related health outcomes. The following section explores the challenges to the development of healthy local food environments.

3.2.2. The Challenges

Urban-Growth Areas

Many participants identified car-dependent retailing as an issue in urban-growth areas. Car dependency was linked to the lack of public transport in new residential developments, described as the "latent vulnerability of Melbourne", where people with "high mortgage vulnerability and high car dependency [live] on the periphery, a long way from the jobs and no public transport options" (PS2). Participants referred to data presented during stakeholder interviews that reported on a Victorian urban planning guideline for growth areas that recommended that 80–90% of dwellings should be within one km of an activity centre anchored by a supermarket [47]. The data showed that only 26% of growth area dwellings were within 1 km of a supermarket, far less than the policy guideline [23].

State government participants agreed that car dependency and the lack of active and public transport infrastructure were obstacles to healthy food access in urban-growth areas; however, there was also the view that "it takes a while for a place to evolve" (SG4) and that eventually these places would have "the best access to supermarket retailing, both in terms of provision and in terms of transport access, walkability, cycling, road access, and connectivity" (SG2). A private sector participant pointed to the important role of the urban planning guideline on fresh food availability because "these PSPs [precinct structure plans] are nominating where the supermarkets can go" (PS1). Despite the master-planned environment of urban-growth areas, local government participants described the challenges they faced in implementation:

> *If you try and do a structure plan for an area and say we should have a corner shop here, we should have a moderate sized activity centre there, understanding all of the research around walking, cycling, and how people use their retail. When the time comes for the owner of what is usually a large greenfield parcel to find a buyer for that land, the perception is either the housing's not here yet, or that the population's not sufficient to support that . . . therefore they come back to council and they want to rezone it for housing. LG9*

Stakeholders noted new "main street" (LG11) pedestrian-oriented retail developments in urban-growth areas that had active street frontages supporting walking and cycling, with car parking placed behind the main street. However, this type of urban design had met resistance from a major retailer who opposed efforts "to change [their] building footprint and the sea of car parking around it" (LG9).

The early delivery of services and infrastructure in new residential developments was seen as critical for health and wellbeing, because "habits of people are formed, especially in these new growth areas, in the first number of years." (PS1). The timely provision of services was a significant challenge, as described by a local government participant:

> *Whilst we can reserve land for an activity centre or a shopping centre, we have no powers to ensure that a supermarket is developed there in a timely manner. We have a statutory planning team who will work with developers, and often with a supermarket they're going to need a population base . . . unfortunately in some areas of our municipality, development is slow and there can be quite a long lag between a development commencing and a supermarket being provided. LG5*

Established Areas

Local and state government participants noted that middle-outer suburbs also experienced interrelated challenges of car dependency, poor public transport, and a poor urban design legacy that hampered healthy food access:

> *Many of the older development areas, many of them probably 1950s to 1970s subdivisions,* [tend] *to have a lot of court bowls* [cul-de-sacs], *which reduce penetration of public transport and increase walking distance to supermarkets. LG10*

Participants described the postwar period when "we were essentially designing residential areas around the motor car" (LG13). However, stakeholders reported it was "more of a challenge to retrofit effectively" (LG7) in the middle-outer suburbs. Therefore, efforts to improve healthy food access were constrained by the lack of "large land holdings that can be configured as supermarkets" (SG7). This led to geographic areas of poor access that were difficult to redress, as described by this local government participant:

> *There are gaps and there always will be some gaps especially in our established areas where it's not possible to retrofit our existing urban areas with new supermarkets. LG5*

Further, state and local government participants reported significant socio-economic disadvantage in middle-outer suburbs that coincided with geographic areas of poor public and private transport access. Hence, poor access to healthy food outlets and car-dependent urban design was compounded by socio-economic disadvantage.

Fast Food Access Across Established and Urban-Growth Areas

Efforts to improve food environments by restricting fast food outlets were discussed, with local government and state government participants noting that fast food outlets had been permitted in residential zones for more than 20 years, when located on a main road.

> *It was known as a McDonald's amendment. It was a big case that* [established area council] *fought to try and stop the Macca's . . .* [however, the Planning Minister] *put through a number of changes into the planning system, where if you were of a certain configuration and met these requirements in the planning scheme, you still need a permit but you met all these ''as of right" requirements. So, it was a lot harder for councils and objectors to argue against it. SG8*

Several participants referred to a planning decision in outer Melbourne, where a fast food chain won an appeal to obtain a planning permit, despite strong opposition from the council and the

community [48]. Against this background, one participant argued there should be a mechanism in the planning law to enable local government "to limit the proliferation of chain fast food outlets in communities" (NG3). A central issue raised by local government and non-government participants was that the planning legislation "doesn't say that we must consider the health of Victorians" (NG2). Hence, local government had limited capacity to restrict the availability of unhealthy food outlets:

> *If somebody was to apply for an application for a fast food place and we were to refuse it on the grounds that it's unhealthy, in basic terms, our likelihood of being able to get support through VCAT* [the planning tribunal] *is probably going to be very low. LG7*

Furthermore, in the planning tribunal environment, one participant noted the considerable burden of self-representation:

> *Part of the issue is around the onus of proof being on the community and others to show harm from the placement of these* [fast food] *outlets, whereas it would be much fairer if these large entities who are creating demand show that they're not doing harm. NG3*

Restricting fast food access in residential areas in both established and growth areas was identified as a significant challenge, and communities were hampered by the urban planning legislative framework.

4. Discussion

Over recent decades, rapid population growth in Australian cities has been accommodated by both low-density development on the urban fringe and increased residential densities in established areas [49]. While previous Australian studies have investigated the differential effects of food environments across socio-economic areas [23,50], little is known about how variations in residential density and suburban development within Australian cities influence food environments and health.

This study used quantitative and qualitative approaches to investigate local food environments across established and urban-growth areas in Melbourne, Australia. Access to supermarkets and fast food chains was found to be significantly greater in established areas across most density and proximity measures. Furthermore, the median distance to the nearest supermarket was less than the median distance to the nearest fast food chain across all areas. Several U.S. studies have investigated food outlet access across urban, suburban, and rural areas [51,52], and a New Zealand study found that travel time to fresh food outlets within the city of Christchurch varied from less than one minute in the city centre to 20 min on the urban–rural fringe [53]. While variations in spatial access to food outlets between urban and rural areas is expected [51,53], it is the intra-city variation that may lead to differential health outcomes within cities, and has implications for local urban planning and design policy. To our knowledge, no Australian research has investigated food environments and BMI across areas of varying suburban development within cities. The present study found that respondents in the urban-growth areas had higher BMI than those living in established areas. These results are similar to those of a South Australian study that found that living further from the city centre was associated with increased waist circumference, suggesting that a high level of car commuting may be a contributing factor [54].

While no associations between residential access to supermarkets and BMI were found in this study, associations were detected between BMI and fast food density in both directions. For established area respondents, BMI increased as the number of fast food outlets increased within the 800 m and 1000 m buffer, in keeping with the hypothesis that fast food access is detrimental to BMI. Unexpectedly, fast food outlet density had a protective effect on BMI for respondents in growth areas within 800 m and 1600 m buffers. A U.S. study reported a similar outcome, where higher density of fast food outlets in nonmetro areas was associated with lower obesity rates [15]. They hypothesized that fast food outlets in nonmetro areas were located along major highways and interstate routes and were therefore utilized by travelers and visitors to the area, rather than residents. It is possible that the fast food chain

outlets in the present study did not reflect a residential neighbourhood food environment for growth area respondents either. A longitudinal study of residents in a new development in an urban-growth area of Melbourne found that over one-third of residents spent two to three hours commuting to work each day [55]. With considerable time spent commuting and at work, the residential food environment may not be where food is purchased. A second possibility is that residents in urban-growth areas have lived in the area for a shorter period of time than residents of established areas, and therefore their weight status is influenced by a prior residential environment [56]. As the PHS dataset did not include a variable indicating length of residency, the analysis did not adjust for this possibility.

Stakeholder interview data pointed to poor public transport access and high car dependency as a major challenge to healthy food access in urban-growth areas. A study in a new urban-growth area development in Melbourne found that it was more than 30 months before the first residents had access to public transport to the shopping centre located five kilometres away [55]. Other studies have noted the considerable delay in policy implementation in new residential developments and have called for the early provision of infrastructure and services to support health outcomes [57–59]. For example, a longitudinal study in the Western Australian capital city Perth found that three years after relocating to a new development, more than two-thirds of residents still did not have access to destinations for daily living, including supermarkets, within 1600 m of household location [58].

Limiting fast food chain access was a common challenge experienced by stakeholders in both established and urban-growth areas. The absence of public health objectives in the urban planning legislation was identified as a barrier when objecting to fast food planning applications. Furthermore, stakeholders noted that the onus of proof was on communities to demonstrate that the fast food outlet would be detrimental to health. The literature suggests that land use regulation can be used to restrict fast food access [60–62]; however, evidence is still emerging. An evaluation of a Los Angeles zoning regulation found little change in the food environment or effects on dietary intake or obesity; however, the authors suggested this may have been because the study timeframe was too short [63]. Furthermore, they noted that the zoning regulation applied to standalone fast food outlets, which tend to be located on major roads and cater for customers who are driving through [63].

Residential density was identified as a key factor that influenced the food environment. The metropolitan planning strategy *Plan Melbourne 2017–2050* identified a residential density target of more than 20 dwellings per hectare to "help create stronger, healthier communities" [64] (p. 51); however, the average dwelling density across Melbourne has been assessed as 14 dwellings per hectare [65]. Our qualitative data suggested that building higher residential densities may be a challenge with "a lot of fear and concern about [urban] growth and development" (LG13), a finding echoed in other Australian cities [66]. The importance of higher residential densities for BMI was demonstrated in a U.K. study where 18 dwellings per hectare (1800 dwellings per km^2) was identified as a threshold for stimulating better weight-related health outcomes [7]. While acknowledging that urban planning policies promoting densification may contribute to improved weight outcomes, it is important to note potential drawbacks, including air and noise pollution, urban heat island effects [3,67–69], increases in road trauma [70], overcrowding, and crime [71].

Compounding the problem of low-density residential development and car-dependent urban design, the present study found that middle-outer established areas of Melbourne that were once outer suburbs were experiencing concentrated disadvantage. In the present study, a higher proportion of respondents in established areas had annual household incomes less than $50,000 and were living in high-disadvantage areas compared with urban-growth area respondents. This was triangulated with qualitative data that pointed to greater socio-economic disadvantage in older middle-outer established areas. Previous research has shown that two middle-outer ring municipalities of Melbourne experienced the highest levels of poor supermarket access and area-level disadvantage when compared with all municipalities [23]. Several studies have documented this shift in the socio-spatial distribution of disadvantage in Australian cities over recent decades, from inner-urban to middle and outer-ring

suburbs built in the postwar period [72,73]. Therefore, we offer three recommendations based on the present study.

First, there is a need for a review of the Victorian urban planning legislative framework to include public health considerations when assessing applications, and to remove the anomaly that allows fast food outlet provision in residential areas. Amending the legislation will assist local government and communities that seek to improve healthy food outlet access or restrict access to fast food outlets. Furthermore, the onus of proof should be reversed so that planning applicants for fast food fast outlets are required to show that a new outlet will not cause harm to residents. As an example, the Western Australian government introduced a provision to the *Liquor Control Act 1988* whereby liquor licence applicants need to show that the application is in the public interest and would not cause harm or ill-health to people, including "at-risk" groups [74]. Second, the Victorian urban planning policy supermarket access guideline should be implemented across all urban Melbourne, both established and urban-growth areas, with priority in disadvantaged areas. Currently, the policy guideline is only implemented in the six urban-growth municipalities of the 31 municipalities of Melbourne. Targeted urban planning policy interventions in geographic areas within cities is warranted to ameliorate inequities [20,75]. A UK study suggested that improved supermarket access combined with interventions to address socio-economic disadvantage may be effective in reducing obesity [76]. Third, there is a disjuncture between urban planning policy that provides guidance for supermarkets in new growth areas based on spatial catchments and the actual establishment of new supermarkets by the private sector based on population catchments. Urban planning and health policy interventions to improve healthy food access should be considered in new residential developments when supermarket development lags. These could include the provision of public transport to the nearest supermarket [55], "green cart" vendors [62], mobile produce markets [77], and tax incentives for supermarkets [78].

This study has limitations. First was the use of cross-sectional data, and therefore the associations detected may be biased by resident self-selection into areas that match food preferences, which might explain the observed differences in BMI. A recent U.S. longitudinal study found no evidence that geographic access to supermarkets or fast food outlets was associated with changes in BMI and suggested that self-selection may be biasing associations found in cross-sectional studies [79]. Second, the associations may be biased by using self-reported height and weight data. However, Australian studies found that self-reported height and weight data to calculate BMI is appropriate for middle-aged and older Australian adults [80]. Third, the food outlet dataset did not include all food outlets, potentially underestimating the food environment where people purchase food. The in-store food environment was also not considered, which may have contributed to observed differences in BMI. An Australian study found that urban-fringe and nonmetropolitan supermarkets had less shelf space for fruit and vegetables and more shelf space for soft drinks compared with urban supermarkets [81]. Finally, an "information power" approach was used to guide the sample size for the qualitative interview data collection, whereby "the more information the sample holds, relevant for the actual study, the lower number of participants is needed". [82] (p. 1759). Given the specificity of the study aims and the purposeful sampling of participants with highly relevant knowledge and experience, it is argued that the sample size achieved sufficient information power. However, the purposeful selection of municipalities with less healthy food environments for the qualitative study may limit the generalizability of our findings.

Nevertheless, this study makes an important contribution to the evidence base using mixed methods approaches and on the intra-urban associations between the food environment and health outcomes. A strength of this study was the rigorous approach to food outlet data validation through comprehensive cross-checking against company websites, White and Yellow page listings, and by using Google Street View. Furthermore, there was contemporaneous collection of food outlet and participant data and inclusion of both supermarket and fast food access in models to account for spatial co-occurrence. Future research at the postcode level would provide finer-grain insights, and

including the "lived experience" of residents in the qualitative strand would provide additional perspectives. For example, a recent study from Spain incorporated residents' perspectives into policy recommendations for obesity prevention [83].

5. Conclusions

This study used a mixed methods approach combining quantitative, spatial, and qualitative data to shed light on the understudied associations between local food environments and health outcomes across areas of varying suburban development in an Australian context. It was found that food outlet access was greater in established areas compared with urban-growth areas, and that fast food access was positively associated with BMI in established areas and negatively associated in growth areas. Urban design and planning policy that supports higher residential densities may influence food environments by increasing healthy food outlet access, leading to better health outcomes and reducing inequities. The methodology and findings may have utility for supporting and guiding urban planning and design policy in other rapidly growing cities worldwide.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/15/7/1392/s1, Table S1: Interview guide, Table S2: GEE models of associations between BMI and measures of supermarket access for urban PHS participants by established versus urban-growth area location.

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Supplementary materials from the published paper are provided in Appendix G.

9.3. Relative density of supermarkets and fast food chains and BMI

As described in section 6.4, a relative density exposure measure was also created for each buffer for the stratified analysis across urban-growth and established areas on Melbourne:

[supermarket outlet + 1] ÷ [supermarket outlet + fast food chain outlet + 1]

The range of supermarket and fast food chain outlets within each buffer is presented in Table 9.1.

Table 9.1. Range of supermarket and fast food chain outlets within each buffer by location

		Suburban development	
	Total	Established area (*n* =1648)	Growth area (*n* = 1493)
	Range	Range	Range
Supermarket outlets			
≤ 800 m	0-4	0-4	0-4
≤ 1000 m	0-7	0-6	0-7
≤ 1600 m	0-9	0-8	0-9
≤ 2000 m	0-10	0-9	0-10
≤ 3000 m	0-20	0-20	0-12
Fast food chain outlets			
≤ 800 m	0-6	0-6	0-5
≤ 1000 m	0-8	0-8	0-6
≤ 1600 m	0-10	0-9	0-10
≤ 2000 m	0-10	0-10	0-10
≤ 3000 m	0-13	0-13	0-13

m; metre
Range; smallest count of outlets - largest count of outlets

The relative density exposure measure was significantly associated with a decrease in mean BMI for participants in established areas within 800 m and 1000 m buffers, and with an increase in mean BMI for participants in growth areas within 800 m. In established areas, for each 10 per cent increase in the relative density measure, mean BMI decreased by 0.12 kg/m^2 (95% CI -0.20, -0.03) within 800 m buffer and decreased by 0.14 kg/m^2 (95% CI -0.22, -0.06) within 1000 m buffer. For participants in growth areas, for each 10 per cent increase in the relative density measure, mean BMI increased by 0.12 kg/m^2 (95% CI 0.00, 0.24) within the 800 m buffer (Table 9.2).

Table 9.2. GEE models of associations between BMI and measures of food outlet exposure for urban PHS participants

	Suburban development								
	Total			Established area (*n* = 1406)			Growth area (*n* = 1306)		
	β[=]	95% CI		β[=]	95% CI		β[=]	95% CI	
BMI (kg/m^2)									
Relative density (%) [I]									
≤ 800m (pedestrian road network)	-0.017	-0.121	0.089	-0.115	-0.201	-0.030†	0.122	0.004	0.241‡
≤ 1000m (pedestrian road network)	-0.052	-0.148	0.044	-0.142	-0.224	-0.059†	0.073	-0.044	0.191
≤ 1600m (pedestrian road network)	0.075	-0.016	0.165	0.021	-0.073	0.115	0.120	-0.022	0.261
≤ 2000m (car road network)	0.043	-0.030	0.117	0.002	-0.098	0.103	0.062	-0.054	0.177
≤ 3000m (car road network)	0.057	-0.048	0.162	0.054	-0.068	0.176	0.028	-0.138	0.194

BMI = body mass index; CI = confidence interval; kg = kilogram m = metre

* Adjusted for age, sex, education level, income, vegetable intake, frequency of sweet drink consumption, frequency of fast food consumption, physical activity, smoking status and clustering at the LGA level

[I] [supermarket outlet + 1]: [supermarket outlet + fast food chain outlet + 1] x 100 %

[=] β coefficients were estimated for ten per cent increase in relative density

† P< 0.01; ‡ *P* < 0.05

9.4. Mixed methods methodological contribution

Qualitative interviewing revealed a methodological issue in using population-weighted centroids to spatially define access when used in conjunction with sausage buffers. Sausage buffers have been proposed as an alternate approach to road network buffers that could be more readily reproduced across a variety of GIS software and platforms (Forsyth et al., 2012). A buffering method that follows the road network but creates a radius around the centre line of the road of constant dimension (Forsyth et al., 2012), it has been shown to be comparable to other buffering techniques when assessed using physical activity outcomes (Frank et al., 2017).

As described in section 7.4, maps were created to visualise the spatial distribution of supermarkets by quintiles of access across urban Melbourne and to depict socio-economically disadvantaged areas where supermarket access was greater than 1 km and where there was additional transport disadvantage. These maps were provided to participants prior to qualitative interviewing.

Data obtained from one interview revealed an error in the spatial visualisation of poor supermarket access (>1 km) in areas of high area-level disadvantage and transport disadvantage. Public transport access had been calculated using a sausage buffer layer that buffers 50 m either side of the street centre line. The sausage buffer depicted areas that were within 400 m of a bus stop, 600 m of a tram stop, or 800 m of a train station. A MB was considered to have public transport access if its population-weighted centroid intersected the sausage buffer.

In a small number of geographic areas in Melbourne, the housing block size was close to or exceeded 50 m in length; in these areas therefore, the MB population-weighted centroid did not always intersect the public transport buffer, which buffered 50 m from the centre line of the road (Figure 9.1). Despite being in a geographic area well-serviced by public transport, these spatial measures identified public transport stops as being inadequate. This error was brought to my attention during one interview. Overall across urban Melbourne, subsequent investigation showed that 20 out of 266 SA1s were incorrectly classified as having high area-level disadvantage, with poor supermarket and public transport access. This was an error of approximately 7.5 %.

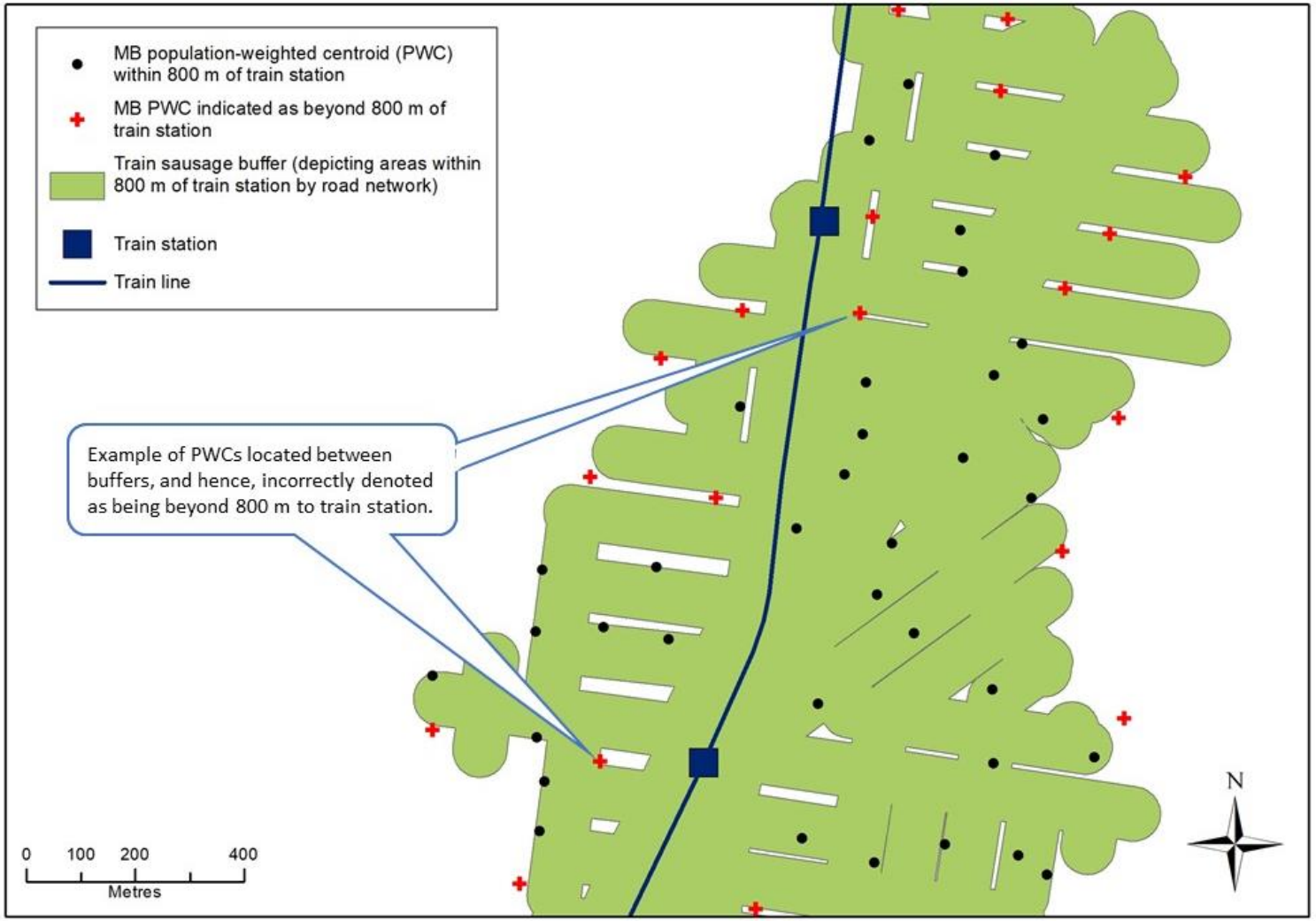

Figure 9.1. Example of Mesh Block population-weighted centroid not intersecting with a public transport sausage buffer.

9.5. Summary

This chapter used both quantitative and qualitative methods to provide a comprehensive account of the under-studied research area of local food environments and suburban development in an Australian context. The study found that participants in established areas of Melbourne had better access to supermarkets and fast food chains, and that differential associations between fast food chains and BMI were present across areas of varying suburban development. While urban-growth and established areas faced common challenges, socio-economic disadvantage in the older, outer established suburbs was identified as a compounding problem. The study illuminated how both urban sprawl and increasing residential density influenced local food environments and health outcomes in an Australian context, providing insights for other rapidly growing cities. It extends the findings from the quantitative analysis (chapter 6) that investigated local food environments across socio-economic areas in Melbourne.

Importantly, the expert local knowledge in a qualitative interview brought to light the error in relation to the analysis using sausage buffers. This validity checking in the interviews improved the accuracy of the spatial analysis.

Together, the quantitative, qualitative and mixed methods research investigated local food environments of Melbourne through an equity lens, and within the context of rapid population growth and suburban development. A range of factors influenced the development of local food environments, from proximal influences at the individual and socio-cultural level to distal macro-environmental influences, including economic, urban planning and other government policies. Urban planning and governance processes which offer potential for equitable, healthy food access will be discussed more fully in the next chapter.

Chapter 10. Discussion

10.1. Introduction

Leading global and national public health and urban planning agencies are promoting government action on food environments to reduce obesity and non-communicable disease related to diet (for example, World Health Organization, 2004, World Health Organization, 2013, American Planning Association, 2007, United Nations, 2016, Local Government Association, 2016a). Accordingly, this mixed methods PhD thesis investigated the local food environment factors that influence dietary and health outcomes and identified spatial indicators of the local food environment to guide urban planning policy and practice in Melbourne, Victoria, Australia. Utilising qualitative interviews with policy makers, this research aimed to identify the urban planning and governance opportunities that could translate the quantitative findings into policy and practice to advance healthy, equitable local food environments.

This chapter first summarises and discusses quantitative, spatial and qualitative findings from this thesis. Urban planning and governance opportunities for healthy local food environments are identified. Study limitations and strengths are then discussed, before the implications and recommendations for policy and practice for government and non-government organisations are presented. Finally, the chapter concludes with implications and recommendations for future research.

10.2. Conceptual framework to inform urban planning policy and practice

An ecological approach was adopted to investigate the individual, social, built environment and policy intervention points and governance actions that have potential to support health and health equity through dietary intake and diet-related health outcomes.

This helped identify upstream neighbourhood-level food environment attributes amenable to intervention which would improve downstream dietary and health outcomes. Following a review of the scientific literature and urban planning policy documents, a conceptual framework of the local food environment was developed to guide urban planning policy and practice (Murphy et al., 2017a). Qualitative data underlined the importance of ecological models as an organising framework for action.

The conceptual framework assists in understanding how local food environments influence dietary intake and health outcomes in an urban setting, responding therefore to the first research question:

1. How does the local food environment influence dietary intake and health outcomes in an urban adult population aged 18 years and over?

As the conceptual framework in chapter 3 depicts, urban planning, alongside a range of other government policies, has the potential to influence dietary and health outcomes by supporting access to food outlets and transport opportunities, and by encouraging mixed land use. Key stakeholder interview data verified the importance of urban planning and design, transport, land use and housing policy acting in tandem to support healthy food environments (see chapter 8) (Murphy et al., 2018b).

Indeed, policy makers have long recognised the value in using upstream policy levers and built environment interventions to create healthier local food environments. In recent years, for example, Victorian local government authorities have adopted a range of policies and strategies to promote the availability and accessibility of healthy food in local areas (such as in the (City of Melbourne, 2012, City of Greater Dandenong, 2015, City of Darebin, 2016, Manningham City Council, 2016). Additionally, a State government parliamentary *Inquiry into Environmental Design and Public Health in Victoria* (2012) recommended urban planning mechanisms to limit the oversupply of fast food outlets in communities, and to facilitate the supply of healthy food choices (Parliament of Victoria, 2012). At an international level, researchers have proposed a Food Environment Policy Index to monitor and benchmark the performance of government initiatives to improve food environments (Swinburn et al., 2013b). This index includes a food retail component to support the availability of healthy food outlets and limit the availability of unhealthy food outlets. If these initiatives are to be implemented in policy and practice, however, thresholds for densities and distances to different types of food outlets need to be specified (that is, how many outlets and how close). Spatial guidance is required for implementation.

The conceptual framework was used to identify and create a suite of spatial food environment measures that have shown significant associations with dietary and health outcomes in previous studies. A review of policy documents found a guideline in Victorian urban planning policy that included a spatial metric for access to food outlets. This guideline recommended that 80-90 per

cent of households in urban-growth areas are within one km of a town centre large enough to allow for provision of a supermarket (Growth Areas Authority, 2009. Revised 2013). These spatial measures were linked to Victorian population health data to assess their utility in an Australian context.

This study therefore sought to fill a research gap by conceptualising and testing food environment measures for spatial metrics to inform urban planning and design policy, with the aim of identifying a set of consistent spatial measures associated with optimal dietary and health outcomes. These could be used in policy settings for benchmarking and monitoring, to thereby assess and measure progress and change in local food environments over time (du Toit, 2015, Wong, 2015). The next section summarises and discusses the quantitative and spatial results stratified across socio-economic areas, and across established and urban-growth residential areas of Melbourne.

10.3. Local food environments, dietary intake and BMI

Local food environment spatial measures identified through the literature and urban planning policy review were presented in Chapter 5 (Table 5.4). They comprised density, relative density and proximity measures for supermarket access and fast food chain access. The food environment measures were linked to Victorian population health data and tested for associations with dietary intake and BMI.

The spatial patterning of food outlet access, dietary intake and health outcomes across geographic areas of Melbourne were investigated. Spatial measures associated with BMI that can be used to guide urban planning policy and practice were identified. The study design recognised that heterogeneity across urban environments exists within cities, and that this may influence urban health and health inequities (Franco et al., 2015, World Health Organization, 2010). It addressed the research questions:

1. How does the local food environment influence dietary intake and health outcomes in an urban adult population aged 18 years and over?
2. Is there spatial patterning of food outlet access, dietary intake and health outcomes across socio-economic areas, and across urban-growth and established areas of Melbourne, Australia?

3. What spatial measures of the local food environment are associated with individual-level dietary intake and health outcomes, and how can they guide urban planning policy and practice?

Summaries of significant associations across socio-economic areas and across established residential and urban-growth areas are presented in Appendix H.

Four trends were discerned from the results that have implications for policy and practice (see section 10.6) and implications for future research (see section 10.7).

First, all significant associations with BMI in the expected direction were found for buffers within a walkable distance of 10 to 15 minutes (that is, within the 800 m and 1000 m buffers) in high disadvantage areas and in established areas.

Second, across socio-economic areas, significant associations with BMI were only found in high disadvantage areas, reinforcing the possibility that local food environments matter more for those with access to fewer resources, particularly where public transport or private vehicle access is limited.

Third, all significant associations in established areas were in the expected direction, while all significant associations in urban-growth areas were in the *un*expected direction, raising the possibility that urban-growth area residents are influenced by their prior neighbourhood residential environments.

Fourth, only food outlet density and relative density measures were significantly associated with BMI. Food outlet proximity measures were not associated with BMI.

These findings are now discussed in more detail, and are contrasted with existing evidence.

10.3.1 Inequitable patterning and associations by area-level socio-economic status

For all food outlet access density and proximity measures, respondents in high disadvantage areas had greater access to supermarkets and fast food chains than respondents living in mid- or low-disadvantage areas. These findings contrast with previous local food environment studies in Melbourne (section 2.4.1); however, the present study was geographically larger than earlier studies and assessed food outlet access across all of urban Melbourne (Murphy et al., 2017b) rather than within a single municipality or selected suburbs.

Overall, there were few significant associations between food outlet access and self-reported dietary intake (servings of fruit and vegetables eaten per day and frequency of consumption of fast food over the previous fortnight) at any geographic scale or strata of disadvantage in the socio-economic area analysis. This is consistent with a previous review, which noted that there was more consistent evidence of associations between the food environment and weight status than the food environment and dietary intake (Giskes et al., 2011). This may be because of the difficulty in accurately measuring dietary intake using participant recall methods. Studies suggest that a larger sample and a more comprehensive measure of dietary intake than fruit and vegetable consumption may be required to detect associations (Giskes et al., 2011, Laraia et al., 2015, Mackenbach et al., 2017).

For the BMI analysis, supermarket density within 800 m and 1000 m had a protective effect on BMI for those living in high disadvantage areas, but not those living in mid- or low-disadvantage areas. The effect size was stronger within the 800 m buffer (-0.34 kg/m^2) than within the 1000 m buffer (-0.30 kg/m^2). Subsequent analysis using a donut-buffer suggested the 800 m buffer may be responsible for associations between supermarket density and BMI within the larger 1000 m buffer (Murphy et al., 2017b). Another Melbourne study found that the odds of walking increased when food outlet destinations, including supermarkets, were within 401 to 800 m, but not within 801 - 1000 m of household location (Gunn et al., 2017).

It may be that people living in high disadvantage areas have fewer resources such as income, transport and time, and therefore are more reliant on proximal access to supermarkets (Murphy et al., 2017b). Other studies have found that associations between food outlet access and BMI varied by area-level socio-economic disadvantage (Stark et al., 2013, Zick et al., 2009). Zick and colleagues (2009) suggested differential food environment associations with BMI across socio-economic areas may arise from differential access to transport. The literature suggests that differential associations may arise if local food environments matter more to some population sub-groups, such as those of low individual-level socio-economic position (Zenk et al., 2015, Feng et al., 2010), and for those residing in low socio-economic areas (Leal and Chaix, 2011, Richardson et al., 2014) (see section 2.6.1). Macintyre hypothesised that limited access to healthy food outlets compounded by area-level socio-economic disadvantage might amplify individual-level BMI risk of people residing in these areas (Macintyre, 2007).

Unexpectedly, fast food chain density within 2000 m had a protective effect on BMI for people living in high disadvantage areas (Table 6.3). Access to fast food outlets is hypothesised to have

a detrimental effect on weight (Fleischhacker et al., 2011); however, another Melbourne study found that fast food outlets within 2000 m of household location had a protective effect on obesity of adult male parents (Crawford et al., 2008). The authors suggested that the availability of 'healthy' food outlets within the 2000 m buffer may have influenced results, and that characteristics of the physical activity environment associated with BMI, such as residential density and walking destinations, provided a protective effect (Crawford et al., 2008). The present study adjusted for supermarket access, so it is not likely that spatial co-occurrence of both fast food outlets and supermarkets within the 2000 m buffer contributed to the protective effect; however, there may have been unmeasured physical activity environment attributes present, such as sporting fields, gyms and fitness centres, previously shown to be associated with lower BMI (Mason et al., 2018). The present study also adjusted for physical activity using a derived variable that combined walking, moderate and vigorous physical activity, which suggests increased physical activity does not explain the findings of decreased BMI within the 2000 m buffer. However, Ewing and colleagues (2014) have argued that greater precision in measuring physical activity is required to disentangle effects (Ewing et al., 2014). It is possible that the Preventive Health Survey questions on physical activity (Table 5.1) did not sufficiently capture and differentiate between neighbourhood walking trips in the recreational and transport domains (Giles-Corti et al., 2006), a factor which may have contributed to these findings.

Unexpected results were found for associations between BMI and relative density of supermarkets to supermarkets and fast food chain outlets within 2000 m and 3000 m buffers in high disadvantage areas, such that relative density was positively associated with BMI. These results contrast with the literature, which suggests that relative density of healthy to unhealthy food outlets may better represent influences on food choice than absolute density measures, and may produce more consistent and plausible results (Mason et al., 2013, Luan et al., 2015, Polsky et al., 2016, Zenk et al., 2015, Cobb et al., 2015). A recent Australian study, for example, found associations with BMI within 1600 m and 3200 m buffers in the expected direction when applying a fast food to supermarket and greengrocer ratio measure (Feng et al., 2018).

10.3.2 Exploring variations across established and urban-growth areas

Uneven suburban development within cities may influence population health and health equity outcomes (see section 2.4.2) (Rydin et al., 2012, World Health Organization, 2010, World Health Organization, 2016b). The six urban-growth areas of Melbourne are characterised by low-

density residential development and high motor vehicle ownership compared with the rest of Melbourne, with poor access to infrastructure, services and public transport, all of which lag behind population settlement (Victorian Auditor-General's Office, 2017, Arundel et al., 2017, Interface Councils, 2017). Qualitative data confirmed the car-dependency of urban-growth area residents and their lack of public transport as an issue. It was described as a significant challenge by key stakeholders with one interviewee commenting that 'a lot of people don't have very good access to things and are actually reliant on the car and are unable to walk to the local shop or supermarket' (SG3). Other stakeholders expressed concern about the habit-forming and intergenerational aspect of car-dependency: 'if there's not good walkable places for kids to start to walk to school until three or four years in, then opportunities are missed - parents are already in the habit of driving kids' (PS1).

A unique contribution to the literature and to the study of the food environment in Melbourne, was the study of spatial patterning of food outlet access across the city. In established local government areas, respondents had significantly greater access to supermarkets and fast food chains within most buffers and were in significantly closer proximity to both types of food outlet compared with respondents from the six urban-growth local government areas. Further, the spatial distribution of supermarkets meant that only 26 per cent of dwellings in urban-growth areas were within one kilometre of a supermarket, compared with 43 per cent of dwellings across Melbourne overall. This indicates that policy standards for supermarket access are falling well behind, particularly in growth areas.

As shown in Chapter 9, supermarket density and proximity were not associated with BMI in either established or urban-growth residential areas. Consistent with the hypothesis that fast food outlet access is detrimental to body weight outcomes, the density of fast food chain outlets within 800 m and 1000 m was positively associated with BMI in established areas; however, contrary to expectations, in urban-growth areas fast food chain density within 800 m and 1600 m was negatively associated with BMI. The relative density of supermarkets to supermarket and fast food chain outlets within 800 and 1000 m was negatively associated with BMI of respondents in established areas. This was consistent with the hypothesis that a greater proportion of supermarkets to food outlets overall is associated with healthy weight. In urban-growth areas, however, there were unexpected associations between relative density and BMI.

Possible explanations for the unexpected results in urban-growth areas were that fast food chains were located on major thoroughfares and highways, perhaps primarily catering for

drivers travelling through the area, and thus did not reflect the neighbourhood food environment (Ahern et al., 2011, Sturm and Hattori, 2015). Alternatively, residents may have lived for a shorter period in the urban-growth areas than residents of established areas, and therefore their weight status was influenced by their previous (rather than current) residential neighbourhood area (Pruchno et al., 2014). It was not possible to investigate whether the weight status of residents in new urban-growth areas may be an artifact of a previous residential exposure as the PHS dataset did not measure length of residency.

10.3.3 Summary

In summary, walkable access to food outlets appeared to play an important role, showing a protective effect on BMI for healthy food outlet access and a detrimental effect on BMI for unhealthy food outlet access. Notably, in disadvantaged areas, walkable access may offer a protective effect if transport access is limited. The findings for respondents living in established residential areas was consistent with the study's hypotheses; however, the results for residents living in urban-growth areas was contradictory, warranting further investigation.

Notwithstanding its limitations, the analyses suggest that, in the Australian context, three spatial measures have potential as local food environment indicators for assessing and monitoring food environments, measures that may offer utility for standards to be incorporated into urban planning policy and practice. These are: i) supermarket density within 800 m; ii) fast food chain density within 800 m; and iii) relative density of supermarket to fast food chain within 800 m. In Canada, spatial standards have been identified to guide public health authorities in assessing local food environments in urban settings (Mahendra et al., 2017). Following a literature review, the Canadian researchers selected three food environment indicators: food outlet density within 1000 m, relative density within 1000 m, and proximity to nearest food outlet. They suggested they be operationalised using an administrative unit centroid (Mahendra et al., 2017); however, in contrast to the present study, the spatial metrics proposed for Canadian authorities were not tested against local population health data. This is important because cities in different contexts are differently designed. European and U.K. cities for instance tend to have higher residential densities than Australian, Canadian and U.S. cities (Sarkar et al., 2017, Congdon, 2017); therefore different country-specific contexts are likely to produce different results. A strength of the present study compared with previous similar studies is the staged approach that commenced with the development of a conceptual framework linking upstream urban planning policy and built environment attributes to downstream health outcomes. Next, a review of the academic

literature and urban planning policies guided the selection of spatial measures that mapped to the conceptual framework. The spatial measures were then linked to Victorian population health data and tested for associations to identify metrics associated with optimal health outcomes. Arising from this comprehensive process, the proposed spatial indicators for monitoring local food environments and guiding urban planning policy and practice effectively represent walkable access to local food outlets. To increase confidence in using these indicators as spatial standards in Victoria, the next step would involve replicating this study using the same spatial indicators with different cohorts in Victoria, and elsewhere in Australia.

The next section summarises findings from key stakeholder interviews with policy makers. Urban planning and governance opportunities to advance healthy local food environments are considered within the context of the literature.

10.4. Governance, urban planning and design policy

Globally, as cities grow larger and become more densely populated, it is important to identify the integrated urban planning and design and transport policies required to create built environments that promote active forms or transport and reduce non-communicable disease (Giles-Corti et al., 2016). Universal and targeted policy interventions affect large numbers of people, having potential to improve urban health and narrow urban health inequities (Marmot, 2010, World Health Organization, 2010). However, collaboration across sectors, integrated approaches, and interdisciplinary work across public health, urban planning, and public policy is required (Franco et al., 2015, Koohsari et al., 2013, Capon, 2017, Rydin et al., 2012, Kickbusch and Gleicher, 2012).

Qualitative interviewing with key stakeholders provided insights into the roles and responsibilities of multiple sectors and levels of government in relation to planning for local food environments. Stakeholders' perspectives on the factors that influence decision-making, and contextual factors that influence the development of local food environments, yielded a set of policy and governance actions through which progress could be made toward creating healthy and equitable local food environments. Using health governance literature as an analytic lens, regulation and finance were identified as governance mechanisms that were weak in the current environment, while urban planning and design policy, partnerships, and political leadership offered the best opportunities for supporting health and reducing inequitable outcomes. The findings of this qualitative phase respond to the fourth and fifth research questions:

4. What contextual factors influence the availability and accessibility of food outlets in urban areas of Melbourne, a city experiencing rapid growth and suburban development?
5. What are the governance barriers and opportunities to support the development of a healthy, equitable local food environment?

A table summarising governance barriers and opportunities for healthy, equitable local food environments is provided in Appendix I.

10.4.1 A deficit of regulation and finance

A large body of literature suggests that coordinated regulatory frameworks across urban planning and public health are key enablers of urban health (World Health Organization, 2016a, Corburn, 2007, McQueen et al., 2012b). Furthermore, an Australian study emphasised the importance of planning law reform to improve local food environments in order to reduce overweight and obesity (Mills, 2014). In line with these views, qualitative findings pointed to the lack of integration across Victorian urban planning and public health legislation as a key barrier to the development of healthy local food environments. The 2012 Victorian parliamentary *Inquiry into environmental design and public health* recommended that health and wellbeing considerations be incorporated into planning legislation and its subordinate instruments, such as planning provisions, planning guidelines, and planning policies (Parliament of Victoria, 2012). While there has been little progress in Victoria, other Australian jurisdictions have succeeded in getting health and wellbeing onto the urban planning legislative agenda. During a review of the planning system in the state of New South Wales, for example, public health advocates were successful in including objectives pertaining to health in draft legislation (Kent et al., 2017), with changes commencing in March 2018 (Department of Planning and Environment, 2018). Planning legislation in the state of Queensland was also amended in 2009 to include reference to issues such as human health, urban congestion and climate change under the purpose of the Act (Department of Infrastructure and Planning, 2009). Later, in 2017, reference to healthy, liveable, and resilient communities was included in the Act (Queensland Government, 2016). While the overarching intent of these planning system reforms may be to stimulate economic growth and cut 'red tape' rather than improve population health (Ruming and Gurran, 2014), nevertheless they represent important opportunities for supporting urban health.

Stakeholders perceived that the neoliberal deregulated planning system was a barrier to healthy food environments. They described it as a system that 'minimises prohibitions' (SG8), and as

being ‘market-led rather than public-interest-led’ (PS2). This is in accord with Buxton and Goodman’s assessment (2014) that describes how successive Victorian governments since 1996 have deregulated the planning system to ‘reduce the strength of land use planning regulations, lessen the contributions of local communities, objectors and local councils to planning decisions and empower development companies’ (Buxton and Goodman, 2014, p.139). They also noted that amendments introduced in 2013, to remove restrictions in commercial zones, facilitated ‘big box’ retailing outside activity centres which undermined traditional, street-based, strip shopping centres (Buxton and Goodman, 2014). This assessment was consistent with qualitative views of interviewees who emphasised the importance of supportive legislative frameworks and argued that new planning scheme zones made it more difficult for local government to ‘restrict or refocus retail in any way’ (LG1). A 2014 example was provided in which the Victorian Planning Tribunal refused a permit for a new supermarket in an urban-growth area on the basis that it would ‘fragment the town centre structure’ and ‘would not be consistent with the delivery of a compact walkable main street town centre’ (Victorian Civil and Administrative Tribunal, 2014). However, the Planning Minister overturned the tribunal decision. It was argued that having a public health objective in planning legislation would make this outcome less likely: ‘that's why we need state government policy support, state government political support [to change the legislation]’ (LG9).

Interviewees identified the lack of funding for both active and public transport infrastructure as a barrier to healthy food outlet access. Active transport infrastructure facilitates walking and cycling to food outlets, which can offset public transport disadvantage (Ma et al., 2018). Access to public transport enables access to resources and services necessary for everyday living, including food (Badland et al., 2014, Badland et al., 2017b), and has the potential to reduce health inequities. The conceptual framework depicted transport opportunities as an upstream neighbourhood attribute that influences downstream behavioural and health outcomes, which was affirmed by quantitative and spatial analysis, particularly for those living in disadvantaged areas. In the present study, government investment in active and public transport infrastructure was not sufficient to support healthy food outlet access, although interviewees and relevant literature suggests this may be amenable to change through adoption of revenue-raising approaches such as land value uplift capture (Newman et al., 2016, McIntosh et al., 2017).

The lack of federal government funding for obesity prevention was identified as another factor that impacted on the capacity of other levels of government and the non-government sector to

advance healthy local food environments. In a recent review, human and financial resources were the most commonly cited factors for the sustainability of obesity prevention interventions and changes in BMI (Whelan et al., 2018).

Interviewees noted that financial support for interagency collaboration can help bridge the gap between urban planning, public health and other portfolios that influence food environments. Funding had been used to place a local government urban planner (LG9) in a public health team, while, in another example, an urban planner described being 'the connector between the various elements of Council and the agencies, and the private sector, to pull all this [healthy urban design] together' (PS2).

These stakeholder views resonate with outcomes from the U.K. Healthy Towns program, which aimed to tackle obesity through the built environment and policy interventions (May Goodwin et al., 2014). A study that investigated the three-year initiative found that it provided opportunities for urban planners and public health practitioners to develop reciprocal working relationships and an 'open channel' of communication that might not have been otherwise possible, and it accelerated 'the integration of planning into public health (including obesity prevention)' (May Goodwin et al., 2014, p. 124). Research literature is replete with calls to break down professional silos between urban planning and health (for example, Kent and Thompson, 2012, Barton and Grant, 2013, Carey and Crammond, 2015, Carmichael et al., 2013, Sreedhara et al., 2017). Finance and investment are governance actions that can bridge the gap and support collaborative effort toward more health-promoting local food environments.

10.4.2 Urban planning and design policy as a lever for change

The findings suggested that urban planning and design policy could support the development of healthy local food environments. Quantitative analysis showed that proximal supermarket access in high disadvantage areas was negatively associated with BMI, and that proximal fast food outlet access in established areas was positively associated with BMI. Urban planning and design policy is a governance lever that could be used to increase access to healthy food outlets and restrict access to unhealthy food outlets; however, the literature on the effectiveness of such approaches is mixed (see section 2.7).

The U.S. Healthy Food Financing Initiative was a $500 million investment to support healthy food outlet access in under-served areas (Office of Community Services, 2017). Several U.S. studies investigated whether the opening of a new supermarket in a food desert brought about changes

to dietary intake, food purchasing, or BMI (Cummins et al., 2014, Dubowitz et al., 2015a, Elbel et al., 2015, Ghosh-Dastidar et al., 2017). While spatial access to healthy food outlets and perceptions of healthy food access increased (Cummins et al., 2014, Dubowitz et al., 2015a), changes to dietary and health outcomes from the new outlet access were not detected. Ghosh-Dastidar and colleagues (2017) found there was a low rate of adoption of the new supermarket for shopping, and considered whether change in residents' shopping habits is slow. It is possible therefore that timely implementation of the Victorian urban planning guideline specifying proximal supermarket access in urban-growth areas would be an important policy intervention (Growth Areas Authority, 2009. Revised 2013). This will provide healthy food outlet access to new residents as their shopping behaviours in their new residential neighbourhood are being established. The timing and delivery of the supermarket may be critical, as interviewees noted that local government authorities 'can reserve land for an activity centre or a shopping centre, [but] we have no powers to ensure that a supermarket is developed there in a timely manner' (LG5). A Western Australian study that investigated implementation of government policy to create walkable neighbourhoods found there was a dose-response relationship between the extent of policy compliance and walking behaviour (Hooper et al., 2014); however, in this study, as noted previously (chapters 6 and 9), policy compliance with the standard for supermarket access in urban-growth areas was only 26 per cent. The implications of the delay in policy implementation are not clear; to date, there do not appear to be any studies in an Australian context on the effects of the introduction of a new supermarket on shopping habits, dietary intake, or BMI, but such a study would be timely.

Qualitative interview participants suggested that the placement of new supermarkets was driven by population catchments and land availability, variables amenable to change through the implementation of spatial policy. In established areas, urban planning and design, transport, land use and housing policy was used in tandem to support the development of healthy, local food environments (chapter 8). By increasing housing density around public transport nodes, the population catchment becomes large enough to support a supermarket. From a health equity perspective, however, it is important to ensure that people have proximal opportunities for healthy food purchasing. For example, as one interviewee noted, 'people on the whole have very easy access to unhealthy food all the time … why aren't there drive-thru bread, milk, fruit and veg on the way home?' (SG9).

Longer timeframes to monitor the effect of healthy food outlet interventions are required, alongside policy interventions to restrict unhealthy food outlets and the relative availability of healthy and unhealthy outlets (Cooksey-Stowers et al., 2017, Feng et al., 2018). Monitoring and evaluating the implementation of spatial policies on food outlet access in urban environments is warranted (Vanderlee and Olstad, 2017, Franco et al., 2015).

10.4.3 Building partnerships and leadership to facilitate action

Consistent with the health governance literature, the study found that the establishment of multi-sectoral partnerships was a governance lever that would support the development of healthy local food environments (Kickbusch and Gleicher, 2012, Ruger, 2011, McQueen et al., 2012b). A shift from vertical 'silos' to collaborative, horizontal partnerships and decision-making is necessary to tackle 'wicked' problems such as obesity and health inequities (McQueen et al., 2012b, Kickbusch and Gleicher, 2012, Gortmaker et al., 2011). Other studies have also highlighted the importance of collaborative partnerships across the traditional silos of public health, land use, and transport policy-making to support decision-making on built environments for better urban health and health equity outcomes (Sreedhara et al., 2017, Barton, 2009, May Goodwin et al., 2014, Lowe et al., 2017).

As an example, the successful advocacy to include health in urban planning legislation in New South Wales (refer section 10.4.1) was led by a coalition of researchers, government and non-government organisations across a range of portfolios from health and other portfolios that coalesced around a shared goal: the inclusion of healthy planning in the legislation (Harris et al., 2017). The legislative change that came into effect in March 2018 (Department of Planning and Environment, 2018) is potentially an important step forward in support of healthy food environments.

Similarly, qualitative interview data described how Victorian researchers, government and non-government organisations worked together to define the characteristics of 20-minute neighbourhoods, a key plank of the metropolitan urban planning strategy for Melbourne. The 20-minute neighbourhood was defined as one where a 'range of local services [are] provided in a neighbourhood, which would include food, either through a supermarket, small supermarket or shop' (SG3). A pilot program to deliver 20-minute neighbourhoods in three locations across Melbourne commenced in 2018 through a partnership comprising state and local government, local communities and non-government organisations (Department of Environment Land Water

and Planning, 2018). Governance for health aims to steer communities to a collective goal in the pursuit of health and wellbeing (Kickbusch and Gleicher, 2012). Partnerships help overcome narrow sectoral interests and provide a platform for collaboration and coordinated action, but leadership is required to facilitate such change (McQueen et al., 2012b, Kickbusch and Gleicher, 2012)

A review of obesity prevention initiatives found that the leadership role encompasses formal high-level policy-makers and decision-makers, organisational leaders, project leaders, opinion leaders, champions, informal leaders, peer leaders, community leaders, religious leaders, and civic and cultural leaders (Whelan et al., 2018). Harnessing leadership is a critical governance action to advance the development of healthy, equitable local food environments. Findings from this research pointed to the need for political leadership at all levels of government, plus distributed leadership across multiple policy actors, as key levers for change. Indeed, political leadership at the ministerial level is essential for health and health equity (Commission on Social Determinants of Health, 2008, Marmot, 2010), and studies have noted its importance for institutional change (de Leeuw, 2017, James et al., 2017), for policy innovation to tackle wicked problems (Torfing and Ansell, 2016), and for providing strong, visible political support for improving food environments (Swinburn et al., 2013b).

The present study participants suggest that political leadership for the creation of healthy food environments is weak at the state government level. This is demonstrated in several ways, including: the low level of investment to support healthy food access; lack of regulatory integration across urban planning and pubic heath; and decision-making that favours private sector interests rather than the community's health and wellbeing. As one participant reported, 'there is a leadership question...if we don't have a lineup of leadership or forms of institutional leadership that can metastasize into something effective, then we need to do something about it' (SG7). Alongside this was the view that worsening diet-related health outcome data would be a catalyst for action. By contrast, political leadership at the local government level was apparent. Evidence and data were key drivers of leadership action, providing an enabling environment for political decision-making to advance healthy, equitable local food environments. One interviewee described how 'we found that this food mapping data, when it was presented to councillors, it had traction … people could see visually what their community looked like... when you looked at the density of fast food outlets, alcohol outlets and supermarkets, that was quite compelling to people that haven't ever thought about healthy food access' (SG9).

10.4.4 Summary

Sections 10.2 to 10.4 summarised and discussed findings from the quantitative, spatial and qualitative analyses, positioned within a conceptual framework for a health-promoting local food environment designed to inform urban planning policy and practice. Three spatial indicators were proposed to monitor the local food environment and to inform Victorian urban planning policy. Urban planning and governance actions to advance healthy, equitable local food environments within cities were considered within the context of the relevant literature. Before drawing implications and recommendations from the findings for research, policy and practice, there are several important limitations to this study that need to be considered, alongside study strengths that were driven by the need to overcome limitations of previous research (see section 2.6).

10.5. Study limitations and strengths

Since this study was initiated and designed in 2014, the field of local food environment research has advanced considerably. In the following sub-sections, the limitations of this study are discussed, followed by its strengths, before considering the implications for research, policy and practice.

10.5.1 Limitations

Cross-sectional analysis

A major limitation of the quantitative analysis was its cross-sectional study design, and therefore its inability to infer causality. It is possible that Preventive Health Survey respondents self-selected into neighbourhoods based on dietary preference. Previous studies have controlled for residential self-selection by asking survey respondents why they moved to their neighbourhood, or by capturing behavioural preferences and using these as covariates in the analysis (McCormack and Shiell, 2011). This survey however did not include questions on residential location or dietary preference.

A longitudinal study design is another method of controlling for self-selection (Garfinkel-Castro et al., 2017), but very few of these studies have been carried out to date. A recent review of food environment studies found that only 25 of the 236 studies (10.6 %) that used geographic analysis to assess local food environments used a longitudinal study design (Lytle and Sokol, 2017). The authors of this review and others (Lytle and Sokol, 2017, Cobb et al., 2015, Caspi et

al., 2012b, Zenk et al., 2017) have argued for more longitudinal local food environment study designs. Several longitudinal studies have recently emerged that have shown no association between food outlet access and BMI. A U.S. longitudinal study found no evidence that geographic access to supermarkets or fast food outlets was associated with changes in BMI, suggesting that self-selection may be biasing associations found in cross-sectional studies (Zenk et al., 2017). Similarly, an Australian longitudinal study found no association between change in fast food chain availability with changes in BMI in women living in disadvantaged areas (Lamb et al., 2017).

Nonetheless, as a cross-sectional analysis, this study was able to assess equity of access to healthy and unhealthy food outlets and to assess implementation of the Victorian urban planning policy guideline to provide a baseline for assessing progress over time. This component of the study showed the importance of geographic scale across socio-economic areas and across established and urban-growth areas (section 10.3). An analysis of the spatial distribution of supermarkets, overlaid with area-level disadvantage and public transport access, identified geographic areas of vulnerability in outer established LGAs and urban-growth LGAs, a finding confirmed by key stakeholder interviews. Hence, a cross-sectional analysis on the extent of urban planning policy implementation offers support to policy-makers and practitioners by identifying geographic areas of inequitable access where targeted effort is required.

Limitations of survey data used for outcome measures

A second limitation to the quantitative analyses is that associations may be biased because self-reported height and weight data were used in the Victorian Preventive Health Survey dataset. However, the Australian Longitudinal Study of Women's Health found substantial agreement between objectively-measured and self-reported BMI of mid-aged Australian women (Burton et al., 2010). Moreover, another Australian study found that using self-reported height and weight data to calculate BMI was appropriate for middle-aged and older Australian adults (Ng et al., 2011). The mean age of the Preventive Health Survey respondents was 54 years, suggesting that there may have been closer agreement between self-report and actual BMI in this mid-aged cohort that lessens the limitations of self-report data.

Self-reported dietary intake measures were also used, and therefore these may also be biased by under-reporting (Macdiarmid and Blundell, 1998). Respondents may have provided a 'socially desirable response', whereby they provide an answer they believe will be viewed favourably by

others rather than an accurate account of their dietary intake (Miller and Miller, 2017). Further, the Victorian Preventive Health Survey relied on a brief screener of several questions to assess dietary intake, and this may not be an accurate reflection of their total or overall dietary intake, although they can give an indication of adherence to dietary guidelines for particular food groups such as fruit and vegetables (Miller and Miller, 2017).

Food environment exposure measures

A third limitation is that the food outlet dataset used in the analysis did not include all food outlets, potentially underestimating the food environment to which people are exposed, and where they purchase food. Supermarkets were used as a proxy for healthy food access. As described in the methods section (section 5.3), research commissioned by the Australian Federal government estimates that while the majority of fruit and vegetable purchasing (72%) occurs in supermarkets (Spencer and Kneebone, 2012), fruit and vegetables are also purchased in other food outlets such as greengrocers and markets. While acknowledging this as a study limitation, supermarkets include a dimension of access related to time, as they open every day and for long hours. In contrast, in the Australian context, greengrocers and fresh food markets have shorter opening hours, with fresh food markets perhaps only trading on certain days of the week. Melbourne's largest fresh produce retail market, for example, is closed on Mondays and Wednesdays, and has shorter trading hours on Tuesdays and Thursdays, closing at 2 pm (Queen Victoria Market, 2018). A Canadian study investigated spatial access to healthy food outlets and public transport in Toronto over a 24-hour period, finding that in the early morning and late at night healthy food access was limited, representing a barrier to many, including shift workers (Widener et al., 2017). Similarly, interviewees highlighted the importance of supermarket opening hours for purchasing food: 'you've got to think about hours of operation as well, that's also about accessibility: shift work, after the kids have gone to bed, that kind of thing as well. So, accessibility in relation to spatial is definitely important but there is capacity for some of our current existing supermarkets to become more accessible through different hours of operation' (LG12).

Fast food chains were used as a proxy for unhealthy food access, and, for pragmatic reasons, smaller independent fast food outlets were not included in the dataset. This means an underestimate of the true level of exposure to fast food outlets by non-inclusion of independent takeaway food outlets, such as fish and chip outlets. While consistent with the approach of many previous studies, it is a limitation. On the other hand, a key stakeholder commented on the

influence of fast food chains that extends beyond the store and its potential for influencing individual preferences, attitudes and beliefs:

> The big multinational fast food outlets have a presence beyond that one shop. They are usually present in big AFL sponsorship deals, our young people are seeing that logo reinforced on their favourite footy or other stars, cricket stars. There's a lot of publicity on the media or even the social media, there's a lot of reinforcement of the brand…and that's why these have to be dealt with differently from just a food shop - I'll say a fish and chip shop or something like that that might be equally as unhealthy (SG9).

Unmeasured exposures that may influence dietary intake and/or BMI

Unmeasured local food environment exposures were a fourth limitation of the research. Although it appeared in the conceptual framework on the pathway to dietary intake, outdoor advertising was not included in the analysis. While studies suggest that unhealthy food outdoor advertising may be concentrated in low socio-economic areas (Isgor et al., 2016, Settle et al., 2014, Lucan et al., 2017) and around primary schools (Kelly et al., 2008), the evidence for its effect on dietary and health outcomes is still emerging. A U.K. study among older adults found no associations between fruit and vegetable intake and advertising in shop windows, nor on billboards and other external locations for unhealthy foods (Hawkesworth et al., 2017); however, a U.S. study found such advertising may be associated with overweight and obesity (Lesser et al., 2013). Additionally, non-residential food environment exposure, such as around workplaces and in-store food environments, were not included in the analysis. One French study found that only 11 per cent of participants shopped at supermarkets in their residential neighbourhood (Chaix et al., 2012). Other studies have found associations between food environments around workplaces and dietary intake (Thornton et al., 2013) and BMI (Moore et al., 2013). The literature review (section 2.4.2) has shown that the in-store food environment within Melbourne varies across urban areas (Cameron, 2018, Palermo et al., 2016), which may influence dietary and health outcomes.

There were also unmeasured physical activity environment exposures that may influence BMI. The physical activity literature has established that built environment attributes and the design of urban environments is associated with physical activity, such that increased residential density, intersection density, public transport density, and parks accounted for large increases

in adult physical activity across 14 cities worldwide (Sallis et al., 2016). Further, recreation and sporting facilities were not included in the analysis, although these may be associated with decreased BMI (Mason et al., 2018).

Multiple comparisons

A fifth limitation relates to multiple testing. The quantitative analysis investigated two food environment availability measures (density, relative density) and an accessibility measure (proximity). The availability measures were operationalised across a range of geographic scales from 800 m to 3000 m that modelled walkable and short driving distances from home. It is possible that multiple testing led to a type I error, where an association was detected by chance. Several methods have been proposed to account for multiple testing, including the Bonferroni and Holm adjustments (Holm, 1979, Romano and Wolf, 2005, Perrett et al., 2006), which have their own limitations as they may increase type II errors, where a true association exists but is not detected (Rothman, 2014). Hence, similar to Olstad and colleagues (2017), all analyses in the study were determined *a priori* based on specific hypotheses informed by associations found in previous studies. Further, sensitivity analyses were conducted on significant results to discern trends across buffer sizes.

Qualitative interviews

A sixth limitation was part of the qualitative data collection. Interviews with participants from state and local government, non-government and the private sector were conducted, but there were no representatives from the urban development industry or the supermarket chains. Although invited to participate, they declined. Finally, with a focus solely on urban settlements in high-income countries, the generalisability of findings is limited.

10.5.2 Strengths

Notwithstanding these limitations, this research study had many strengths that arise from the study design which sought to overcome limitations previously identified in the literature (section 2.6). A comprehensive approach to food outlet data verification, discussed below, was another study strength.

Conceptualisation and mixed method study design

The development of a conceptual framework to underpin the quantitative and spatial analysis was a strength of this study. All spatial measures that were investigated in the study both

mapped to the conceptual framework and were identified *a priori* from the literature and policy. The analysis used person-centred measures to eliminate aggregation error, while operationalising measures at a range of geographic scales informed by travel survey data on the distances people travel to purchase food from different food outlet types. Recognising the heterogeneity of food outlet access measures, the analysis investigated a range of measures to determine which food environment measures were associated with optimal and less optimal health outcomes. An equity lens was applied by stratifying analyses across socio-economic areas, with implications for research, policy and practice, which will be discussed in the next sections.

The mixed methods study design was also a major strength of this research. As depicted in Figure 4.1, the quantitative and spatial analysis informed the sampling strategy for the qualitative strand. Qualitative interviewing helped contextualise and explain the results from the quantitative and spatial analyses. Together, the quantitative, spatial and qualitative strands shed light on the unexplored research area of local food environments within cities across areas of varying suburban development in an Australian context, filling a gap in the literature.

Secondary food outlet data verification

Accessing accurate and comprehensive food outlet spatial data across large geographic areas presents a major challenge, and has been frequently noted as such in the food environment literature (Matthews et al., 2009, Lucan, 2015). It is estimated that secondary data sources represent only 52 to 68 per cent of the food outlets that exist in an area (Moore and Diez-Roux, 2014). Non-contemporaneous collection of food outlet data and health outcome data is another source of error (Thornton and Kavanagh, 2010): if the health data are not collected near to the same time as the food exposure outlet data, the associations between food outlet exposure and dietary intake may be biased. A strength of this research has been the comprehensive cross-checking of food outlet data, triangulating data with other retail data sources, including company websites, White and Yellow page listings, and Google Street View (Lucan, 2015). Google Street View has been shown to be a promising tool for virtual audits of built environment features (Bethlehem et al., 2014, Charreire et al., 2014, Lake et al., 2010, Pliakas et al., 2017). A virtual audit of all food outlets was conducted if there was uncertainty about the existence of the food outlet after cross-checking commercial business listings with company websites and White and Yellow page listings.

10.6. Implications for policy and practice

This study aims to conceptualise and develop local food environment indicators to inform urban planning policy, and to identify governance actions that will advance healthy, equitable local food environments within cities. Multiple sectors have a role in influencing the development of local food environments. Drawing on the quantitative, spatial and qualitative findings, this section outlines the implications for policy and practice, offering recommendations for each sector to support the development of healthy, equitable local food environments in Victoria. The recommendations are summarised in section 10.6.4.

10.6.1. State government

The state government has a role to play across multiple processes of governance. In this section the implications for state government are considered and recommendations presented across each domain of governance. This section begins with the regulatory framework, potentially the most challenging and change-resistant mechanism of governance.

Regulatory reform

Regulatory reform is required. The key reform recommended through this research is the inclusion of public health and wellbeing as one objective in the relevant planning legislation. In Victoria, the *Planning and Environment Act 1987* provides the legislative framework for planning provisions and controls, municipal planning schemes, planning policies, zones and overlays that determine how land may be used or developed (Department of Environment Land Water and Planning, 2015). An amendment to the Act will support local government and communities who seek to foster the provision of healthy food outlets or restrict fast food outlets for public health reasons. On appeal, the planning tribunal reviews decisions by interpreting the provisions, policies and other procedures that are based on the Act (Municipal Association of Victoria, 2016b). Amending the Act to include an objective dealing with health and wellbeing would then 'cascade down into the land uses' (SG8). Section 10.4.1 shows how this has been achieved in draft New South Wales legislation (Kent et al., 2017).

A second potential regulatory reform is the removal of the provision whereby a planning permit is not required for convenience restaurants that abut a 'Road Zone' in the 'General Residential Zone'. As outlined in chapter nine, this provision prevents local government authorities from controlling the supply of fast food outlets in their communities (Department of Environment Land Water and Planning, 2016b). In tandem with this legislative change, the state government

should investigate options for placing the onus of proof on applicants for new fast food outlets that they will not cause harm. Controls on liquor outlets that have already been introduced into one Australian jurisdiction offer an example. The Western Australian government, for example, introduced a provision to the *Liquor Control Act 1988* requiring liquor licence applicants to show that the application was in the public interest and would not cause harm or ill-health to people, including 'at-risk' groups (Department of Racing Gaming and Liquor, 2017). In Victoria, public health groups have advocated for similar provisions, arguing that under current legislation objectors have an 'impossible task' where they are required to show a causal relationship between a new liquor licence and the prospective risk of harm (Alcohol Policy Coalition, 2016, p. 27, Room, 2014). Onus of proof requirements on fast food chain applicants could play an important role in reducing the availability of fast food outlets.

Finance

Government investment in infrastructure and initiatives to support the development of healthy local food environments is required. It offers potential to support healthy food access in two ways. First, it can improve transport opportunities to healthy food outlets through the provision of public transport, walking and cycling infrastructure. This research demonstrated it is not just the availability of food outlets that is important; it is the location and accessibility of outlets. State government investment and advocacy to the federal government for investment in transport opportunities is therefore important. Land-value uplift capture strategies to finance public transport infrastructure were recommended in the qualitative strand. Second, government investment in obesity prevention was noted as a significant contributor to Victorian efforts to support healthy food environments, for example in its provision of funding used at the local government level to embed an urban planner in a public health team and to build capacity in urban planning for supportive environments for healthy eating. State government investment and advocacy to federal government for obesity prevention funding is therefore an action that can support the development of healthy local food environments. Additionally, the state Government should advocate to the Federal government for a sugar-sweetened beverages (SSB) tax to raise revenue for obesity prevention initiatives. An Australian study estimated there would be a gain in health-adjusted life years, reduced non-communicable disease prevalence, decreased health care costs, and increased revenue of $400 million each year from a 20 per cent SSB tax (Veerman et al., 2016).

Urban planning and design policy

State governments have a significant role to play in the development of urban planning and design policy and guidance, and can act to support the development of healthy and equitable local food environments.

The first recommendation is that the Victorian state government should monitor the implementation of the Precinct Structure Planning Guideline on supermarket access in urban-growth areas (Growth Areas Authority, 2009. Revised 2013). This study assessed the extent of implementation of this policy guideline, finding that only 26 per cent of urban-growth area dwellings were within 1 km of a supermarket. This policy had not previously been assessed, so the data presented in this analysis based on 2013 spatial data could form a baseline measure. Monitoring implementation of the guideline and publishing spatial access data on the distribution of supermarkets across Melbourne will identify gaps where targeted effort is required to improve healthy food access.

Second, quantitative analysis demonstrated the protective effect of supermarket access within 800 m and 1000 m in high disadvantage areas. It is therefore recommended that the supermarket access guideline is implemented across all urban Melbourne, both in established and urban-growth areas with a focus on high disadvantage areas. Targeted urban planning and design policy interventions in geographic areas of the city are warranted to ameliorate inequities (World Health Organization, 2010, Xu and Wang, 2015). Currently, the policy guideline is only implemented in the six urban-growth local government areas of Melbourne; hence, this recommendation extends policy guidance to the other 25 local government areas that comprise the established areas of urban Melbourne.

Third, the Victorian parliamentary *Inquiry into environmental design and public health* (Parliament of Victoria, 2012) recommended that the state government support local government in mapping food outlets, and also recommended restrictions on the supply of fast food outlets. The state government should disseminate guidance to local government on spatial indicators of the local food environment, how they may be applied to support heathy food access, and how they should be monitored. Based on research findings in this thesis, the local food environment indicators would comprise:

i. the density of supermarkets within 800 m;
ii. the density of fast food chains within 800 m; and
iii. the relative density of supermarkets: supermarkets and fast food chains within 800 m.

As discussed earlier, quantitative analysis showed that density of supermarkets within 800 m and 1000 m was protective of BMI, with the effect stronger at 800 m. While 1000 m offers benefit and aligns with the current Precinct Structure Planning Guideline, 800 m is better and should be considered in the current Victorian Planning Authority review of those Guidelines. Another Melbourne study found 800 m supermarket density was associated with increased odds of walking (Gunn et al., 2017), while a Perth study found the 800 m buffer for supermarkets was associated with healthy dietary intake (Trapp et al., 2015). Even though each outcome was different, the findings all point to 800 m as an important spatial metric for supermarket availability in Australia. Quantitative analysis also showed associations between fast food chain density within 800 m and 1000 m and BMI for those residing in the established areas of Melbourne, and that increasing the relative availability of supermarkets to fast food outlets within 800 m and 1000 m was protective of BMI. Results in the present study showed a protective effect of fast food chains in the urban-growth areas. This is counter-intuitive and requires further investigation in other studies.

Local food environment indicators should therefore be monitored to guide urban planning policy and practice at the local government level. State government should provide advice on how the local food environment indicators can inform urban planning and design, and advice on other policy interventions that address food outlet availability and accessibility in local areas. For example, ensuring proximal access to supermarkets within 800 m, and public transport opportunities, could be adopted as spatial policy within a local government planning scheme, and should be reflected in the state government's Precinct Structure Planning Guidelines. Prioritising disadvantaged areas could also be a focus. Local food environment indicators would also have utility for non-government and community health organisations that implement public interventions to improve healthy food access.

Under the existing legislative framework, a local government authority seeking to restrict proximal access to fast food is unlikely to be successful; however, monitoring access and local level health outcomes may have potential to support argument before the planning tribunal. Further, if legislative change is achieved by inclusion of health as an objective into the urban planning regulatory framework, then the potential to restrict fast food proliferation is strengthened. In the U.K., local government authorities have introduced exclusion zones around schools and parks, and implemented saturation guidelines that restrict the number of fast food outlets and specify minimum distances between two outlets (Local Government Association,

2016b). The state government urban planning and health portfolios should collaborate to draft guidelines for the Victorian context that limit the number of planning permits available for fast food chains within a geographic area and that monitor the healthy to unhealthy food outlet mix.

At this point it is worth noting a caveat on recommendations about spatial access to food outlets. As outlined previously, the Australian supermarket industry is highly concentrated, with two main supermarket chains currently accounting for more than two-thirds of market share (Cloutman, 2017). These supermarket chains have come under scrutiny for their role in underpaying primary producers of milk, fruit and vegetables and underpaying workers (for example, Meldrum-Hanna et al., 2015), and for the power and influence they exert on the Australian food system (Pulker et al., 2018). While there have been public health nutrition benefits arising from improved food safety, the two supermarket chains have also been the source of detrimental impacts by promoting the consumption of unhealthy foods (Pulker et al., 2018). Nevertheless, as supermarkets are where most people purchase their fresh food (Euromonitor International, 2017), their important role in providing access to healthy food cannot be ignored. Recommendations for improved spatial access to supermarkets should therefore include independent small supermarkets, not just the main operators. This may also safeguard against the possibility of increases in co-located packaged liquor outlets owned by the two major supermarket chains. In the past fifteen years, the number of packaged liquor outlets has increased by almost 50 per cent in Victoria (Alcohol Policy Coalition, 2017). Initiatives to support supermarket access should also be considered alongside concurrent and complementary advocacy by all sectors for improved price, promotion and placement of healthy food items in the in-store environment.

Finally, the fourth urban planning and design policy recommendation to state government is that they develop a planning guideline for the provision of municipal fresh food markets similar to the supermarket access guideline, specifying that most dwellings be within 1 km of a municipal market in new residential development areas and urban renewal areas. Publicly-owned municipal markets have been recommended by urban economists to improve fresh food access locally in Victoria (Spiller, 2017, Donovan et al., 2011).

Partnerships and coordination

An ongoing coordinating platform for local food environments in Victoria is needed, either as a standalone platform or as part of a partnership around a broader priority of healthy built

environments or liveable communities. Several interviewees noted the mutually beneficial outcomes of a time-limited coordination effort around 'healthy design' that was jointly led by the health and urban planning portfolios of state government to inform the metropolitan planning strategy, *Plan Melbourne*. Ongoing coordination efforts are required.

Leadership

Political leadership from the Premier and Ministers for Planning and Health is required to create a mandate for action and drive change. Governance processes, such as reviewing and amending planning regulation and increasing investment in built environment attributes supportive of healthy food access, are reliant on political leadership at the highest level. Political leadership is required to set a long-term strategic vision for change. The WHO Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013-20 recommends governments provide leadership and adopt whole-of-government multi-sectoral approaches across portfolios such as health, agriculture, employment, environment, finance, food, housing, industry, economic development, and urban planning to address non-communicable disease prevention (World Health Organization, 2013). The Action Plan calls for a halt in the rise of diabetes and obesity (World Health Organization, 2013). As a matter of priority, the state government should develop an obesity prevention strategy, establishing shared goals, setting priorities and milestones, and committing funding for its implementation. Interventions that target local food environments and physical activity environments would be key pillars of the strategy. The implementation of the strategy would require high-level interdepartmental leadership with evaluation, monitoring of actions, and accountability structures.

Spatial and population health data

The availability of local fine-grained data was noted by stakeholders as an important driver for leadership at the local level (see chapter 8). Political leadership could be activated by data and evidence. Local fine-grained data of food outlet distribution and its associations with health outcomes provide evidence to present before planning tribunals, and provides a focus and imperative for local government and civic action. It can be used to identify geographic areas of disadvantage with poorer health outcomes and health inequities.

State government could support the data needs of communities by providing geospatial food outlet data in an open data repository. Currently, open access geospatial data is available for residential development sites, wetlands, water resources and a range of other built environment

attributes (Data.Vic, 2018). In Victoria, food businesses are registered with their local government authority under the Food Act 1984, and since 2010 these registrations have been transmitted to the state government (Department of Health, 2012). As a medium-term priority, an ongoing program to progressively geocode food business registrations as they are reported each year would assist local governments, communities and researchers in accessing spatial data on food outlet access. Alternatively, the feasibility of amending the reporting tool to include geocoordinates of food business could be investigated. Such an initiative would also allow smaller, independent food retailers to be included in analyses.

The state government should review its population health data collection protocols to ensure that a proportion of data collected is routinely geocoded. This would require appropriate ethical approvals, protocols and privacy statements at the time of data collection; however, it would assist the government, researchers and communities in identifying place-based inequities within the city of Melbourne, and across regional and rural areas.

The state government lacks a robust dietary risk assessment system. A brief screener relying on several questions only was used in the population health survey, however this does not reflect total or overall dietary intake or risk. Brief screeners are routinely used in the absence of a routine nutrition monitoring system for surveillance purposes (Miller and Miller, 2017). Therefore, routine dietary monitoring is recommended to provide the dietary intake data to inform the ongoing assessment and monitoring of local food environments and health, and to inform policy and governance. Further, the state government should ensure that the psychometric properties of all population health survey questions have been established prior to survey distribution, and, where possible, enable comparability with other surveys or national/international standards. In addition, questions that are suitable for longitudinal monitoring should be considered. Introducing a length of residency survey question and/or establishing a longitudinal data study design should also be investigated. Researchers in the U.S. have begun linking electronic health record data to built environment and spatial data in population health research studies (Schinasi et al., 2018). It is estimated that by the end of 2018, 98 per cent of all Australians will have an electronic health record after the implementation of a national opt-out participation protocol (Australian Digital Health Agency, 2017). The State government could work with the Australian Digital Health Agency and/or the national spatial database initiative, Australian Urban Research Infrastructure Network (aurin.org.au), to investigate the feasibility of linking Australian electronic health data to spatial data.

10.6.2. Local government

While many of the governance actions identified at the state government level have a corollary at the local government level, in general there are fewer governance levers available to local government. For example, local government has less access to revenue raising mechanisms. It raises finance through rates (land tax), which account for less than four per cent of taxes collected in Australia, compared with 80 per cent collected by the Federal government and 16 per cent collected by state governments (Municipal Association of Victoria, 2016a).

Urban planning and design policy are a powerful lever, with multiple interviewees describing their use of urban planning, land use, transport and housing policies together to create the conditions for the development of healthy, equitable local food environments. Implementation of the supermarket urban planning guideline in both urban-growth and established area is important for socio-economic and transport-disadvantaged residents. Local governments should use the local food environment indicators to monitor healthy and unhealthy food outlet access within the walkable catchment of 800 m.

Ongoing coordinating platforms for healthy local food environments at the local government level are required, including food policy coalitions and other partnership structures bringing together diverse stakeholders that focus attention on elements of the food system, including spatial access to food outlets (for example, McCartan and Palermo, 2017, Caraher et al., 2013). At a minimum, stronger and enduring coordination efforts across the urban planning and public health areas of local government are required. One urban planner interviewee noted the benefits of being physically co-located with the public health team. The literature suggests that collaboration across land use, transport and public health portfolios can enhance built environment decision-making (Sreedhara et al., 2017).

As the level of government closest to the community, local government plays an important role, bringing local food environment issues to the attention of their community and being well placed to provide leadership for change. Interviewees noted the importance of fine-grained local level data availability for motivating action, articulating how it could support their representation at the planning tribunal. For instance, upon seeing local food environment maps produced for stakeholder interviews, one interviewee said: ‘as soon as I saw this [maps] I was a bit excited…In a VCAT environment a sitting member…will often use a radial catchment to decide whether a house is near to services ignoring the fact it's all cul-de-sacs and there are no

pedestrian cut throughs …planning needs evidence to produce the changes in the planning scheme that might eventually make it harder to open a fast food outlet' (LG9). While local governments may have had the geospatial expertise to map local food outlets registered under the *Food Act*, interviewees reported that funding support was lacking. It is therefore a priority that local government and state government work together to ensure that food outlets are geocoded, and that this spatial data are readily available for multiple purposes. In 2017, six Metropolitan Partnerships were established across Melbourne with representatives from state and local government, community organisations and the business sector to provide advice to State government on regional priorities (Department of Environment Land Water and Planning, 2017). Fine-grained data on local food environments, transport and socio-economic disadvantage to local communities could support directions for local food environments as a regional priority.

10.6.3. Non-government

Given non-government organisations important advocacy and coordination roles, it is a priority that they organise around a shared goal. The success of tobacco control in Australia has been attributed to concerted action by anti-tobacco non-government organisations, the use of evidence and data, and a consensus position on priorities for action (Studlar, 2005, Australian National Preventive Health Agency, 2013). In 2017, more than 35 Australian non-government, public health, community and research organisations called on the Federal government to take action on obesity, coming together for the first time with a shared position on eight evidence-based actions (Obesity Policy Coalition and Global Obesity Centre, 2017). Similar action on obesity prevention is required at state government level, which could advocate for health in urban planning legislation as a core demand.

10.6.4. Summary of recommendations for Victoria

In the previous sections, the implications for policy and practice were discussed. Table 10.1 summarises the recommendations for Victoria for each process of governance. Most recommendations are directed toward state government, where the largest re-orientation of effort toward healthy, equitable local food environments is required.

Table 10.1. Summary of recommendations for Victoria

Governance process	Action	Sector & portfolio
Regulation	Amend *Planning and Environment Act 1987* to include public health and wellbeing as an objective.	SG (UP)
	Remove planning provision that allows convenience restaurants in the residential zone.	SG (UP)
	Reverse onus of proof on harm from new fast food fast outlets during planning permit application process.	SG (UP)
Finance	Increase investment in public and active transport infrastructure to improve accessibility to heathy food outlets.	SG (CA)
	Increase investment in preventive health to support healthy food environment initiatives.	SG (CA)
	Advocate to Federal government for increased investment in public transport infrastructure and preventive health initiatives to support local food environments.	SG (CA), LG, NG
	Advocate for comprehensive land value capture strategies and a sugar-sweetened beverage tax to finance public transport infrastructure and preventive health initiatives.	SG (CA), LG, NG
Urban planning and design policy	Monitor the implementation of the Precinct Structure Planning (PSP) guideline on supermarket access in urban-growth areas. Publish data.	SG (UP)
	Implement PSP guideline across both urban-growth and established local government areas of Melbourne.	SG (UP)
	Adopt and disseminate indicators of the local food environment for monitoring that comprise: • the density of supermarkets within 800 m • the density of fast food chains within 800 • the relative density of supermarket to supermarkets and fast food chains within 800 m	SG (UP & PH)
	Provide guidance on the application of the local food environment indicators to local government and the non-government sector and how they can inform urban planning and other policy interventions for healthy equitable local food environments.	SG (PH)
	Prepare guidelines recommending municipal markets in new residential developments and incorporate these into PSP guidelines.	SG (UP)
	Use spatial indicators to monitor food outlet access at the local level and to inform urban planning and other policy interventions for creating healthy, equitable local food environments.	LG, NG
Partnerships and coordination	Ensure ongoing coordinating platforms for local food environments.	SG (PH), LG,
	Embed an urban planner in public health unit (and vice versa) to build capacity and enhance collaboration	SG (UP & PH), LG

Leadership	Develop a statewide obesity prevention strategy that includes objectives for healthy, equitable local food environments.	SG (PH)
	Develop a consensus position to inform advocacy on local food environments to federal and state governments.	LG, NG
Data and information	Geocode food outlet data.	SG (PH), LG
	Provide geocoded food outlet data in an open access data repository.	SG (PH)
	Undertake routine dietary monitoring to provide the dietary intake data for the ongoing assessment and monitoring of local food environments and health.	SG (PH)
	Explore electronic health data linkage to food outlet spatial data.	SG (PH)
	Review psychometric properties of population health data survey questions and data collection protocols.	SG (PH)
SG: State government; LG: local government; NG: non-government organisation; UP: urban planning; PH: public health; CA: central agency (Dept. Premier & Cabinet / Dept. Treasury & Finance)		

10.7. Implications for future research

In this research, the development of the conceptual framework and the mixed methods study design were used to identify both spatial indicators for the local food environment and urban planning and governance opportunities to advance healthy equitable local food environments. Based on this study, implications and recommendations for future research are discussed. During the conduct of this study, technological innovation and efforts to modify food environments have gained prominence. The local food environment is rapidly changing. Within this changing context, implications and recommendations for future research are also discussed.

10.7.1 Recommendations arising from this research

There are five key recommendations for future research arising from this study. First, this study demonstrates the importance of testing geographic scale and multiple measures in food environment research to identify spatial metrics associated with optimal health outcomes to inform urban planning policy. Geographic scale should routinely be considered in food environment research. A recent review also recommended the use of multiple food environment spatial measures to provide a comprehensive description of food environment exposure based on *a priori* hypotheses (Bivoltsis et al., 2018). In this study, while geographic scale pertaining to residential food environments was investigated, there is scope for future research to investigate the 'activity space': the locations that a person visits when they purchase food (for example, Thornton et al., 2017).

Second, this study demonstrates there are differential associations of food environment exposure on health across geographic areas within cities. In this study, variations across socio-economic areas and variations across established and urban-growth areas were observed. Urban environments within cities are heterogeneous, such that fine-grained analysis is important to understand the differences within cities and how this affects communities. Fine-grained analysis can identify geographic areas of inequity where targeted urban planning and policy interventions can be directed to reduce inequities. Local fine-grained data are important for political leadership, influential in a planning tribunal environment, and valuable as a driver for change.

Third, this study underlines the importance of equity analyses in food environment research. To support the development of healthy and equitable local food environments, it is necessary to routinely incorporate an equity dimension into analyses. Assessing public transport access

alongside food outlet access is recommended to identify geographic areas of multiple disadvantage.

Fourth, this study highlighted the strengths of using a mixed methods approach to enhance the utility of the research and to support research translation. The quantitative and spatial analysis described the problem, while the qualitative data collection used key stakeholder interviews to take the next steps toward identifying a solution by generating ideas for urban planning policy and governance opportunities to advance local food environments. Local food environment research would benefit from mixed methods approaches so as to move beyond describing the problem. Future research could incorporate the 'lived experiences' of people living in communities. Qualitative interviewing with residents with lived experience of local food environments would provide further and differing insights. A recent Spanish study showed how the perspective of residents was incorporated into a process that also engaged researchers and policymakers to generate built environment, socio-cultural environments and economic environment policy recommendations for obesity prevention (Diez et al., 2018).

Fifth, as noted in section 10.5.1, this study employed a cross-sectional dataset and analysis. Longitudinal study designs and natural experiment studies are recommended to deepen our understanding of local food environments and health. Natural experiment studies in food environment research are scarce (MacMillan et al., 2018); and in an Australian context only one study was found. This study evaluated the impact of a new fast food restaurant on residents' eating behaviour, finding no increase in fast food consumption (Thornton et al., 2016a). Longitudinal and natural experiment studies can provide valuable insights into how changes in the urban food environment affect dietary and health outcomes. Strong engagement and collaboration with government can drive targeted and policy-relevant research that includes longitudinal studies and natural experiment studies on policy implementation.

10.7.2 Recommendations arising from new contextual factors

There are two additional recommendations for future research arising from technological innovation and new contextual influences on the local food environment.

First, population health data used in this research were collected in 2013. At that time, internet retailing accounted for 2.5 per cent of the retail volume of fresh food in Australia, increasing to 3.2 per cent by 2016 (Euromonitor International, 2017). While coming off a low base, it is estimated that online grocery shopping is the fastest growing retail channel compared with

purchasing in physical 'bricks and mortar' supermarkets (Inside Retail, 2018). One of the major supermarket chains has been trialling a 30-minute home delivery service using the online food delivery company, Deliveroo (Cloutman, 2017). The fast food and convenience food industry in Australia is also changing, with online delivery sales expected to increase from 10 per cent of the fast food market in 2017 to 23 per cent in 2025 (Mitchell, 2018); hence, associations between neighbourhood food environments and dietary and health outcomes will change as new technologies in food delivery services become more widely adopted. Implications for future research include investigating how these innovations in food access effect dietary and health outcomes, and identifying whether there are opportunities to harness innovation to improve health outcomes and reduce inequities.

Second, efforts are underway to assess Australian supermarket companies against obesity prevention and nutrition criteria, and to provide recommendations on how they can support consumers in making healthier choices (Sacks et al., 2018). Indeed, advocacy and monitoring efforts are occurring globally (The Food Trust and Robert Wood Johnson Foundation, 2011, Swinburn et al., 2013a). If the supermarket industry heeds the call to improve the healthiness of their product offerings, and improves the price, placement and promotion of healthy options, it is possible that the effects of supermarket access on dietary and health outcomes will improve. Further research is needed to categorise food outlets in terms of their relative contribution to access to healthy and unhealthy food. There are other developments that may influence local food environment research, such as: the introduction of kilojoule labelling in Victorian supermarket chains and large chain food businesses in 2018 (Department of Health and Human Services, 2017a); the possible introduction of a sugar-sweetened beverage tax that has been adopted in many countries and has wide support from Australian researchers, public health and consumer groups (Backholer et al., 2017, Backholer and Martin, 2017); and improvements to the nutritional quality of fast food chain menu offerings (Soo et al., 2018). Future research should investigate how changes to the in-store environment act as intermediaries on associations between physical access to the food outlet and dietary and health outcomes.

10.8. Summary

In this chapter, the findings from the quantitative, spatial and qualitative analyses were summarised and synthesised with reference to the existing literature. This was in response to the study aims to conceptualise and develop local food environment indicators to inform urban

planning policy and practice, and to identify governance actions to advance healthy, equitable local food environments within cities.

The chapter highlighted the utility of the conceptual framework that underpinned the quantitative analysis, and the value of the health governance literature that provided an analytic lens for the qualitative data. Urban planning policy and governance actions were identified that have potential for healthy, equitable local food environments. The research had several limitations relating to its study design and data. These were discussed alongside the study strengths that were designed to overcome several limitations identified in previous food environment research. Despite its limitations, the research provided many insights with implications for policy and practice. These were considered and developed into a set of recommendations for Victorian government and non-government organisations. Finally, the chapter discussed the implications and recommendations for future research.

The next chapter concludes the thesis. It indicates how the aims of the thesis were fulfilled, outlining how each of the five research questions were answered. The chapter includes a section on research translation activities, and it summarises how this thesis constitutes an original contribution to knowledge in the field of local food environment research.

Chapter 11. Conclusion

This research conceptualised and developed local food environment indicators to inform urban planning policy and practice, and identified governance actions to advance healthy, equitable local food environments within cities. Quantitative and spatial analyses showed that food outlet access varied across socio-economic areas and across urban-growth and established areas of Melbourne, Victoria. Differential associations between food environments and body mass index were detected across geographic areas. Key stakeholder interviews were conducted to contextualise and explain the quantitative and spatial results. Based on these data, urban planning and governance actions were proposed for healthy, equitable local food environments.

Chapters One and Two provided the rationale and background to the research, and presented the research aims and questions. Briefly, this thesis aimed to fill a research gap by identifying spatial measures of the local food environment associated with optimal dietary intake and BMI that could be used to inform urban planning policy and practice. In doing so, the research sought to address several methodological challenges that have hampered local food environment research to date internationally. Inconclusive findings in the body of research have been linked to the heterogeneity of measures and to the choice of geographic scale; therefore, this thesis explored the relationship between a range of exposure measures (proximity, density and relative density) for supermarket and fast food chain access, and dietary intake and BMI. The density and relative density measures were also explored at varying geographic scales to identify the thresholds and distances associated with optimal dietary and health outcomes for different types of food outlets. Spatial evidence is required to inform urban planning policy and the delivery of healthy food environments, which in turn can improve population dietary and weight outcomes.

Further, the evidence was limited in relation to how local food environments varied at the intra-city level, and how this influenced health and health equity. In response to this knowledge gap, an equity analysis was conducted to interrogate local food environments by area-level disadvantage and to explore their associations with dietary and weight outcomes so as to illuminate the hidden inequities within the city at a neighbourhood-level. Local food environments were found to matter more to people living in high disadvantage areas. Similarly, the intra-city variation across urban-growth and established areas was investigated to better

understand how rapid population growth and suburban development influenced food environments and health.

Chapter Three presented a new conceptual framework that was developed as part of this research to inform urban planning policy and practice. It described the pathways from urban planning and other government policies to built environment attributes of the food environment, through to behavioural outcomes that influence weight status, to long-term health outcomes. The conceptual framework, published in the *Health Promotion Journal of Australia* (Murphy et al., 2017a), informed subsequent quantitative and spatial analysis. Chapter Four described the mixed methods research design incorporating quantitative, spatial and qualitative approaches, followed by Chapter Five, which described the quantitative data and statistical analysis.

Chapter Six was the first of the results chapters. It reported the associations between access to supermarkets and fast food chains across diverse socio-economic areas. The findings showed that walkable access to supermarkets was important for healthy weight in high disadvantage areas, while walkable access to fast food chain outlets in established areas was detrimental to health. A unique contribution to the literature and to the study of the food environments in Melbourne was the study of spatial patterning of supermarket access across the city, which included measures of area-level disadvantage and transport disadvantage. Geographic areas with multiple disadvantages were identified; this methodology offers utility for other food environment research in urban settings. For the first time, the extent of implementation of a Victorian urban planning policy on supermarket access was assessed. This chapter included a paper published in the journal *Public Health Nutrition* (Murphy et al., 2017b).

Qualitative data collection and analytic methods through a health governance theoretical lens were presented in Chapter Seven. Twenty-seven key stakeholder interviews with policy-makers and practitioners were conducted to identify contextual factors that influenced the availability and accessibility of food outlets, and to explore governance barriers to, and opportunities for, supporting heathy equitable food environments. The results were reported in Chapter Eight and included a paper was published in the journal *Cities & Health* (Murphy et al., 2018b). The final results chapter, Chapter Nine, reported the mixed methods investigation into local food environments in the context of rapid population growth and suburban development. This chapter, combining quantitative and qualitative results of the analysis across areas of varying

suburban development, included a paper that was published in the *International Journal of Environmental Research and Public Health* (Murphy et al., 2018a).

Together, these chapters answered the five research questions, which are revisited below.

11.1 Answering the research questions

1. How does the local food environment influence dietary intake and health outcomes in an urban adult population aged 18 years and over?

This thesis confirmed that the local food environment influences health outcomes in an urban adult population. While association with dietary intake were also investigated across diverse socio-economic areas, either the effect size was generally too small to be of practical significance or no significant associations were detected. Supermarket density within walkable distances was found to be protective for healthy weight for people living in high disadvantage areas, while fast food chain density within walkable distance from home was found to be detrimental to weight for those residing in established areas of urban Melbourne. The relative density of healthy to unhealthy food outlets within walkable distances was protective for healthy weight for people residing in established areas. All significant associations for urban-growth area residents were in the unexpected direction, suggesting the influence of a prior residential environment. This warrants further investigation.

2. Is there spatial patterning of food outlet access, dietary intake and health outcomes across socio-economic areas, and across urban-growth and established areas of Melbourne, Australia?

The second research question was answered with findings showing that socio-spatial patterning of food outlets, dietary and health outcomes occurs across Melbourne. People living in high disadvantage areas of Melbourne had greater access to both supermarkets and fast food chains than people residing in mid- or low-disadvantage areas. Participants from high disadvantage areas had a lower daily vegetable intake and a higher BMI than those residing in low disadvantage areas. Spatial patterning was found across areas of varying suburban development. People residing in established areas have greater access to supermarkets and fast food chains, higher fruit intake and lower BMI. Approximately 40 per cent of established area participants lived in high disadvantage areas. Approximately 40 per cent of growth area participants lived in mid-disadvantage areas.

3. What spatial measures of the local food environment are associated with individual-level dietary intake and health outcomes, and how can they guide urban planning policy and practice?

A major outcome of this research was the development and testing of local food environment spatial measures to inform urban planning policy and practice. It is recommended that the measures be adopted as local food environment indicators for benchmarking and monitoring of food outlet access in local areas. The three recommended spatial indicators comprise:

- supermarket density within 800 m
- fast food chain density within 800 m
- relative density of supermarkets to supermarkets and fast food chains within 800 m.

State government policy guidance could support application of the local food environment indicators by local government, non-government and other organisations.

4. What contextual factors influence the availability and accessibility of food outlets in urban areas of Melbourne, a city experiencing rapid growth and suburban development?

In response to the fourth research question, quantitative and spatial analyses and qualitative interviewing identified individual, socio-cultural and macro-level environmental and policy factors that influenced the availability and accessibility of food outlets. Specifically, food preference, shopping behaviours, and socio-demographics played important roles in influencing the availability of food outlet types in local areas through demand-side drivers, such as preference for specific cultural cuisines. At a macro-level, population catchments, land availability, and patterns of suburban development were key contextual factors that influenced the location of supermarkets and fast food chains.

5. What are the governance barriers and opportunities to support the development of a healthy, equitable local food environment?

A weak urban planning legislative framework and a lack of finance or investment in initiatives to support healthy food outlet accessibility were identified as barriers to the development of health-promoting and equitable local food environments. Urban planning and design policy, strengthened by partnerships and coordination across sectors and portfolios, were identified as governance processes that could be harnessed to support the development of healthy local food environments. Political leadership at all levels of government, and distributed leadership across

multiple policy actors, including civic society, were key levers for change. The availability of local, fine-grained data was an important driver of such leadership, offering potential for a planning tribunal environment.

11.2 Contribution to knowledge

This thesis makes several original contributions to knowledge.

11.2.1 Theoretical

First, a new conceptual framework was developed that mapped urban planning and other government policy to built environment attributes that had an influence on food outlet accessibility and availability, and on behavioural and health outcomes.

11.2.2 Empirical

Second, spatial measures of supermarket and fast food outlet access, associated with optimal health outcomes, were developed to inform urban planning policy and practice. Spatial measures for different food outlet types and at a range of geographic scales were tested across socio-economic areas and across areas of varying suburban development at the intra-city level. Differential associations between food outlet spatial measures and BMI were found across diverse geographic areas within urban Melbourne. The research advanced understanding of the importance of geographic scale in food environment research. Further, the distances that people travel to access food outlet types, and their transport mode, should routinely be considered in food environment research. This study was the first investigation of food outlet access and its associations with BMI across established and urban-growth areas within Melbourne.

Third, for the first time a Victorian urban planning policy regarding supermarket access was assessed. Implementation of the spatial policy across metropolitan Melbourne fell well short of the guideline. New evidence regarding geographic areas of poor supermarket access (> 1 km), socio-economic disadvantage, and transport disadvantage was generated.

11.2.3 Methodological

Fourth, spatial analysis identified a methodological issue when using Mesh Block population-weighted centroids together with sausage buffers to assess areas of poor supermarket access and public transport disadvantage. In this specific residential context, where housing block sizes

were greater than the sausage buffering distance (that is, 50 m), inaccuracies were detected. This is a methodological limitation to using sausage buffers that needs to be considered in other research contexts. Alternative approaches could be adopted to avoid this problem, such as using (more computationally demanding) land parcel-based access measures rather than measures based on population-weighted centroids.

11.2.4 Policy and practice

Fifth, the research adopted an embedded knowledge translation approach. Quantitative and spatial data were presented to qualitative interviewees as part of the mixed methods research approach. Additionally, the quantitative and spatial analysis contributed to a new evidence-based liveability index to support urban liveability that is in development (Badland et al., 2014, Arundel et al., 2017); it contributed to development of a local living measure of land use mix and diversity as part of a national liveability study (Badland et al., 2017a); and it contributed to development of a food environment indicator for a City Resilience Index for Melbourne (100 Resilient Cities, 2016).

Last, policy and practice recommendations for state and local government and non-government organisations to support healthy, equitable local food environments were developed. A first step has been the inclusion of one of the local food environment indicators as a progress measure in the Victorian Public Health and Wellbeing outcomes framework (Department of Health and Human Services, 2016b). Research translation efforts are underway to facilitate adoption of the local food environment indicators into policy and practice.

11.3 Concluding comments

Obesity is a major public health challenge and a risk factor for many non-communicable diseases (Butland et al., 2007). Inequities in the distribution of diet-related diseases including obesity, and health outcomes across populations are also a major concern. It is well recognised within public health that it is inadequate to rely solely on actions at the individual level to elicit behaviour change (Butland et al., 2007, Wilkinson and Marmot, 2003). Obesity is a complex systems problem where behaviour is influenced by multiple interacting individual and socio-cultural and environmental factors; hence, action at multiple levels of influence by a range of actors is required (Kopelman et al., 2007, Huang et al., 2009). An ecological approach was therefore adopted in this study to investigate the individual, social, built environment and policy factors that influence dietary intake and BMI.

This thesis investigated access to food outlets, and associations with health behaviours and outcomes across diverse geographic areas within a rapidly growing city. Spatial indicators of the local food environment designed to guide urban planning policy and practice were developed, filling a research gap. These were supported by urban planning policy and governance actions to translate findings into policy and practice. This thesis therefore contributes to evidence regarding how to advance healthy, equitable local food environments in order to improve population health outcomes and to reduce the inequitable distribution of diet-related non-communicable disease.

Changing the local food environment for improved health and health equity will require integrated efforts, including urban planning and design policy, partnerships, and leadership from multiple levels of government and sectors and a range of policy actors, including civil society. This thesis provides directions and suggests recommendations on the way forward for research, policy and practice to advance healthy, equitable local food environments within cities.

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Appendices

Appendix A. Administrative units

Mesh Blocks (MB), Statistical Areas Level 1 (SA1) and Statistical Areas Level 2 (SA2) are geographic areas defined by the ABS for administrative purposes (Australian Bureau of Statistics, 2011a). MBs, the smallest geographical areas, contain approximately 30 to 60 dwellings (Australian Bureau of Statistics, 2011b); the SA1 administrative unit comprises approximately 400 persons (Australian Bureau of Statistics, 2011c); and the SA2 administrative area contains between 3,000 and 25,000 persons (average 10,000 persons) (Australian Bureau of Statistics, 2011d), approximating a suburb or part-suburb in metropolitan areas. Figure 5.1 shows the relative size of these administrative units in more densely populated inner suburbs of Melbourne.

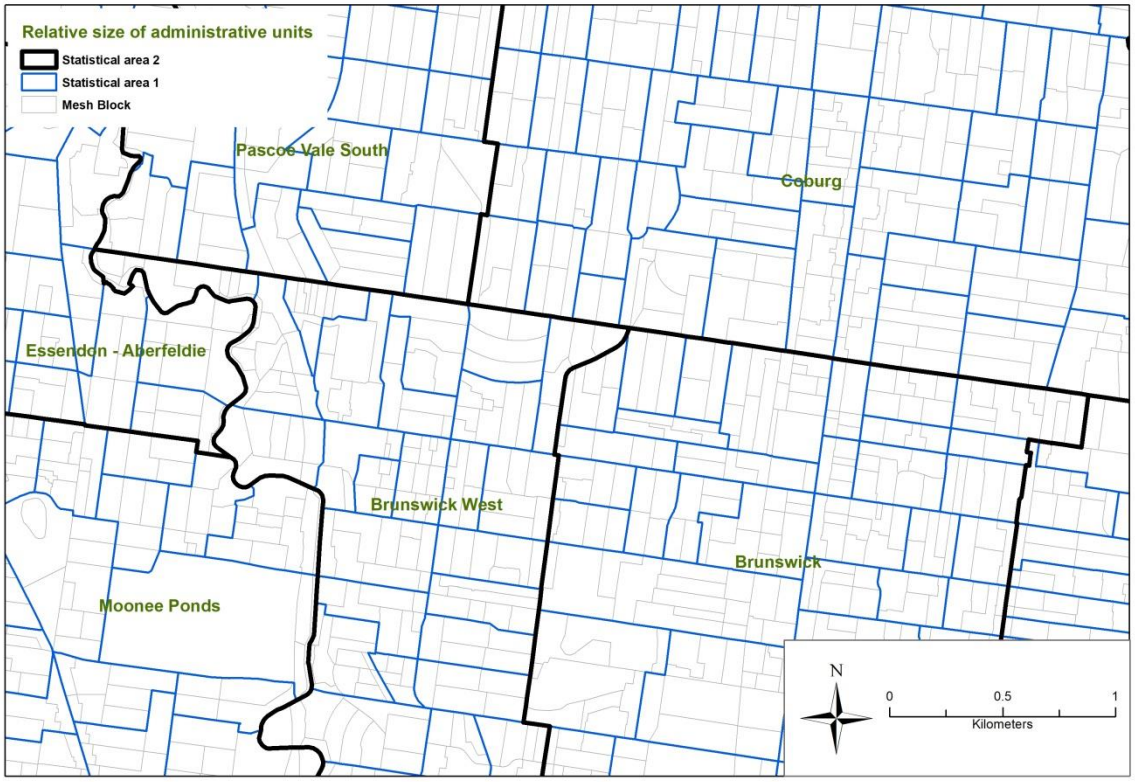

Figure A1. Example of the relative size of SA2, SA1 and Mesh Blocks in inner Melbourne

Appendix B. Supplementary material for *Public Health Nutrition* published paper

Supplementary Table 1: GEE models of associations between outcome (vegetable intake, fruit intake, BMI) and measures of supermarket access for urban PHS participants

				Area-level disadvantage								
	Total			High (*n* 1059)			Mid (*n* 1058)			Low (*n* 954)		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI	
Vegetable intake (daily serve)*												
Supermarket density												
<= 800m (pedestrian road network)	0.045	-0.035,	0.125	0.057	-0.071,	0.184	0.018	-0.059,	0.095	0.085	-0.075,	0.245
<= 1000m (pedestrian road network)	0.050	-0.006,	0.106	0.070	-0.038,	0.177	0.059	-0.061,	0.178	0.021	-0.066,	0.108
<= 1600m (pedestrian road network)	0.021	-0.018,	0.060	0.003	-0.064,	0.071	0.041	-0.047,	0.129	0.035	-0.021,	0.092
<= 2000m (car road network)	0.011	-0.013,	0.034	0.020	-0.031,	0.070	0.007	-0.060,	0.073	0.004	-0.031,	0.038
<= 3000m (car road network)	0.010	-0.004,	0.025	0.000	-0.027,	0.028ƚ	0.023	-0.040,	0.085	0.016	-0.002,	0.034
Supermarket proximity (pedestrian road network)	-0.051	-0.099,	-0.003‡	-0.049	-0.189,	0.092	-0.088	-0.200,	0.025	-0.021	-0.138,	0.095
Fruit intake (daily serve)*												
Supermarket density												
<= 800m (pedestrian road network)	-0.058	-0.097,	-0.018§	-0.064	-0.138,	0.010	-0.008	-0.067,	0.052	-0.053	-0.154,	0.047
<= 1000m (pedestrian road network)	-0.023	-0.057,	0.011	-0.035	-0.097,	0.027	0.046	-0.005,	0.096	-0.011	-0.126,	0.054
<= 1600m (pedestrian road network)	-0.020	-0.057,	0.016	-0.040	-0.094,	0.013	0.034	-0.029,	0.097	-0.010	-0.096,	0.075
<= 2000m (car road network)	0.001	-0.023,	0.026	0.000	-0.036,	0.035	0.013	-0.026,	0.053	0.023	-0.015,	0.061
<= 3000m (car road network)	-0.007	-0.022,	0.009	-0.007	-0.040,	0.026	0.000	-0.024,	0.024	0.009	-0.013,	0.032
Supermarket proximity (pedestrian road network)	0.011	-0.042,	0.063	0.042	-0.064,	0.148	0.008	-0.085,	0.101	-0.013	-0.122,	0.096
	Total			High (*n* 923)			Mid (*n* 937)			Low (*n* 852)		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI	
BMI (kg/m2)II												
Supermarket density												
<= 2000m (car road network)	-0.084	-0.247,	0.079	-0.063	-0.296,	0.171	-0.043	-0.344,	0.258	-0.182	-0.388,	0.023
<= 3000m (car road network)	0.023	-0.081,	0.127	0.056	-0.117,	0.230	-0.002	-0.130,	0.126	-0.025	-0.093,	0.043
Supermarket proximity (pedestrian road network)	-0.071	-0.439,	0.298	0.105	-0.303,	0.513	-0.186	-0.951,	0.578	0.022	-0.255,	0.299

* Adjusted for age, sex, education level, income, knowledge, self-efficacy, habit strength, social norm (injunctive), social norm (descriptive), fast food chain access and clustering at the LGA level
ƚ Model failed to converge after adjusting for fast food access;
‡ $P < 0.05$
§ $P < 0.01$
II Adjusted for age, sex, education level, income, vegetable intake, frequency of sweet drink consumption, frequency of fast food consumption, physical activity, smoking status, fast food chain access and clustering at the LGA level

Supplementary Table 2: Full regression output of GEE model of associations between BMI, supermarket access (within 800m and donut-buffer 801-1000m) & covariates for urban PHS participants in high disadvantaged areas

	Area-level disadvantage			
BMI (kg/m2) *	High (*n*923)			
	β	95% CI		*P* value
Supermarket				
<= 800m (pedestrian road network)	-0.366	-0.671,	-0.062	0.018
801 - 1000m (pedestrian road network)	-0.190	-0.792,	0.411	0.535
Fast food chain				
<= 800m (pedestrian road network)	0.082	-0.340,	0.504	0.703
801 - 1000m (pedestrian road network)	0.267	-0.300,	0.833	0.356
Sex				
male	ref			
female	-0.404	-0.849,	0.041	0.075
Age (years)				
18-29 years	ref			
30-49 years	2.281	0.678,	3.884	0.005
50-64 years	3.682	2.234,	5.130	0.000
>/= 65 years	2.646	1.004,	4.289	0.002
Education				
Primary	ref			
Secondary	0.329	-1.392,	2.050	0.708
Tertiary	-0.076	-2.417,	2.264	0.949
Household income				
$0 - $49,999	ref			
$50,000 - $79,999	-0.087	-1.020,	0.847	0.855
$80,000 - $124,999	1.190	-0.446,	2.827	0.154
≥ $125,000	-0.602	-1.683,	0.479	0.275
Refused/don't know	-1.515	-3.083,	0.052	0.058
Dietary intake				
Vegetable consumption (serves/day)	0.220	0.091,	0.349	0.001
Sweet drink consumption (frequency/fortnight)	0.032	0.000,	0.065	0.051
Fast food consumption (frequency/fortnight)	0.162	-0.080,	0.405	0.190
Physical activity				
Inactive	ref			
Insufficient activity (frequency & duration)	-1.414	-2.854,	0.025	0.054
Sufficient activity (frequency & duration)	-2.852	-4.290,	-1.414	0.000
Smoking status				
Not a current smoker	ref			
Current smoker	-1.142	-1.789,	-0.496	0.001

*Adjusted for clustering at the LGA level

Explanatory data on spatial uncertainty

Mesh Block population-weighted centroids were used to calculate the spatial distribution of supermarkets and public transport access. While variation in MB size is reduced by considering only urban areas in the metropolitan region, spatial uncertainly exists.

There were 39,989 Mesh Blocks with residential or agricultural land use category in the urban centres of the Melbourne metropolitan region. The following table describes the data:

Supplementary Table 3: Spatial uncertainty	
Mesh Block (n = 39,989)	Mesh Block area (1 ha = 10,000 sq metres)
min	0.07
max	1370.22
mean	4.72
SD	19.59
median	2.94
Inter-quartile range (IQR) (Q3 – Q1)	2.09 (4.08 – 1.99)

The data are positively skewed. The range of the data are very high (1370 ha) compared with the IQR (2.09 ha), indicating the presence of outliers. This is because the size of the mesh block depends on population density. The median, by being less than the mean, indicates the data are positively skewed.

Therefore, the IQR is a better measure of the spread of the MB area data as it is not influenced by the outliers. Using the IQR to represent the spatial uncertainty our analysis, the variation in the spatial extent of the Mesh Block area is 2.09 ha.

Plain Language Statement

Melbourne School of Population and Global Health

THE UNIVERSITY OF MELBOURNE

PhD research project: Government and private sector stakeholder perspectives on supporting healthy equitable local food environments.

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Introduction

Thank you for your interest in this PhD research project. The following few pages will provide you with information about the project, to help you decide if you would like to take part in this research. Please take the time to read this information carefully. You are welcome to ask questions about any aspect of this research.

Your participation is voluntary. If you don't wish to take part, you don't have to. If you begin participating, you can also stop at any time.

What is this PhD research about?

The aim of this PhD research is to investigate the perspectives of local and state government and private sector stakeholders on their roles and responsibilities in creating healthy equitable food environments in local neighbourhoods. Evidence suggests that proximity to, and the density of food outlets, such as supermarkets and fast food chains, has the potential to influence dietary intake and weight status of the community in surrounding areas. This effect may be greater in disadvantaged areas.

This study is interested in identifying: urban planning and policy mechanisms that can be used to support better spatial access to healthy food at a local level; the

factors that currently inform decision-making; and the potential for collaboration among key stakeholders to create healthy equitable local food environments.

What will I be asked to do?

Should you agree to participate, you will be asked to participate in an interview either in person or over the phone for approximately 45 minutes that will be audio-recorded on a smart phone or laptop. The interviews can be conducted at your workplace, at a public place, at The University of Melbourne, or by telephone. Prior to the interview you will be asked to read a short report about healthy food access and weight status in local government areas in Melbourne. We will email you the results of our recent research that investigated associations between body mass index (BMI) and access to food outlets across Melbourne; and maps of supermarket access across Melbourne with a focus on access in disadvantaged areas.

What are the possible benefits?

The potential benefits of this research is that it may assist in identifying feasible urban planning and policy mechanisms across multiple stakeholders to create healthy equitable local food environments. The research may inform Victorian urban planning and policy strategies to create healthy food environments and contribute to reduced inequities in healthy food access and dietary outcomes.

What are the possible risks?

Whilst interview responses will be kept confidential and participants de-identified, there are only 15-20 interviews being conducted, so it is possible that someone may still identify you based on the nature of the response to the question. You have the option of receiving a transcript of the interview so you can check your comments have been interpreted accurately.

Do I have to take part?

No. Participation is completely voluntary. You are able to withdraw (quit) at any time. If you decide not to participate or choose to withdraw from the interview, you will not be disadvantaged in any way, and we will not use any unprocessed information you have provided. However, unless you specifically request otherwise, any information already provided by you during your participation would be retained by the Student Researcher and Responsible Researcher for potential use in the PhD thesis and publications.

Will I hear about the results of this project?

A summary of the interviews and selected quotes will be used for the Student Researcher's PhD thesis and will likely be published in one or more peer-reviewed journal articles, and conference papers.

What will happen to information about me?

Anonymity and confidentiality will be maintained. Field notes will be stored in a locked filing cabinet. Recorded and transcribed interview data will be stored electronically on a password protected computer system. All data will be stored at The University of Melbourne for 5 years and will be destroyed after this time.

The transcribed interviews will be stored in an anonymous form without participant names, however in the Student Researcher's PhD thesis, journal publications or conference presentations, participants will be referred to with descriptors such as 'Growth council urban planner', 'Middle-ring council urban planner', 'State government urban planner', "private sector urban planner' to provide context.

Where can I get further information?

If you would like more information about the project, please contact the researchers; Prof Billie Giles-Corti (Responsible Researcher) Email: b.giles-corti@unimelb.edu.au or
Dr Helen Jordan (Co Researcher) Email: h.jordan@unimelb.edu.au

Who can I contact if I have any concerns about the project?

This PhD research project has been approved by the Human Research Ethics Committee of The University of Melbourne. If you have any concerns or complaints about the conduct of this research project, which you do not wish to discuss with the research team, you should contact the Manager, Human Research Ethics, Office for Research Ethics and Integrity, University of Melbourne, VIC 3010. Tel: +61 3 8344 2073 or Email: HumanEthics-complaints@unimelb.edu.au. All complaints will be treated confidentially. In any correspondence please provide the name of the research team or the name or ethics ID number of the research project.

Consent Form

Melbourne School of Population and Global Health

THE UNIVERSITY OF MELBOURNE

PhD research project:
Government and private sector stakeholder perspectives on supporting healthy equitable local food environments.

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Name of Participant: _____

1. I consent to participate in this PhD research project, the details of which have been explained to me, and I have been provided with a written plain language statement to keep.

2. I understand that the purpose of this research is to investigate the perspectives of local and state government and private sector stakeholders on their roles and responsibilities in creating healthy food environments in local neighbourhoods.

3. I understand that my participation in this project is for research purposes only.

4. I acknowledge that the possible effects of participating in this PhD research project have been explained to my satisfaction.

5. In this project I will be required to participate in an interview either in person or over the phone for approximately 45 minutes; and prior to the interview read the results of our recent research that investigated associations between body mass index (BMI) and access to food outlets across Melbourne; and look at maps of supermarket access across Melbourne with a focus on access in disadvantaged areas.

6. I understand that my interviews may be audio-recorded on a smart phone or laptop and transcribed.

7. I understand that my participation is voluntary and that I am free to withdraw from this project anytime without explanation or prejudice and to withdraw any unprocessed data that I have provided.

8. I understand that the data from this PhD research will be stored at the University of Melbourne and will be destroyed after 5 years.

9. I have been informed that the confidentiality of the information I provide will be safeguarded subject to any legal requirements; my data will be password protected and accessible only by the named researchers.

10. I understand that given the small number of participants involved in the study, it may not be possible to guarantee my anonymity.

11. I understand that after I sign and return this consent form, it will be retained by the researcher.

Participant Signature: _____ **Date:** _____

Appendix D. Two-page report provided to interview participants

PhD research project: Government and private sector stakeholder perspectives on supporting healthy equitable local food environments

Background

Spatial access to food outlets, such as supermarkets and fast food chains, may influence dietary intake and diet-related health outcomes. Many studies have considered how neighbourhood food environments influence health [1-4], hypothesising that good access to supermarkets is protective of health, and that good access to fast food outlets is detrimental to health. While the evidence is inconsistent, the association between supermarket access and more optimal body weight has been documented across many studies [5].

If proximity and density of food outlets in a neighbourhood has the potential to influence dietary and health outcomes, the spatial patterning of food outlets, particularly in socioeconomically disadvantaged neighbourhoods is important to understand. In the United States, 'food deserts' or local areas of poor access to healthy food outlets are well documented in disadvantaged neighbourhoods [6, 7], however for other high income countries such as Australia or the United Kingdom, the evidence on the presence of food deserts is equivocal [6, 8].

Method

My PhD research into local food environment comprises a quantitative and qualitative study. The quantitative study investigated associations between supermarket and fast food chain access, dietary intake and body mass index (BMI) in urban Melbourne. I proposed a conceptual framework (Figure 1) for how neighbourhood attributes, including the availability and accessibility of food outlets, influence dietary intake and weight status [9]. Spatial measures of food outlet access were created at a range of geographic scales and tested with Victorian population health data (n=2712) to identify the most appropriate measures for optimal health outcomes to inform urban planning policy.

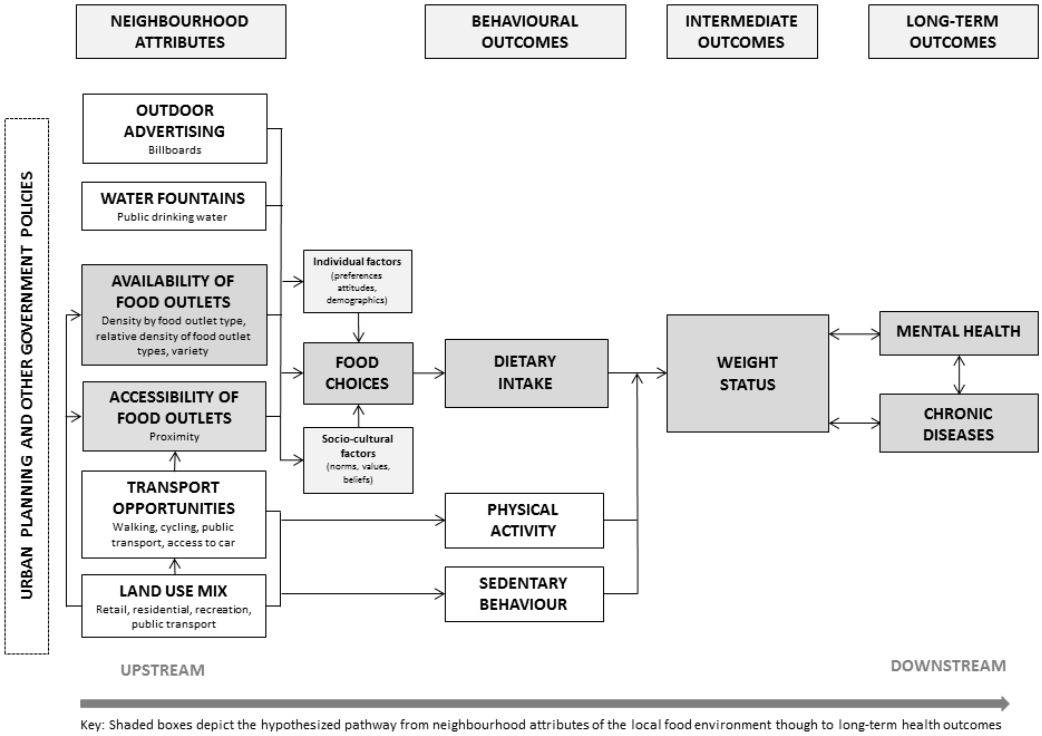

Figure 1 Conceptual framework to inform urban planning policy and practice

Results

After adjusting for demographics, socioeconomic position, dietary intake, physical activity, smoking and fast food access, participants in more disadvantaged areas had a mean decrease in BMI (0.30 kg/m2) for each additional supermarket present within 1 km of household location. Optimal supermarket density for reduced BMI (0.34 kg/m2) was found at 800 m. Significant findings were not present for participants who lived in mid or low-disadvantaged areas, suggesting that people in disadvantaged neighbourhoods are more reliant on proximal supermarket access (unpublished results).

Further, the quantitative study assessed the implementation of a Victorian urban planning policy [10] that provides guidance on the location of supermarkets in growth areas. The policy specifies that 80-90% of households should be located within one kilometre of a town centre large enough to allow for provision of a supermarket [10].

Spatial analysis showed that only 32% *of study participants* in urban Melbourne lived within one km of a supermarket, far fewer than the policy guideline of 80-90% of residents in growth areas of Melbourne. Analysis of the spatial distribution of supermarkets across Melbourne found that

overall 43% *of all dwellings* in urban Melbourne were within 1 km of a supermarket, or alternatively 57% of all dwellings were beyond 1 km of a supermarket.

When considering areas of high disadvantage (Index of Relative Socio-economic Disadvantage deciles 1-3) across all local government areas, Brimbank and Greater Dandenong experienced the poorest access, with approximately half the dwellings beyond 1 km of a supermarket and in the most disadvantaged areas (unpublished results).

References

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3. Rahmanian, E., et al., *The association between the built environment and dietary intake - a systematic review.* Asia Pac J Clin Nutr, 2014. **23**(2): p. 183-96.
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6. Beaulac, J., E. Kristjansson, and S. Cummins, *A systematic review of food deserts, 1966-2007.* Prev Chronic Dis, 2009. **6**(3): p. A105.
7. Walker, R.E., C.R. Keane, and J.G. Burke, *Disparities and access to healthy food in the United States: A review of food deserts literature.* Health & Place, 2010. **16**(5): p. 876-884.
8. Cummins, S. and S. Macintyre, *Food environments and obesity—neighbourhood or nation?* International Journal of Epidemiology, 2006. **35**(1): p. 100-104.
9. Murphy, M., et al., *Indicators of a health-promoting local food environment: a conceptual framework to inform urban planning policy and practice.* Health Promot J Austr, 2016: p. -.
10. Growth Areas Authority, *Precinct Structure Planning Guidelines Part Two: Preparing the Precinct Structure Plan*. 2009. Revised 2013, State Government of Victoria: Melbourne.

Appendix E. Examples of maps provided to interview participants

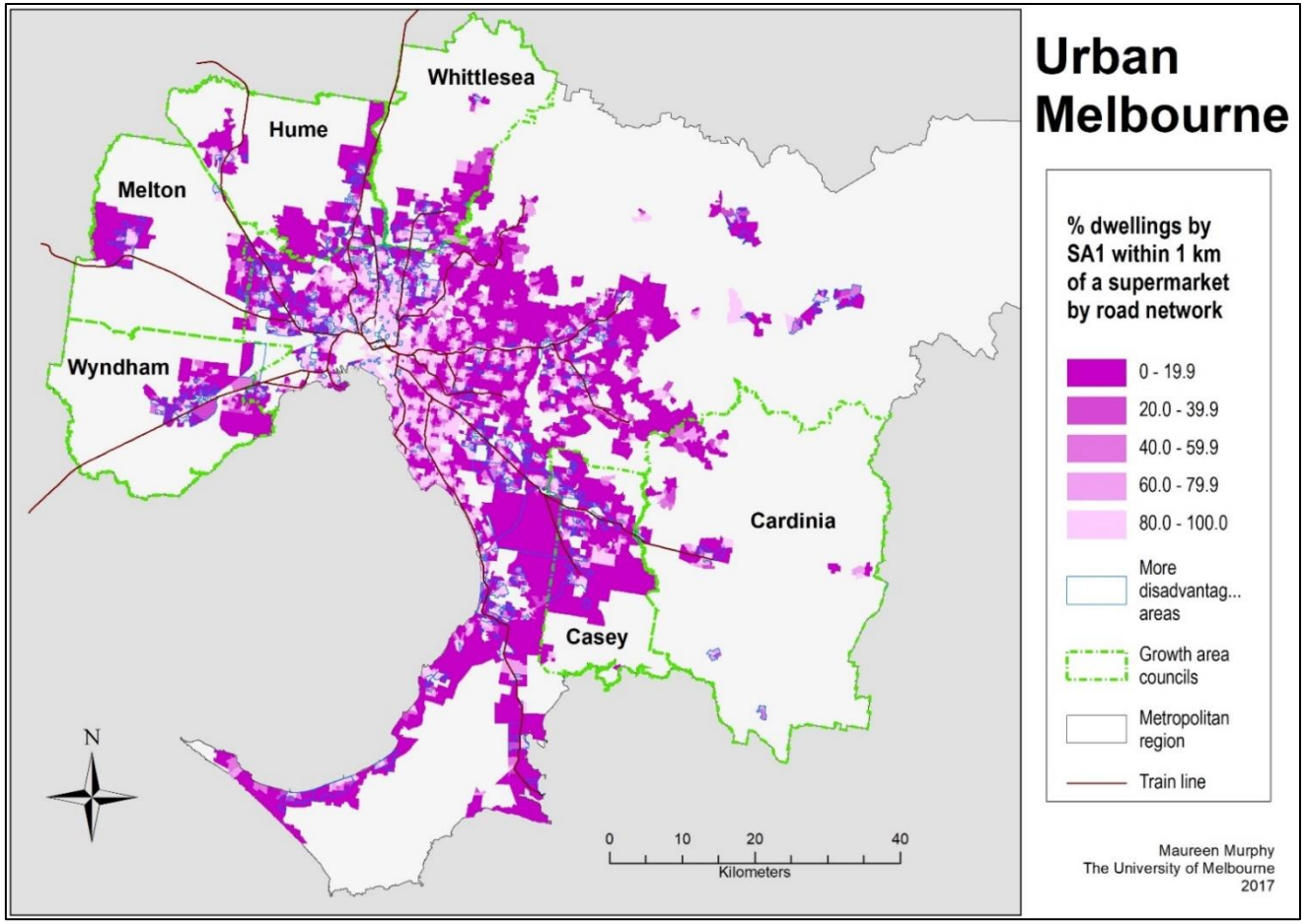

Figure E.1. Spatial distribution of supermarket access at SA1 level across urban Melbourne, Australia: percentage of dwellings within 1 km road network distance to the nearest supermarket (SA1, statistical areas level 1; LGA, local government area)

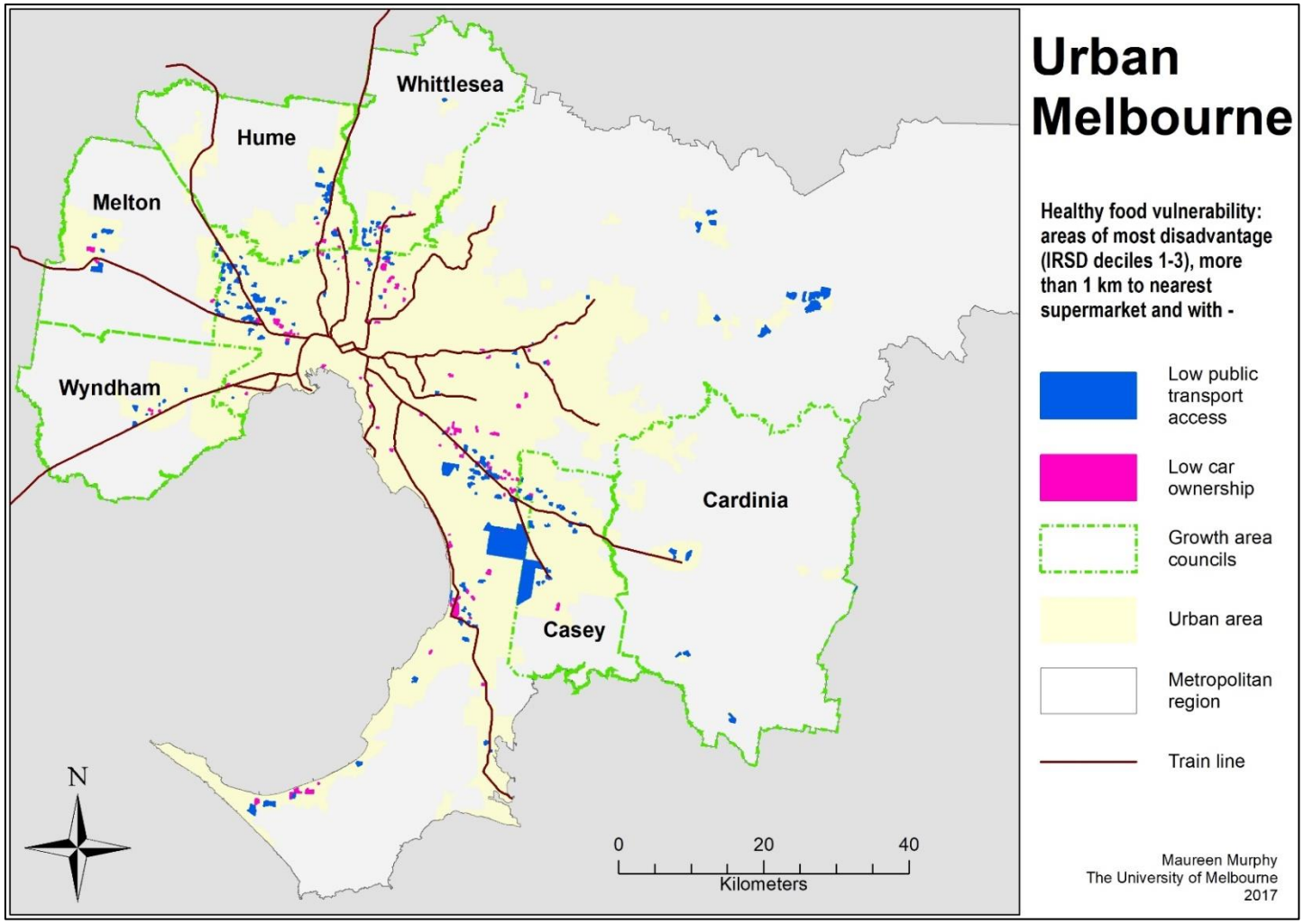

Figure E.2. Geographic areas of high disadvantage across urban Melbourne, Australia where distance to the nearest supermarket by road network is more than 1 km and with low public transport access or low car ownership

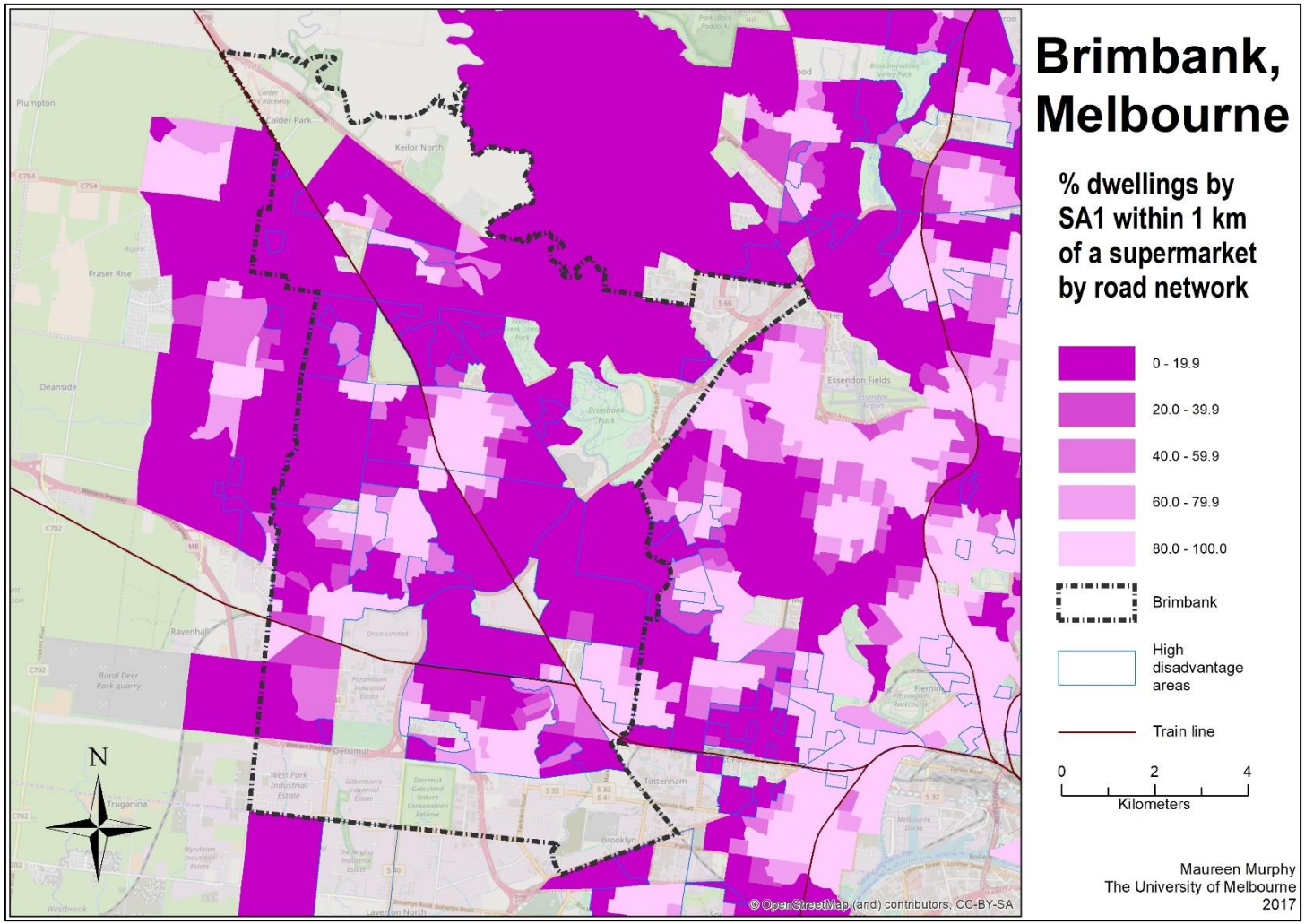

Figure E.3. Spatial distribution of supermarket access at SA1 level in Brimbank, Melbourne

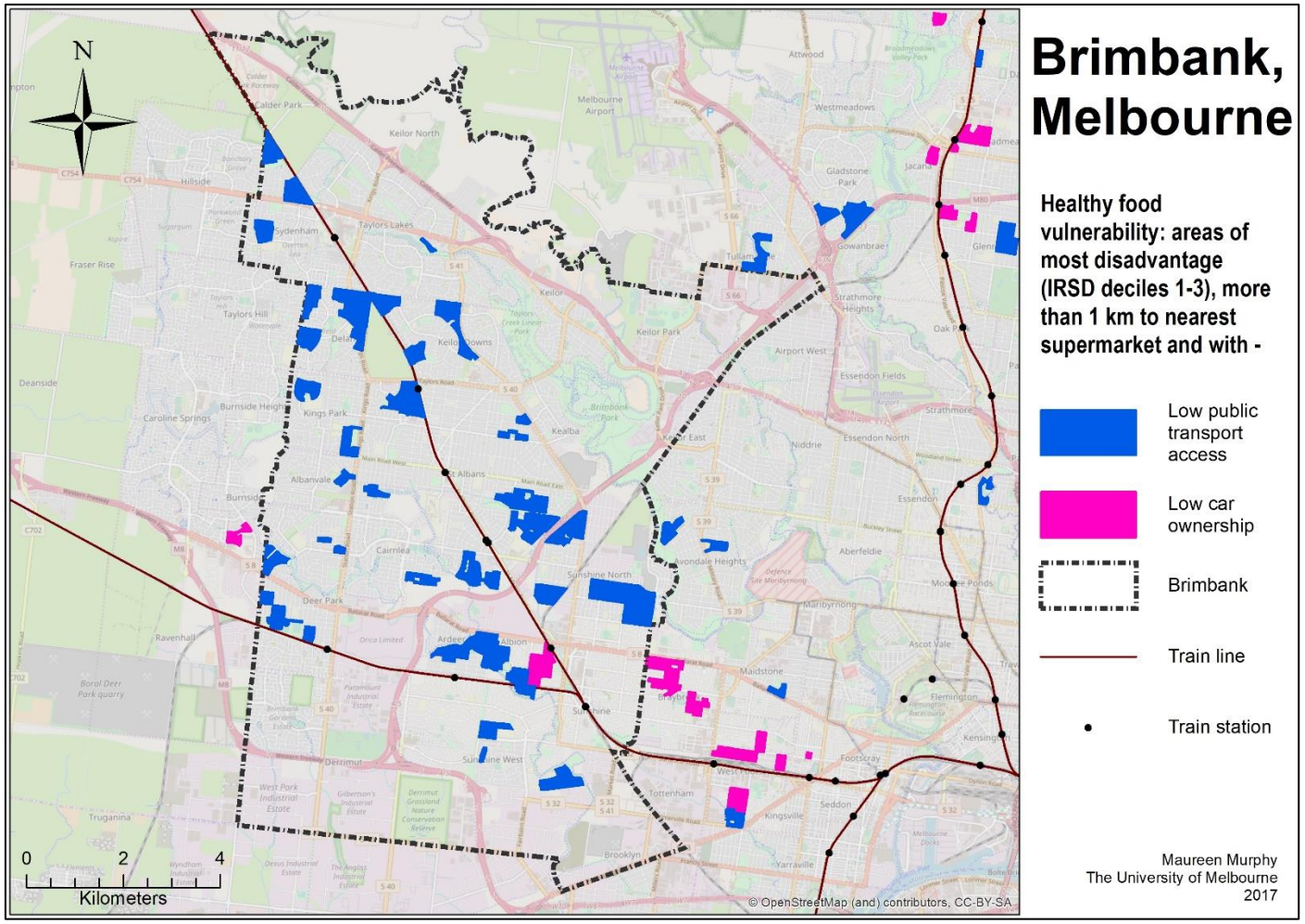

Figure E.4. Geographic areas of high disadvantage in Brimbank, Melbourne, where distance to the nearest supermarket by road network is more than 1 km and with low public transport access or low car ownership

Appendix F. Coding framework

Table F.1. Coding framework

Roles & responsibilities		
	Commonwealth	
	Community / public	
	Developers & industry	
	Local government & councillors	
	Non-government orgs & peaks	
	Planning consultants	
	State government & Planning Minister	
	Supermarkets & Fast food chains	
Barriers & challenges		
	Economic environment	
		Public transport provision
	Policy environment	
		Lack of collaboration/ integrated health & urban planning
	Political environment	
		Competing priorities, change in government, electoral cycles
	Regulatory environment	
		Neoliberal ideology
Influences on local food environments		
	Individual-level factors that influence food purchasing	
		knowledge choice
		preference-consumer demand
		price & shopping habits
	Macro-level factors	
		population catchments
		land availability

Governance for local food environments		
	Advocacy	
	Data and evidence	
		local data & spatial data
		best practice & tools
	Finance	
	Leadership	
		accountability
		mutli-sector multi-level
		political leadership
		shared goals-commitment
	Partnerships & coordination	
		civic participation
	Regulation and legislation	
	Urban planning policy	
		housing
		land use planning
		transport
		urban design

Appendix G. Supplementary material for *International Journal of Environmental Research and Public Health* published paper

Table S1: Interview Guide

Introduction	*In this study, local food environments are defined as are the places in an urban area or neighbourhood where people shop for food within a 20-minute walking or short driving distance from home.*
Questions	1. Who, if anyone, is responsible for ensuring that the community that you serve has access to a healthy local food environment? 2. What is the role of your organisation, if any, in influencing food environments? 3. In Victoria, there is an urban planning guideline for growth areas that specifies that 80-90% of households should be located within one kilometre of a town centre large enough to allow for provision of a supermarket. 4. Were you aware of this or any other guidelines or policies that influence the types of food environments delivered in local communities? In what way could your organisation act on these guidelines/policies? Has your organisation implemented any strategies that would address these guidelines/policies? If so, what are they? 5. What are the barriers, if any, to creating healthy food environments in your local community? Have you, or your organisation experienced these barriers? **6.** What factors, if any, would facilitate your organisation helping to create healthy food environments in your local community?
Quantitative & spatial data	*Refer to 2-page report and metro Melbourne and/or local government maps from the quantitative strand.*
Questions	7. Based on these findings, which organisation, if any, would be responsible for acting on these findings; and what might facilitate this, if anything? 8. How important is having local data about food environments? What local data is most useful? How does it influence local decision-making, if at all? 9. What are the other influences, if any, on local decision-making about food environments? 10. Which other organisations - if any – might have a role in creating healthy food environments? What is their role? 11. Does your organisation work with this organisation? Why/ why not? 12. What different types of organisations need to work together to support healthier food environments? Under what circumstances might they come together to do this work? What would the co-benefits be? 13. What do you think are the key factors that must be in place in order to create healthy food environments?

Table S2: GEE models of associations between BMI and measures of supermarket access for urban PHS participants by established vs urban-growth area location

					Location							
BMI (kg/m²) *	Total				Established LGA (*n* = 1406)				Growth area LGA (*n* = 1306)			
	β	95% CI		*P* value	β	95% CI		P value	β	95% CI		P value
Supermarket density												
<= 800m (pedestrian road network)	-0.049	-0.379	0.282	0.773	0.019	-0.424	0.461	0.933	-0.162	-0.708	0.385	0.562
<= 1000m (pedestrian road network)	-0.027	-0.252	0.197	0.811	-0.006	-0.198	0.184	0.944	-0.034	-0.459	0.391	0.875
<= 1600m (pedestrian road network)	0.066	-0.118	0.251	0.480	0.040	-0.212	0.293	0.753	0.106	-0.151	0.364	0.419
<= 2000m (car road network)	-0.097	-0.242	0.049	0.194	-0.021	-0.207	0.164	0.822	-0.201	-0.427	0.024	0.080
<= 3000m (car road network)	0.009	-0.067	0.085	0.815	0.012	-0.052	0.075	0.719	0.017	-0.178	0.211	0.866
Supermarket proximity												
(pedestrian road network) (km)	-0.034	-0.391	0.323	0.851	0.025	-0.260	0.310	0.863	-0.042	-0.705	0.620	0.900

IRSD, Index of Relative Socio-economic Disadvantage; BMI= body mass index

* Adjusted for age, gender, education level, income, vegetable intake, fruit intake, frequency of soft drink consumption, frequency of fast food consumption, physical activity, smoking, fast food chain access, IRSD and clustering at the LGA level

Appendix H. Summary of significant findings

Table H.1. Significant associations between BMI and food outlet access measures across socioeconomic areas of Melbourne, Australia

Measure	Strata	Buffer size	Direction	Association	Cross-reference to results
Density of supermarket outlets	High disadvantage areas	800 m 1000 m	Negative Negative	Expected Expected	Section 6.2
Density of fast food chain outlets	High disadvantage areas	2000 m	Negative Negative	Unexpected	Section 6.3
Relative density [supermarket outlet + 1] ÷ [supermarket outlet + fast food chain outlet + 1]	High disadvantage areas	2000 m 3000 m	Positive Positive	Unexpected Unexpected	Section 6.3

Table H.2. Significant associations between BMI and food outlet access measures across established residential and urban growth areas of Melbourne, Australia

Measure	Strata	Scale	Direction	Associations	Cross-reference to results
Density of fast food chain outlets	Established residential areas	800 m 1000 m	Positive Positive	Expected Expected	Section 9.2.
	Urban growth areas	800 m 1600 m	Negative Negative	Unexpected Unexpected	Section 9.2.
Relative density [supermarket outlet + 1] ÷ [supermarket outlet + fast food chain outlet + 1]	Established residential areas	800 m 1000 m	Negative Negative	Expected Expected	Section 9.3
	Urban growth areas	800 m	Positive	Unexpected	Section 9.3.

Appendix I. Summary of key governance barriers and opportunities

Table I.1. Summary of key governance barriers and opportunities

Governance mechanism	Barriers	Cross-reference to results
Regulation	• Poor integration across urban planning and public health legislation. Public health not an objective within Planning and Environment Act. • Neoliberal regulatory framework favours free market and minimises prohibition. • Planning provisions facilitate fast food access in residential areas.	Section 8.2
Finance	• Local government in 'rate-capped' environment. • Federal and State government funding deficit for public and active transport infrastructure. • Lack of Federal government obesity prevention funding. • Restricted land availability/high cost of land impedes healthy food access in established areas.	Section 8.2 Section 9.2
	Opportunities	
Urban planning and design policy	• Housing, land use, urban design and transport policy together influence health food access. • Main street urban design, public and active transport infrastructure support healthy food outlet access. • One kilometre growth area urban planning guideline important for weight in low socioeconomic areas.	Section 8.2 Section 6.2
Partnerships	• Responsibilities dispersed across many sectors and portfolios. Statewide, regional and local partnership structures are essential as a coordinating platform for healthy food access	Section 8.2
Leadership	• Political leadership activated by worsening health outcomes (Federal level) and fine-grained local data (local government level). • Distributed leadership across multiple levels of government and sectors. • Civil society advocating for and driving change.	Section 8.2