Health and physical activity among elderly Melbournians to develop urban design directions

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Abstract: *Melbourne's suburbs are rapidly expanding as its population increases. In addition, the average age of the population is climbing, leading to a greater burden on the Victorian public health system. To reduce this, the city should develop in a manner that promotes physical activity and specifically active transport. This study aims to determine the health impact that the urban environment and subsequent active transport time use has on elderly residents. Data sets from 22 Local Government Areas (LGA) of metropolitan Melbourne have been assessed to identify any correlations between elderly health and physical activity. Three bio-indicators were used to indicate elderly health: type 2 diabetes, depression & anxiety and ischaemic heart disease. Furthermore, the walkability of an LGA, measured by its Walk Score™, was used as an indicator of physical activity and an adequate substitute for active transport time use data. The outcomes of this study suggest an inverse correlation between type 2 diabetes and walkability, indicating a relationship between health and urban design. The outcomes relating to the other health bio-indicators are less clear with further study required to determine what influence urban design has on ischaemic heart disease, depression and anxiety. Overall, the results of this study have potential to reduce the pressure of an aging population on society by promoting discussion within the urban design and policy making sphere in Melbourne and comparable cities.*

1 Introduction

Melbourne's rapid population growth is a prominent, contemporary issue that was well documented in national newspapers during 2016 (Lucas, 2016; Anderson, 2016; Short, 2016; Tomazin, 2016). A key characteristic of this population change is the increased mean age. The Australian Bureau of Statistics (ABS, 2009) predicts that 23% of Australia's population to be over 65 by 2056. A larger elderly population implies increased strain on existing health and community services (ABS, 2009). To accommodate this phenomenon, Melbourne is expanding and new infrastructure is continually in demand (Outer Suburban/Interface Services and Development Committee, 2013), resulting in a once-in-a-generation opportunity to design cities to promote elderly health. However, government strategies have mainly focused on management techniques, such as aged care reform (Department of Health, 2016), rather than preventative measures via infrastructure design. Active transport as mitigation to declining health, is not sufficiently implemented in Australia: for example, the Active Health Kids Australia (2015) report on school-aged children undertaking active transport rated Australia a C, showing declining performance. Therefore, focus should be on promoting general health through active transport participation.

Overall, this study aims to provide evidence for the necessity of active transport within new urban developments in Melbourne, as supportive infrastructure is required for our increasing elderly population. This can ensure a more resilient society and will reduce the demand on a strained health care system. While this study aims to provide a reference for future urban planning, details of specific design are outside the scope of this study.

To achieve these aims, datasets for active transport and health bio-indicators were compared and any correlations determined. To achieve these aims, datasets for active transport and health bio-indicators were compared, and any correlations determined. Active transport was measured through a combination of walkability and time-use data sources. The health of the elderly population being investigated was measured by three bio-indicators: ischaemic heart diseases, type 2 diabetes and anxiety/depression statistics per spatial cadastre. These bio-indicators are all national health priorities (Australian Institute of Health and Welfare, 2016) and it is expected that an inverse relationship between bio-indicator prevalence and walkability exists.

Current research relating to active transport and walkability specific to Melbourne is limited. Barr (2016) identifies a correlation in Melbournian suburbs between public transport accessibility, walking and health, but does not focus on amenities other than public transport characteristic to a neighbourhood. Xu (2016) relates walkability to active transport and health in Melbourne, but only looks at four suburbs for data and only uses type 2 diabetes as a health bio-indicator. Additionally, while the 2007-08 Victorian Integrated Study of Transport and Activity (VISTA) was used by Beavis and Moodie (2014) as a measure for time-use to investigate health benefits of long-term changes in active transport in Melbourne, no previous studies have used both VISTA as well as its precursor, the Victorian Activity and Transport Survey (VATS), for time-use data as a measure of active transport. Therefore, a gap exists in the current literature relating walkability, active transport and health across all of Melbourne. It is assumed that health benefits from walking occur over a long period of time (Reiner, Niermann, Jekauc & Woll, 2013) and using both VATS and VISTA gives a longitudinal reflection of local walking trends. This report uses both surveys for analysis, thereby adding to the current knowledge base of active transport and health in Melbourne.

2 Literature Review

2.1 Terminology

Elderly Population: Individuals aged 65 years or over for the purpose of this study.

Local Government Area (LGA): A city or council area, the smallest form of Australian government.

Physical Activity Levels: Low to moderate intensity to keep with the active transport form of physical activity discussed in this study. By increasing the intensity, individuals may be excluded from participation due to the strenuous nature. Furthermore, the target form of physical activity lends itself to low-moderate physical activity.

Active Transport: Transport between two spatial locations by utilising non-motorised modes including walking and cycling. For this study, active transport will be reduced to walking. This is due to the age of the target individuals and the possible exclusion of individuals based upon assets including access to and knowledge of bicycle operations.

Health Impact: Three bio-indicators have been selected to determine the correlation between physical activity through active transport and health; type 2 diabetes, anxiety & depression and ischaemic heart diseases. By selecting two physical and one mental health attribute, whole of body health can be determined whilst maintaining specificity in the study.

Walkability: Measure of the successful integration of active transport, specifically walking, within a spatial area. This can be determined through aggregated scores based on multiple criteria or time use data from existing surveys specific to transport. It is heavily influenced by the urban design of the spatial area, including green space, availability of public transport, density, availability of services etc.

2.2 Relationship between Walkability and Physical Activity

Initial analysis within this study requires understanding the impact of local urban environment on the frequency of active transport use and physical activity. Without this correlation, geographical variation in the bio-indicators cannot be attributed to neighbourhood walkability.

A large variety of walkability indices have been proposed in the literature, but their applicability varies. Frank et al. (2010) measures net residential density, retail floor area ratio, intersection density and land use mix to assess walkability. Whilst this is generally a robust methodology, the required information is not easily accessible. The Irvine-Minnesota Inventory categorises walkability using over 150 indicators obtained primarily, and restrictively through on-foot surveys (Day, Boarnet, Alfonzo, & Forsyth, 2006). Talen and Koschinsky (2013) identify that GIS measurement tools could be utilised to identify physical qualitative differences in geometric land use and urban design not accounted for indices such as Walk Score™ that consider the proximity of nearby amenities. However, Walk Score™ is the only methodology found to apply to Melbourne (Walk Score, 2016). The complex nature of other methodologies, though potentially more representative, do not have the capacity to be applied to Melbourne without difficulty and efforts beyond the scope of this research.

Walk Score™ is therefore the simplest methodology to adapt for this proposal, as it has already been applied to Melbourne and requires comparatively little data manipulation. However, as a proprietary algorithm, Walk Score™ cannot be deeply analysed. Issues with the index are discussed further on. Despite this, a number of studies undertaken have determined that higher Walk Score™ areas have higher incidents of walking (Hirsch, Moore, Evenson, Rodriguez, & Roux, 2013; Hirsch, Roux, Moore, Evenson, & Rodriguez, 2014; Manaugh & El-Geneidy, 2011).

Hirsch et al., (2013) used data from American cities to compare local Walk Score™ to self-reported walking rates. The study found a linear increase in the rate of walking when comparing those in low walkability areas with people living in a 'Walkers Paradise' with Walk Score™ > 90 (Walk Score, 2016). A follow-up study in 2014 over a much smaller sample size found that a 10-point increase in Walk Score™ correlated with walking an extra 16 minutes a week and improved the amount of walking for transport (Hirsch et al., 2014). This conclusion is supported by the findings of Manaugh & El-Geneidy (2011), noting the strength of the index in predicting shopping trips in the Vancouver areas analysed.

Manaugh & El-Geneidy (2011) also showed a reduced impact on retired citizens, suggesting they are impacted differently compared to typical adults, and are more strongly impacted by other forces not factored into the Walk Score™ algorithm. In designing walkability indices for separate age groups, Moura, Cambra, & Gonçalves (2017) found a correlated drop in scores between the adult and elderly indices. This demonstrates that any walkability index scores not designed specifically for the elderly and should only be used comparatively to demonstrate where better outcomes could be achieved. Consequently, the qualitative labelling of Walk Score™ (e.g. 'Walker's Paradise', 'Somewhat Walkable', 'Car-dependant'; Walk Score, 2016) will be ignored in this report.

There are some problems associated with applying Walk Score™ in the context of this research. As discussed, the protected nature of the system limits the extent of the analysis but enough information is given to identify areas of concern. Walk Score™ is calculated using travel distances to 13 amenities: restaurants, bars, cafes, supermarkets, cinemas, schools, green spaces, libraries, book stores, gyms, hardware stores, and clothing and music retail. It is unclear whether the categories are weighted, despite the asymmetric frequency with which the population access these facilities. Schools and supermarkets are accessed with higher trip generation than a hardware store or a library. An unweighted index doesn't account for this phenomenon and equates the convenience of living next to a hardware store with a supermarket or primary school. Five of the thirteen factors are retail related, possible explaining the stronger correlation of Walk Score™ to retail errands observed by Manaugh & El-Geneidy (2011). Additionally, the increasing prevalence of online distribution platforms, particularly for book and music retail, makes the proximity of these amenities less relevant.

Notably, only the factors of intersection and housing density are used in the methodology for this approach. The topography of the area is not considered, despite variable terrain being a significant impediment to a comfortable walking distance, particularly for reduced mobility in the elderly. Similarly, amenities such as pavement quality and walking safety are not accounted for. No consideration of public transport is also a weakness of the index, as nearby transport options would attract walking trips to these stops. This is instead taken into account in the companion index Transit

Score™, with the intention they be used in conjunction. However, Transit Score™ has not yet been applied to Melbourne and hence this complementary data could not be utilised.

Despite these issues, Walk Score™ is the best choice for use in this proposal because it is the only walkability index measured comprehensively across Melbourne with a validated correlation to physical activity. A more accurate index could be devised, or Walk Score™ adapted to reflect more modern trip generators and weighted accordingly. This is beyond the scope of this proposal and recommended for future research. Walk Score™ is therefore used in this study with awareness of its bias toward retail errands and against public transport connectivity.

2.3 Relationship between Health and Physical Activity

A strong relationship exists between physical activity and health, with numerous existing studies documenting this correlation (Singh, Clements, & Singh, 2001; Beavis & Moodie, 2014; Möbius-Winkler et al., 2016). By approximating the health of an individual through three bio-indicators, the correlation between walkability and health can be developed. The urban design of Melbourne and comparable cities can then be influenced in order support incidental physical activity.

2.3.1 Depression & Anxiety and Physical Activity

Considering 3 million Australians live with the effects of depression or anxiety (ABS, 2008), the use of depression and anxiety as an indicator of an individual's health within this study is appropriate. Furthermore, anxiety affects 1 in 4 Australians, with over 2 million people experiencing anxiety annually (ABS, 2008). Varying levels of depression will effect, on average, 1 in 5 women and 1 in 8 men (ABS, 2008). For elderly individuals, depression prevalence is 10-15%, and anxiety prevalence approximately 10% (Haralambous et al., 2009).

Numerous existing studies have outlined the correlation between reduced instances of depression and anxiety in elderly cohorts with increased physical activity. For example, McNeil, LeBlanc, and Joyner (1991) undertook a detailed study of over 30 people that found a reduced level of both psychological and somatic symptoms of depression after undertaking exercise over a six-week period.

This approach was further developed by Singh, Clements, and Singh (2001) who tested the feasibility and efficacy of unsupervised exercise as a long-term treatment for clinical depression in elderly patients, by assessing 32 subjects. Despite this small sample size, results found that individuals who had continued to exercise saw a change in mental health and were 33% likely to still be exercising (Singh, Clements, & Singh, 2001).

In an analysis of 140 elderly members over 62 years, a higher level of physical activity was found to reduce the rate of depression and anxiety within an individual based on the Depressive Inventory and State-Trait Anxiety Inventory (Teixeira, Vasconcelos-Raposo, Fernandes, & Brustad, 2013). They found explicit evidence in support of "…the view that regular physical activity is effective in preventing deleterious feelings and moods…" (Teixeira et al., 2013). Coherent with results discussed above, Krause, Goldenhar, Liang, Jay, and Maeda (1993) contend that "…more frequent physical exercise is associated with less psychological distress", through their study of 2200 elderly individuals in a nationwide survey.

The minimal physical activity for an elderly individual to realise the benefits of reduced health-related issues including depression and anxiety was analysed in a summary article by Nelson et al. (2007). The results identified the need for promotion of moderate intensity aerobic activity, muscle strengthening activity and indirect physical activity related interventions. Nelson et al. (2007) supported the necessity of older adults to be physically active and a physical activity should be a high priority in disease prevention.

Various studies suggested that social cohesion is a stronger factor in the perception of quality of life, which can impact the prevalence of depression and anxiety (Friedman, Parikh, Giunta, Fahs, & Gallo 2012; Engel et al., 2016). Here, walkability ranked below social aspects of community cohesion and safety. Street connectivity, an element of walkability remains relevant, but as a facilitator of social connection rather than directly improving health outcomes. This social interaction and support assists in the treatment and mitigation of depression & anxiety (McNeil et al., 1991; Krause et al., 1993). Further research could be undertaken to determine the direct and indirect benefits of social interaction and physical activity on the treatment and mitigation of mental health and how this relates to urban design. Social interaction and these benefits will not feature as a part of this study.

It is important that urban design decisions encourage physical activity and social interactions in order to help mitigate and reduce the instances of increased poor mental health experiences. This is explicit in an Italian study completed by Melis, Gelormino, Marra, Ferracin, & Costa (2015) to determine the relationship between the built environment and mental health triggers, which found a correlation between antidepressant prescriptions and availability to public transport and urban density.

2.3.2 Type 2 Diabetes and Physical Activity

Type 2 diabetes is an appropriate bio-indicator of health related to physical activity, particularly for the elderly, for a variety of reasons. Firstly, type 2 diabetes is becoming increasingly common in Australia, with 0.8% of Australian adults developing diabetes annually. Prevalence rates are higher amongst elderly individuals, at 1.4% (Barr et al., 2005). Unlike the genetic causality of type 1 diabetes, there is a strong relationship between type 2 diabetes and physical activity, with most studies indicating an inverse correlation between physical activity and prevalence of this disease (Sigal et al., 2006; LaMonte et al. 2005).

The relationship between physical activity of all kinds and type 2 diabetes has been reiterated by multiples studies (Sigal et al., 2006; Tuomilehto et al, 2001; Pan et al. 1997). Overall, the studies found that low participation in physical activity directly correlated to a higher chance of contracting type 2 diabetes for both genders. More recent research has focused on the role of active transport in the prevention and management (Beavies & Moodie, 2014; Rissel & Curac, 2012). To our knowledge, there has been no study conducted to find the specific relationship between active transport and type 2 diabetes in Melbourne, but key studies have linked active transport with significant health benefits and positive outcomes for type 2 diabetes. Beavis & Moodie (2014) found a general, significant association between active transport and beneficial health outcomes in Melbourne using data from VISTA07-08. Rissel & Curac (2012) supported this conclusion for a sample population in New South Wales. Furthermore, Laverty, Palladino, Lee & Millet (2015) extrapolate these findings to six middle income countries, showing that the general pattern holds regardless of socio-economic status. Mueller et al. (2015) confirmed the general relationship in a systematic review, also explaining that the health benefits of active travel outweigh any potential disadvantages, such as exposure to air pollution and traffic accidents, regardless of geographic location. However, a systematic review by Saunders et al. (2013) only confirmed that active transport 'might' have type 2 diabetes-related health benefits.

Fewer studies have investigated the relationship between the walkability of an area and the prevalence of type 2 diabetes, a concept only recently gaining traction, with no consensus yet reached. For example, Barr et al., (2016) found in a cross-sectional study using AusDiab data that public transport accessibility increased walking, with no clear association with diabetes, amongst other disorders. Supporting this, Herrick, Yount & Eyler (2015) investigated the link between built environment in America and diabetes, finding that a higher Walk Score™ in fact increased the risk of type 2 diabetes. However, both these studies have significant limitations: Barr et al. (2016) only looked at public transport accessibility and not holistic walkability, and Herrick, Yount & Eyler (2015) used a sample population with little diversity, so results may not be generalizable. Additionally, only basic health tests for diabetes were undertaken, resulting in possible undetected cases. In conjunction, case studies by Sunquist et al. (2011) and Cunningham-Myrie et al. (2015) found that in Sweden and Jamaica respectively, people living in more walkable areas had higher use active transportation. Therefore, it can be extrapolated that walkability has positive health benefits, particularly in relation to type 2 diabetes. Overall, the relationship between walkability and type 2 diabetes is inconclusive.

Despite few studies in the area, evidence suggests that active transport and physical activity amongst the elderly reduces the risk of type 2 diabetes, and is an important way to manage the disease. Smith et al. (2007) found a positive relationship amongst 50 to 90-year-olds between walking and risk reduction of cardiovascular disease after type 2 diabetes developed. Stessman & Jacobs (2014) also supported these findings, demonstrating lower mortality rates in participants with diabetes who partook in physical activity.

The greatest limitation to using type 2 diabetes as a bio-indicaor is the large number of other factors influencing disease development. A number of factors have been identified to reduce the risk of type 2 diabetes including; weight, diet, smoking, education and age (Kwaśniewska et al., 2009), alcohol intake and disease history including cardiovascular disease (Smith et al., 2007), and income, labour status and psychological health (NEPCP, 2015). However, while a variety of factors affect disease, LaMonte et al. (2005) maintain that fitness is an independent indicator of type 2 diabetes.

2.3.3 Ischaemic Heart Disease and Physical Activity

Ischaemic heart disease (IHD), also known as coronary artery disease and coronary heart disease, is appropriate for use as a bio-indicator when studying the senior health in Melbourne. In 2014, IHD was the leading cause of deaths in Australia (ABS, 2016). Mortality of males was higher than females (11,082 vs 9,091 respectively), and one in seven males and one in eight females died from IHD (ABS, 2016). Furthermore, even though there are no age or geographic boundaries for IHD (World Health Organization, 2015), the ABS reported the leading cause of death among persons aged 45 and over was IHD, differing from the younger age groups (ABS, 2016). The Australian Department of Health (DoH) found that advancing age was one of the major risk factors, and the others were genetic predisposition, gender and ethnicity (DoH, 2015).

As a subset of cardiovascular disease (CVD), IHD is non-communicable and shares the same modifiable behavioural risk factors such as tobacco smoking, sedentary, unhealthy diet and overconsumption of alcohol with diabetes (DoH), 2015). However, many studies have identified the correlation between IHD or CVD and insufficient activity.

A trial conducted by Möbius-Winkler et al. (2016) to investigate the relationship between physical activity and IHD found increases in Coronary Collateral Flow Index (CFI) in both highly active and moderately active participants, showing that both type of activity could lead to a similar positive effect on patients. This trial demonstrated that physical activity would help some patients with stable IHD to gain a better health conditions. However, four-week follow-up was relatively short to identify the duration of the intervention. Hambrecht et al., (2000, 2004) predicted that "functional results might be expected early after only 4 weeks of interventional treatment favouring the concept of high-intensity/short-duration exercise", but this did not fit the result achieved herein. Although the doses of exercise designated in this study exceeded the standard cardiac rehabilitation programs and current physical activity recommendations, further investigations are required to identify whether activity levels less than those tested in this trial would achieve the same goal. This study recommended a weekly 10-hour moderate to high intensive activities to improve CFI (Möbius-Winkler et al., 2016).

The mechanism between improvement of CFI and physical activity remains unclear, but the correlation exists and for prevention of CVD, leisure time physical activity is inversely related to the prevalence rate of CVD, even though the effect is limited. Current guidelines from WHO and Department of Health suggest at least 30 minutes accumulated of moderate-intensive physical activity per day (Archer & Blair, 2011; National Vascular Disease Prevention Alliance, 2010). Hamer & Chida, (2008) reviewed eight studies, integrated them into the overall analysis and gained 15 separate Risk Ratios. The inclusive criteria for study selection excluded studies with unhealthy participants, all-cause mortality or cross-sectional assessment containing other diseases, and replicated data set, as opposed to Möbius-Winkler et al., (2016). The result demonstrated that the preventative effects of active transport against cardiovascular risks was limited, with an overall 11% reduction, being more robust for females than males. However, the reason for the bias is still unclear. Limitations of this review were also inversely contributed to the final outcomes. Although fully adjusted models by introducing Hazard Ratios were used for analysis, confounders, like benefits from other activities, still existed and affected the outcomes. Also affecting results was the use of self-reported data for analysis, which was not precise and inclined to recall bias.

The limitations to using IHD as a bio-indicator as a measure of senior health related to active transport in Melbourne are covariates of other diseases (ABS, 2016), interrelation between IHDs and other diseases (Health.gov.au, 2015), heterogeneity of regions, gender, and ethnicity (Health.gov.au, 2015; World Health Organization, 2015), and other modifiable behavioural risk factors, like unhealthy diets (Health.gov.au, 2015; World Health Organization, 2015).

2.4 Summary of Literature Review

In conclusion, current literature confirms that Walk Score™ is an appropriate measure of walkability and that anxiety and depression, type 2 diabetes and IHDs are relevant bio-indicators of health when assessing the benefits of walking. However, gaps exist in the current knowledge, including the specific inclusion of all three health bio-indicators and the use of VATS and VISTA surveys as a measure of time-use. Additionally, active transport and health have not been considered on a comprehensive LGA scale across Melbourne.

3 Methodology

In order to realise the objectives of the research, two methodology techniques have been employed.

The primary technique of this research is data examination and mathematical modelling. This includes data collection, manipulation and analysis to identify any correlations between physical activity and health with regards to impacts on urban design. This methodology was chosen because it is a low-cost way to analyse data that has already been collected by external parties. It does not require special equipment and allows independence in research assumptions and final interpretations. As a consequence, data used in this research has been collected externally, using methodology techniques such as questionnaires and surveys. This secondary methodology is limited because it is second-hand data that was not collected for the purposes of this paper. This means some manipulation is required.

Alternative methodologies were not employed for various reasons. Field measurements would yield data that is specifically tailored to the outcomes of this research, but privacy, financial and temporal restrictions restricted this methodology. For example, observations of individual activity patterns would be invasive. Furthermore, the magnitude of staff required to determine a sufficient result for the entire Victorian population would be unattainable within the budget and timeframe of this paper. Additionally, computer simulation could have been employed to emulate bio-indicator and walkability levels per LGA, but this would require the use of an intricate and detailed model that was difficult to create within the scope of this research.

It is suggested that the short-comings of this research with regards to the utilisation of secondary data be mitigated in future. This would require the creation, approval and undertaking of survey and questionnaires relating to physical activity and health prevalence within all metropolitan LGAs.

4 Method

This research is comprised of three distinct phases: data source collection, data manipulation and data examination. This segmented approach allowed clear distinction of work pathways, ensuring a timely task completion. The work structure shown in Appendix 10.2 details the framework forming the paper.

4.1 Data Source Collection

The 'data sources' phase is required to collate the data sets needed for the following stages.

4.1.1 Walkability

Walkability data was obtained via three datasets; Walk Score™, the Victorian Integrated Survey of Travel and Activity (VISTA) and the Victorian Activity and Travel Survey (VATS).

Walk Score™ data was obtained from their website (Walk Score, 2016). However it is not provided at the LGA level for the use of this analysis, with suburban scores given instead. To determine the LGA score, an average weighted by population was used (Equation 1).

$$\boldsymbol{WalkScore_{LGA}} = \frac{\sum(\boldsymbol{WalkScore_{suburb}} \times \boldsymbol{Population_{suburb}})}{\boldsymbol{Population_{LGA}}} \quad (1)$$

This allows larger suburbs to have a greater impact on the averaged Walk Score™ of the LGA. There are locations across Melbourne where suburbs cross LGA lines. Here, only the population living in the relevant LGA was considered, as described by the 2011 Census (ABS, 2011a).

The VISTA data available surveyed respondents on their transport choices for individuals on a single specified day during the 2007/08 and 2009/10 financial years. These surveys have a small sample size of 11,400 households. It gives data relating age, gender, location and employment to transport method and purpose. From this, the quantity of walking trips for the elderly population can be determined (VISTA, 2010). The survey counts the occurrences and approximate distances and times of trips.

The VATS study was the predecessor to VISTA, conducted from1994 to 2002. Like VISTA, it can connect age and location to transport method and purpose, considering both distance and time-use. It surveyed 10,000 households per year to provide its datasets (VATS, 2002). Due to a restructured survey design in 2000, resulting in increased response issues, there is a decreased number of responses for the following years. Furthermore, for this survey, missing data points were assigned values using proportional weightings. Compounding this variation was a change in the weighting methodology, were a simplified procedure was used compared to earlier years. This is likely the cause of the significant jump in results between 1999 and 2000. This makes comparing the results of the two periods problematic when using the native weightings in the data. To combat this, the two periods will be looked at individually against the walkability score.

4.1.2 Health Bio-indicators

Data sources for health bio-indicators in the report will come from four different sources. The 2001 Victorian Health Information Surveillance System (VHISS) was the only dataset found that separates each LGA by age, as required by this report and provides data for all three bio-indicators. Despite not being recent information, it will be used as a preliminary source to compare health and Walk Score™ for consistency between bio-indicators. More recent sources were also included for each bio-indicator for comparison with VHISS data.

On recommendation from Loretta Vaughan (Department of Health and Human Services, VDHHS), the Beyond Blue organisation, Professor Anthony Jorm (University of Melbourne) and Professor Billie Giles-Corti (University of Melbourne), the 2011 Victorian Population Health Survey (VPHS) was used for anxiety and depression prevalence data, despite requiring manipulation to provide necessary filters for this research. The National Diabetes Services Scheme (NDSS) will be used as a secondary source for type 2 diabetes prevalence data, because it is recent (last updated on 30th September 2016) (NDSS, 2016) and provides data separated by age and LGA across all types of diabetes. It will require manipulation to obtain this data for only type 2 diabetes. Dr Beverley Balkau (INSERM) and Professor Dianna Magliano (BakerIDI Heart and Diabetes Institute), two prominent figures in type 2 diabetes research, were contacted for advice on appropriate databases. However, these contacts did not yield appropriate results. The second dataset for IHD is mortality incidences sourced from the Victorian Department of Health and Human Services (VDHHS) (2014). The use of mortality instead of prevalence is based on data availability. Further research should endeavour to source current prevalence data relating to IHD. The Heart Foundation was contacted but did not reply via email.

Other than the 2001 VHISS data, the above dataset could not fully satisfy the research filter requirements. They were manipulated to provide appropriate results separation using basic assumptions, explained in section 0 and appendix 10.1.

4.2 Data Manipulation

The second phase of the research project will be to reorganise the data to produce results aligned with the requirements of this report. In this regard, filters will be placed over the data sets to ensure they meet specific requirements to enable the final phases to be completed.

4.2.1 Spatial Analysis

A filter and key pillar within the scope of this research project are the understanding of the spatial incidence of the three bio-indicators. This understanding allows for identification of any correlations between the health status of the elderly individual and the physical activity traits of the spatial entity.

To realise this spatial analysis, data has been collated and manipulated based on LGA. The selection and resolution of data sets was influenced by privacy and data availability. This resulted in the use of 22 LGAs within Victoria that had high levels of urbanism. The inclusion of data outside this would provide no benefit to this research due to insufficient population and car usage being dominant.

The criteria to determine the suburbs analysed as part of this study include:

1. Analysis of gross densities, with a natural divide identifying fully urban areas as greater than 900 persons per km^2 (ABS, 2011a)
2. Analysis of Walk Score™ suburb data availability to determine LGA Weighted Walk Score™, minimising the need for estimation of values.
3. Analysis of population growth for each LGA, with areas of disproportionate change in their elderly population suggesting significant inter-LGA migration giving results impacted by the both the current and previous walkability (ABS, 2011a).

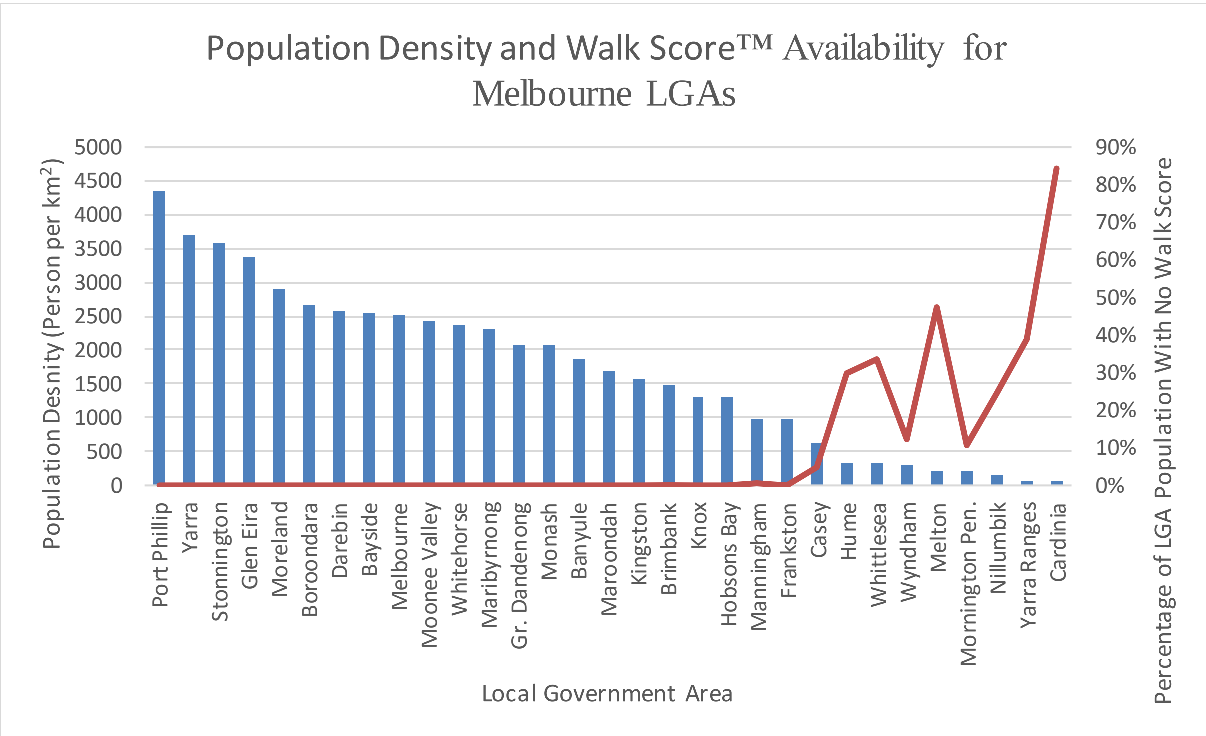

Figure 1: Population density and Walk Score™ availability for Melbourne LGAs
(ABS, 2011a; Walk Score, 2016)

This resulted in the following suburbs being chosen for this study:

- City of Banyule
- City of Bayside
- City of Boroondara
- City of Brimbank
- City of Darebin
- City of Frankston
- City of Glen Eira
- City of Greater Dandenong
- City of Hobsons Bay
- City of Kingston
- City of Knox
- City of Manningham
- City of Maribyrnong
- City of Maroondah
- City of Melbourne
- City of Monash
- City of Moonee Valley
- City of Moreland
- City of Port Phillip
- City of Stonnington
- City of Whitehorse
- City of Yarra

The remaining Greater Melbourne LGAs failed on all three criteria with the exception of the City of Casey, which was a borderline case for Criteria 1 and 2; however, its population growth results suggested higher compatibility with the removed LGAs, and hence it was also removed.

The elderly population growth within the City of Melbourne (35%) is also of concern. With a significant growth in the elderly population, much of the data will be representative of persons who have moved into the area. The health status of the population will therefore not be fully representative of the local walkability, but also of the location that person previously resided. This characteristic of the City of Melbourne will be considered when divergent results for the LGA occur.

4.2.2 Bio-indicators

Datasets from VPHS, NDSS and VDHHS needed to be reorganised in order to achieve the filters required for this research. For the VPHS and VDHHS, bio-indicator data was provided by LGA but was not separated into age groups within this spatial constraint. However, data on a larger spatial scale (state-wide for VPHS, nation-wide for ABS) was provided according to the required age groups. A weighting factor for elderly residents was calculated using the larger spatial data and applied to each LGA statistic. For the NDSS, data was separated by age and LGA, but only for all types of diabetes. Therefore, it was assumed the difference in type of diabetes does not change according to locality, and the national percentage of people with type 2 diabetes was applied to LGA data. Detailed calculations for each data source are available in appendix 10.1.

4.3 Data Examination

The final phase of the research is to identify any correlations between health and physical activity under the imposed filters described above. This examination process will also be accompanied by linear regression and statistical analysis to ensure conclusions and outcomes found are valid. For ease of visualisation, results have been mapped using GIS software to provide a spatial understanding of health across metropolitan Melbourne.

4.3.1 Filters

The primary filter of this research is age, with particular reference to elderly populations. The decision to focus on the elderly population is important as the needs of this group are expanding both due to increased average age and a larger cohort of the Australian Population featuring in this group. Furthermore, this population group are considered vulnerable to increased incidents of these bio-indicators and as such need directed mitigation strategies to address this. Other factors such as gender, socio-economic status and lifestyle habits are likely to significantly impact public health outcomes (Kwasniewka et al., 2010; Wasfi et al., 2016; Wen & Rissel, 2008). However, due to temporal restriction of this research and unavailability of specific data, these factors will not be measured in this report. It is recommended to include these factors in future study on the topic.

5 Results

5.1 Correlation of Walkability and Time Use Data

Time use data has been analysed against walkability of an LGA by use of a weighted LGA Walk Score™ in order to assist in the identification of any correlation between health and physical activity.

In the 1994-1999 VATS data, a significantly large time use value was identified for the City of Melbourne, 30.2 minutes per person per day (pp pd). The other data sets do not show as high a result in Melbourne; 21.13 and 21.52 minutes' pp pd for the 2000-2002 VATS and 2007-2010 VISTA data respectively. This suggests this is an error in the expansion weightings within VATS. There was a significantly lower response in Melbourne to the VATS than other urban LGAs; Melbourne had 322 persons respond, the lowest of any Greater Melbourne LGA and one-quarter the average responses of the other LGAs on the register at 1423. This will have caused unrepresentative results to be scaled up to a greater degree than occurred in the other LGAs. The City of Melbourne was therefore removed for VATS, providing a significantly larger coefficient of determination (r^2 of 0.84 vs 0.68) for the data set (Figure 2).

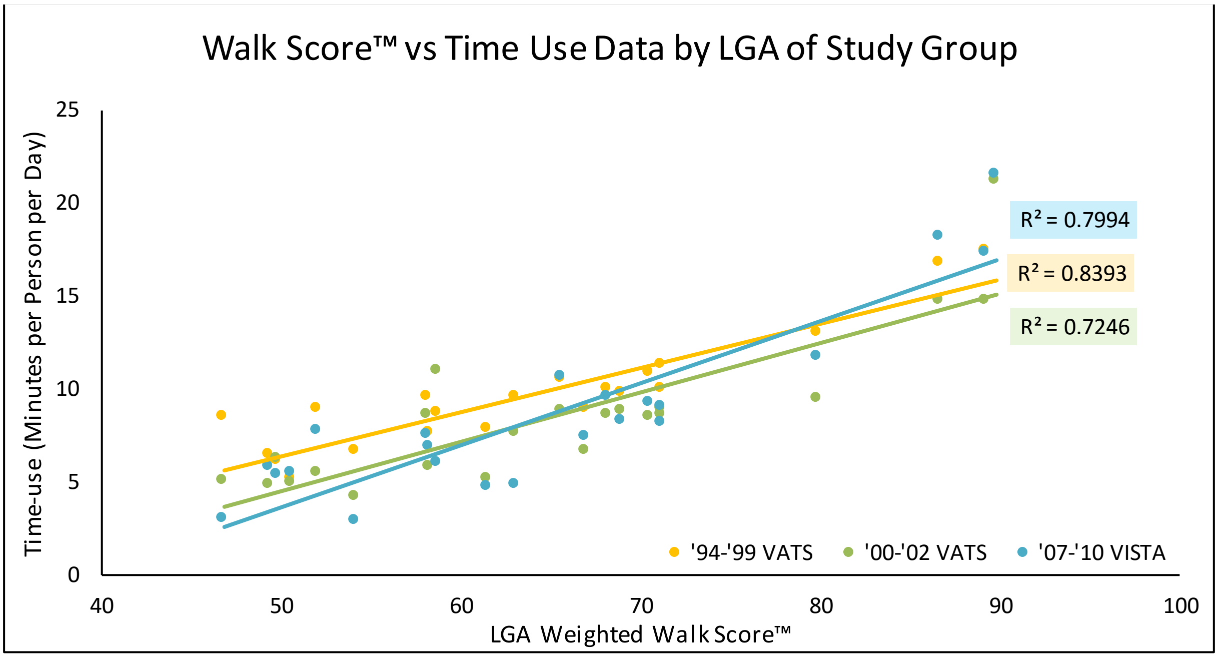

Figure 2: Walk Score™ vs time-use with birth year pre-1951, divided by LGA excluding '94-'99 Melbourne result

Using these sets of data allows temporal understanding of the impact of walkability in an area, as well as increasing confidence in the data sets as a whole. There are individual confidence issues for each data source due to fidelity and the small number of people surveyed in each year, however, as a whole they represent a valuable indication of the typical active transport occurring in an area. As each data set is relaying a similar correlation to Walk Score™, they support each other to give a strong conclusion. The use of this data, as with the Walk Score™ issues relating to representing elderly walkability discussed in Section 2.2 limits this analysis from obtaining quantitative results. Despite these differences and the data uncertainties discussed earlier, each independently shows a similar trend between increasing Walk Score™ and the amount of walking occurring in an area amongst the elderly population. Hence, going forward, Walk Score™ can be used as an acceptable indicator of walkability for elderly Melbournians.

5.2 Correlation of Elderly Health and Active Transport

LGA weighted Walk Scores™ were plotted against prevalence data for each bio-indicator, with the exception of VDHHS data for IHD, which was plotted for mortality rates. This provides a comparison between walkability and elderly health in each LGA, due to the correlation between Walk Score™ and active transport time-use determined above. This will assist in understanding how the design of walkable neighbourhoods impacts population health and therefore the externalities associated.

5.2.1 Type 2 Diabetes and Physical Activity

VHISS 2001 and NDSS 2016 type 2 diabetes prevalence data were plotted against Walk Score™, as demonstrated in Figure 3 Figure 4 respectively. Both yielded inverse relationships; as LGA walkability increases, the prevalence of type 2 diabetes decreases. This is to be expected, because higher walkability is correlated with higher participation in active transport, and the literature review outlines that participation in physical activity generally reduces risk of type 2 diabetes. However, after a linear ordinary least squares regression analysis was performed on the data, the coefficient of determination (r^2) was found to be very low for both datasets, particularly for the VHISS 2001 data, which yielded an r^2 value of 0.067. NDSS 2016 data had a slightly higher, but still relatively low, r^2 value of 0.27. Figure 12 highlights the areas of high type 2 diabetes prevalence within the study bounds.

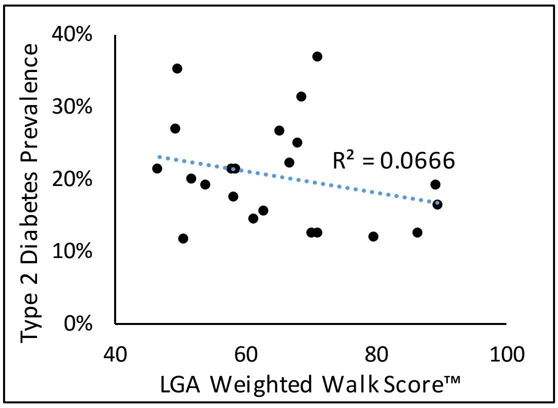

Figure 3: Type 2 Diabetes Prevalence in Elderly Persons vs. Walk Score™, VHISS 2001

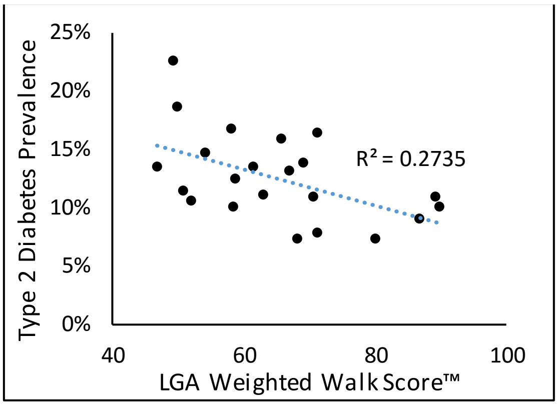

Figure 4: Type 2 Diabetes Prevalence in Elderly Persons vs. Walk Score™, NDSS 2016

5.2.2 IHD and Physical Activity

IHD prevalence rates in elderly persons from VHISS (2001) and mortality rates in elderly persons from VDHHS (2016) plotted against Walk Score™ are shown in Figure 5 and Figure 6 respectively. Figure 5 shows no correlation between IHD prevalence and Walk Score™ with low variation excluding the Bayside value. In other words, the prevalence of IHD is not influenced by the walkability of the LGA. Figure 6, however, demonstrates an inverse relationship between IHD mortality and Walk Score™. The linear regression shows r^2 values for Figure 5 and Figure 6 of 0.0013 and 0.35 respectively. Figure 13 highlights the areas of high IHD mortality within the study bounds.

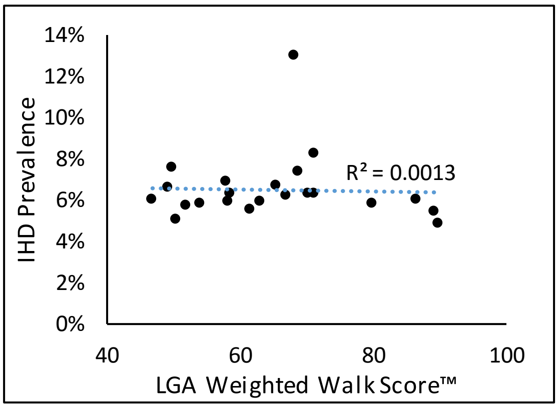

Figure 5: IHD Prevalence in Elderly Persons vs. Walk Score™, VHISS 2001

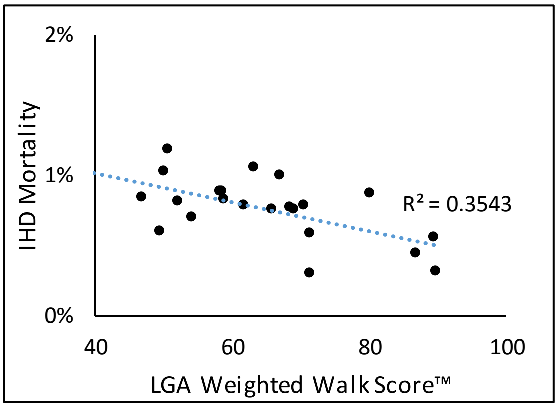

Figure 6: IHD Mortality in Elderly Persons vs. Walk Score™, VDHHS 2016

5.2.3 Anxiety & Depression and Physical Activity

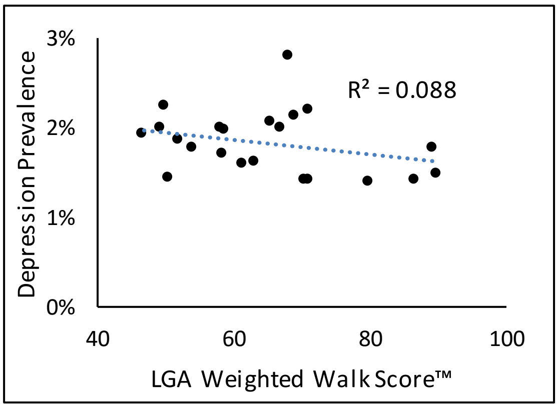

Figure 7: Depression Prevalence in Elderly Persons vs. Walk Score™, VHISS 2001

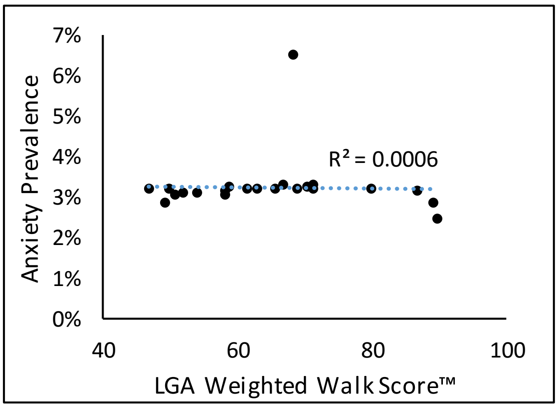

Figure 8: Anxiety Prevalence in Elderly Persons vs. Walk Score™, VHISS 2001

VHISS 2001 and VPHS 2011 depression and anxiety prevalence data were plotted against Walk Score™ as shown in Figure 7, Figure 8 and **Error! Reference source not found.**. Analysis of the VHISS 2001 data produced no relationship between anxiety prevalence and walkability. In other words, the prevalence of depression & anxiety is not influenced by the LGA Weighted Walk Score™. However, there is a general inverse relationship between depression prevalence and Walk Score™ for the VHISS 2001 data, suggesting that increasing walkability does play some role in decreasing depression in elderly citizens. The VPHS 2011 data shows a positive correlation between anxiety and depression prevalence and walkability, with an r^2 value of 0.35. Figure 10 highlights the areas of high Anxiety & Depression prevalence within the study bounds.

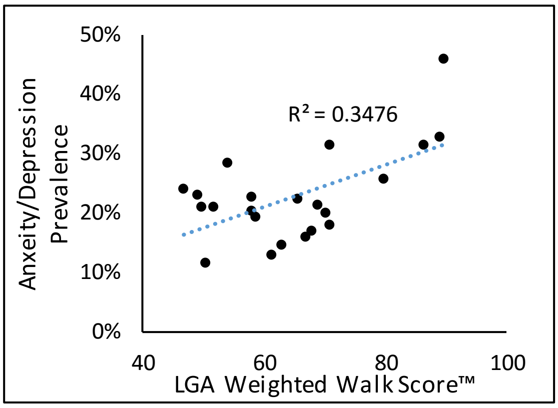

Figure 9: Anxiety/Depression Prevalence in Elderly Persons vs. Walk Score™, VPHS 2011

5.2.4 GIS Mapping Comparisons

Heat maps of walkability, and the three bio-indicators are shown in Figure 10, Figure 11, Figure 12 and Figure 13. These maps were compiled on ArcGIS and give a general visualization of health patterns compared to walkability in LGAs chosen for study in this research. From observation, type 2 diabetes prevalence and IHD mortality both correlate inversely to Walk Score™, because 'lighter' areas in Figure 12 and Figure 13 corresponding to areas with healthier populations for these bio-indicators, generally match with darker areas in Figure 10, corresponding to higher Walk Score™. It can also be seen that anxiety and depression prevalence generally follows the opposite pattern, particularly in inner Melbourne areas where walkability is high, but anxiety and depression prevalence is also high.

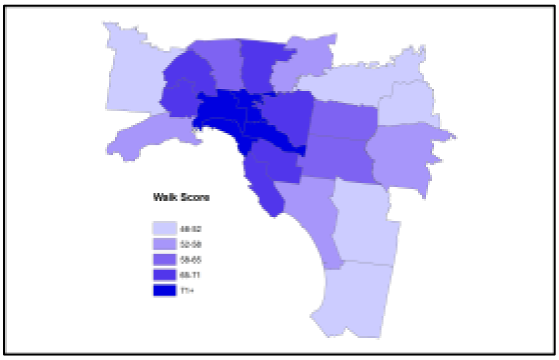

Figure 10: LGA Weighted Walk Score™ within Study Bounds

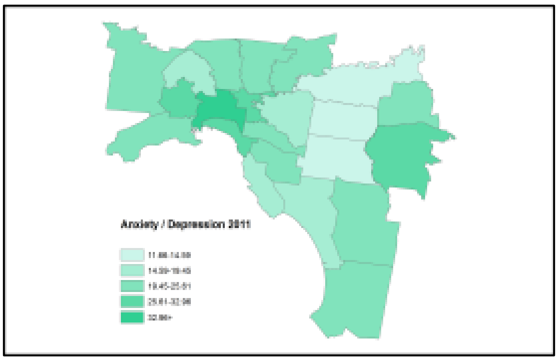

Figure 11: Anxiety & Depression Prevalence (VHPS 2011) within Study Bounds

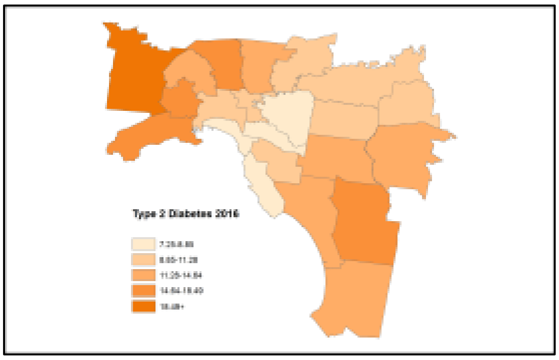

Figure 12: Type 2 Diabetes Prevalence (NDSS 2016) within Study Bounds

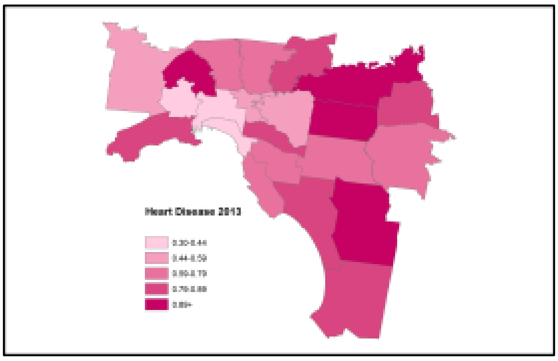

Figure 13: IHD Mortality (VDHHS 2016) within Study Bounds

6 Discussion

6.1 Analysis of results

Overall, results were mixed regarding the relationship between health and walkability. At least one dataset for all three bio-indicators yielded an inverse relationship, albeit of differing scales, between active transport and health, supporting the initial hypothesis that a more walkable area means a healthier elderly population and hence less burden on the Victorian public health system.

However, the data showed no correlation for anxiety or depression for the VHISS 2001 data, with no spatial change in prevalence. Additionally, there was a positive relationship between anxiety/depression prevalence for elderly persons and Walk Score™ for VPHS 2011 data (**Error! Reference source not found.**), suggesting prevalence of these mental illnesses in more walkable areas, though a causal link is unlikely. Overall, the coefficients of determination (R^2) for every bio-indicator dataset were very low, with the best being 0.35 for the relationship between IHDs mortality and Walk Score™ from VDHHS 2016 data (Figure 6). The comparison of anxiety prevalence and Walk Score™ from VHISS 2001 data yields a strong coefficient of variation, 17.0 despite a poor R^2 value after the divergent Bayside result is removed. A similar but not as severe effect occurs for IHD prevalence comparison from VHISS 2001. Both these showed relatively flat correlation, and hence any relationships discovered between health and walkability are not particularly significant, despite the initial hypothesis.

Evidence of no correlation can be explained by three main reasons. Primarily, as noted in the literature review, a causational link cannot be drawn between each bio-indicator and physical activity alone. For example, type 2 diabetes is potentially a cumulative outcome of a variety of factors detailed previously. Furthermore, type 2 diabetes prevalence increases the risk of IHD (Smith et al., 2007), potentially resulting in correlation founds between the two bio-indicators and active transport were double counted.

Additionally, all datasets do not provide information gathered by observation but require individuals to take some measure of control over their health. For example, the VPHS data is self-reported (DoH, 2011), while the NDSS register only counts individuals who have proactively sought medical help for their illness (NDSS, 2015). This means that data for each bio-indicator are influenced by individual means, values and understanding of health. Lastly, the VPHS 2011, NDSS 2016 and VDHHS 2016 datasets were not plotted from raw results, but utilised generalised statistics to achieve the output desired for analysis. This manipulation required assumptions for each dataset that may not be representative of actual health statistics. This explains the generally lower variation in VHISS 2001 data, which was not manipulated at all despite the low relationship demonstrated

It is unclear why the highest R^2 exists for the IHD mortality data (Figure 6). This particular relationship is individual because it uses mortality data rather than prevalence data, potentially indicating that the higher significance is due to deaths rather than disease incidence. This implies that active transport can be useful in disease management more than in prevention. This research aimed to reduce the burden on the public health system, but focused mainly on prevalence due to temporal restrictions. The Australian Institute of Health and Welfare (2014) suggests that the burden of disease is calculated using disability-adjusted life years (DALYs), which can be considered as a combination of prevalence and mortality. It is suggested that DALYs are used in further research to account for overall burden of disease.

The anomaly in results was the positive relationship between anxiety & depression prevalence and Walk Score™ for VPHS 2011 data. Possible reasons include the dominance of alternative factors within this relationship that intensify with increasingly denser urban forms. Additionally, anxiety and depression have traditionally been under-reported due to societal acceptance (Mental Health Foundation of Australia, 2016), leading to poor data quality particularly acute in the 2001 data, evidenced in the sharp increase in prevalence between 2001 and 2011. Further research should investigate this, with particular reference to urban design.

6.2 Implications of results

While coefficients of determination are low in each relationship, it can be argued that this does not necessarily decrease the applicability of results obtained from this research. The role of external influencers on disease and data weaknesses mean that correlation strength is expected to be low. However, general inverse correlations have been identified for almost all three bio-indictors compared to walkability, meaning that walkability can still be used as a tool to improve population health and cut public expenditure on health. These results can be implemented in three main ways:

1. The walkability of existing areas that rank low on the Walk Score™ scale can be improved. This would be a costly endeavour, as changing existing infrastructure is difficult with wide-ranging implications. However, the impact footprint would cover a large number of people.
2. New areas can be designed for maximum walkability, which is more efficient than re-designing for walkability after a neighbourhood is established. However, this option will only affect residents in outer Melburnian locations.
3. Population awareness of active transport implications on health can be increased. For example, an index number that relates walkability to health can be developed and used as a mandatory real-estate marketing tool to assist individuals contemplating moving house.

Using the idea that walkability and health are inversely proportional, which is suggested by this research, and extrapolating that poor health can in some way be combatted by increasing local walkability, a cost analysis should be performed to determine, from an economic perspective, which option should be undertaken. This can be done by comparing the amount saved by reducing the burden on the public health system through disease prevention against the cost of each option to justify which option, or combination of options, should be implemented. This task is recommended for future research, as it is outside the scope of this report.

Non-economic benefits of increasing population health should also be considered when justifying reactionary procedures.

6.3 Opportunities for future research

Due to temporal and financial restrictions, this study has several limitations that could be further explored. They include:

- Understanding the role other factors influence health of individuals and how that relates to urban design e.g. gender, socio-economic status, lifestyle habits
- Undertaking an economic analysis comparing potential reduction in disease prevalence against costs associated with improving local walkability
- Developing a real estate health-walkability index based on a multitude of inputs
- Conducting purpose-built studies investigating both prevalence and mortality rates for all bio-indicators, to eliminate the need for data manipulation
- Developing a walkability index that is more accurate than Walk Score™.

7 Conclusion

As the average age of Melbourne's population increases, consideration must be made to develop a resilient and disease free society. Analysis of time-use data and LGA Weighted Walk Score™ found a significant correlation between low to moderate physical activity and walkability. This walkability relationship was then analysed against three health bio-indicators. Consistent with the studies initial hypotheses, the results of this study indicate there is an inverse relationship between type 2 diabetes and LGA Weighted Walk Score™. In other words, the prevalence of type 2 diabetes is reduced through increased physical activity, especially via low to moderate intensity activity such as active transport. However, analysis of ischaemic heart disease and depression & anxiety data did not yield comparable results, with a positive or zero relationship found between the health bio-indicator and LGA Weighted Walk Score™. This was not consistent with the initial hypotheses of the study, with further research suggested to determine what influences these results. Overall, it is hoped that the results of this study will reduce the pressure of an aging population on society by promoting discussion within the urban design and policy making sphere in Melbourne and comparable cities.

8 Acknowledgements

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10 Appendices

10.1 Detailed data manipulation calculations for Bio-Indicator datasets

10.1.1 Victorian Health Information Surveillance System 2001

Victorian Health Information Surveillance System 2001 data was used for all three bio-indicators. No manipulation was necessary as the data was provided with all the filters required for this report.

10.1.2 Victorian Population Health Survey 2011

Victorian Population Health Survey 2011 data was used for depression & anxiety. The following data is provided as part of this dataset:

1. Percentage of elderly people in Victoria (metropolitan and rural) with depression & anxiety ($p_{elderly/depression\&anxiety}$)
2. Percentage of people in each LGA with depression & anxiety ($p_{depression\&anxiety/LGA}$)

The output required is the percentage of the elderly population in each LGA with depression & anxiety ($p_{elderly/depression\&anxiety/LGA}$).

A weighting factor was calculated for elderly people with depression & anxiety (DA) as a percentage of total population with the depression & anxiety, because prevalence is not evenly spread across age groups.

$$\boldsymbol{F_{65+}} = \frac{\boldsymbol{Population_{65+_{DA}}}}{\boldsymbol{Population_{DA}}} \tag{2}$$

$$\boldsymbol{Population_{DA_{65+}}} = \boldsymbol{p_{DA|65+}} * \boldsymbol{Population_{65+}} \tag{3}$$

$$\boldsymbol{Population_{DA}} = \sum(\boldsymbol{p_{DA|age\ group}} * \boldsymbol{Population_{age\ group}}) \tag{4}$$

Where:

F_{65+} = weighting factor for elderly people with each bio-indicator

$Population_{65+|DA}$ = number of elderly people with depression & anxiety in Victoria

$Popualtion_{DA}$ = number of people with depression & anxiety in Victoria

$Population_{65+}$ = number of elderly people in Victoria (from ABS Census 2011)

$p_{DA|age\ group}$ = percentage of Victorians in each age group with depression & anxiety

$Population_{age\ group}$ = number of Victorians in each age group (from ABS Census 2011)

Subsequently, the percentage of the elderly population of a LGA with depression & anxiety was calculated using the equation below.

$$p_{LGA_{DA|65+}} = \frac{Population_{LGA} * p_{DA|LGA} * F_{65+}}{Population_{LGA_{65+}}} \tag{5}$$

$Population_{LGA}$ = number of people in LGA (from ABS Census 2011)

$Population_{LGA|65+}$ = number of people in LGA that are elderly (from ABS Census 2011)

10.1.3 Victorian Department of Health and Human Services, 2014

Data from analysed product is used for estimate of mortality of IHDs as underlying cause of death. Existing data has been listed below.

1. Number of people by age on a LGA basis ($N_{Age\ Group}$);
2. Number of deaths relating to IHD by age, across the nation ($N_{IHD|Age\ Group}$);
3. Mortality due to IHD per LGA ($p_{IHD\text{-}LGA}$);

The bio-indicator pertaining to IHDs could be calculated by the following equation,

$$p_{IHD-LGA|Age\ Group|} = p_{IHD} \times \frac{N_{IHD|Age\ Group|}}{N_{IHD|Total\ Ages|}} \times \frac{P_{LGA|Age\ Group|}}{P_{Nation|Age\ Group|}} \quad (6)$$

$p_{IHD-LGA|Age\ Group|}$ = mortality of IHDs in each age group on a LGA basis.

10.1.4 National Diabetes Services Scheme 2016

This data was used for type 2 diabetes. Within each LGA, the following data is given:

1. percentage of population registered with NDSS ($p_{registered}$)
2. percentage of registrants that have type 2 diabetes (p_{T2D})
3. percentage of registrants in each ten-year age bracket ($p_{10\text{-}yr\ age\ group}$)
4. percentage of registrants in each gender category (p_{male}, p_{female})

The required output is ($p_{elderly/bio\text{-}indicator/LGA}$). This will be calculated by applying equation 7.

$$p_{65+|T2D|LGA} = \frac{\Sigma(p_{T2D|age\ group} * Population_{age\ group|LGA})}{Population\_LGA|65+} \quad (7)$$

$$p_{65+|T2D|LGA} = \frac{\Sigma(p_{T2D|age\ group} * Population_{age\ group|LGA})}{Population\_LGA|65+} \quad (8)$$

$$p_{age\ group|T2D} = p_{T2D} * p_{10-yr\ age\ group} \quad (9)$$

$p_{age\ group/T2D}$ = percentage of people in each age group with type 2 diabetes

$Population_{age\ group/LGA}$ = number of people in each age group in the LGA

10.2 Work flow structure of Research Method

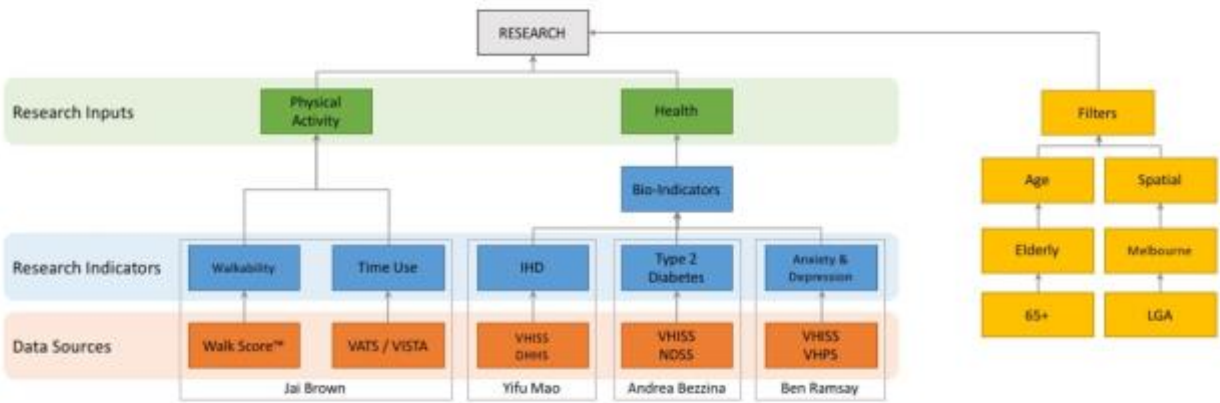

Figure 14: Research Structure