CHAPTER 1 INTRODUCTION

The direct medical costs of the number of overweight and obese people was reported to cost $117 billion in 2000 (US Surgeon General 2000) in the US and $680 to 1239 million in 1995/96 (Department of Health and Ageing n.d.) in Australia. Obesity is linked to a number of major diseases including chronic diseases such as hypertension, type 2 diabetes, colon cancer, osteoarthritis, osteoporosis and coronary heart disease (Ewing et al. 2003). Obesity is reported to be an epidemic (Cameron et al. 2003; Contaldo and Pasanisi 2003), particularly in western countries with 31% of adults aged over 20 years in the US either overweight or obese in 1999-2000 (CDC 2004). A similar situation is reported in Australia with 16.7% of the adult population (aged 18 or older) obese in 2001 and 34.4% overweight (Australian Institute of Health and Welfare 2003). The numbers of overweight and obese people have increased significantly in recent years, rising from 40% overweight or obese in Australia in 1989-90 to 51% by 2001 (Australian Institute of Health and Welfare (AIHW) 2003). Similar increases are reported for other western countries like Canada and the United Kingdom (International Obesity Task Force n.d.).

The increasing numbers of overweight or obese people has been linked with the increasingly sedentary lifestyles and insufficient levels of physical activity. The US Surgeon General (1996) highlighted the link between increasing girth and decreasing activity levels and suggested that moderate intensity activity such as frequent walking could improve the health outcomes for overweight

and obese people. Since this seminal report in 1996, public health researchers have been investigating which factors influence people to be active. Programs to encourage activity in Australia have included Exercise: Make it a Part of your Day; Exercise: Take Another Step, National Heart Foundation; National Physical Activity Guidelines DHAC 1999 (Bauman et al. 2002). In conjunction with programs such as these, research into what influences physical activity has taken two major streams, individual influences and environmental influences. It is the latter area of research that is of relevance to this study.

Environmental features including the availability of walking or cycling paths and parks as well as safety may influence walking or bicycling during leisure and commuting (Wendel-Vos et al. 2004). Ball et al. (2001) correlated aesthetic appeal of the environment, convenience and availability of walking companions with higher rates of walking. Owen et al (2000) proposed behaviour settings such as the local community, home, work, location of education facilities and transport access as important in influencing walking behaviour, while Sallis, Bauman and Pratt (1998) included policy and environmental factors such as natural and constructed environments and included issues such as weather and geography. The presence of resources relevant to physical activity, such as sidewalks, parks, exercise classes and health clubs make it easier for people to be physically active according to Sallis et al. (1997).

The presence, surface and condition of footpaths, path continuity, route directness, street widths, vehicle parking, traffic volume, speed and calming infrastructure were found to be important in a study by Pikora et al. (2002). Giles-Corti and Donovon (2001) in the study on environmental and individual determinants of physical activity (SEID project) examined the relative influences of individual, social and physical environmental determinants of recreational physical activity stressed the importance of spatial access and reported that the most frequently used facilities were the streets (45.6%), public open space (28.8%) and the beach (22.7%). Humpel et al. (2002) found an association between higher walking behaviour and coastal locations, while the results of a study by Troped et al. (2001) on the use of a community rail-trail found that physical barriers, travel distance and hilly terrain should be taken into account in the planning of community trails. Higher numbers of fast-food outlets were found to be positively correlated with lower socio-economic status (SES) areas in Melbourne in a study by Reidpath et al. (2002).

Humpel, Owen and Leslie (2002) reviewed 18 studies that assessed the relationships between physical activity behaviour and physical environmental attributes, grouping the studies into five classes; accessibility, opportunity for activity, weather, safety and aesthetics. The studies outlined above highlight a numbers of factors linked with walking activity, but what they do not include explicitly is the influence of the built environment and how this may be impacting upon people's capacity and ability to walk. Health professionals are starting to recognise the importance of the built environment and are now

looking to the findings of research from the transport planning and urban planning professions (Saelens, Sallis and Frank 2003).

Transport and planning studies have for the most part been concerned with transit, vehicle trips, air quality and urban design issues, but there is a growing awareness that urban design is also a health issue. While the planning and transportation research questions differ from those of public health professionals, the physical environment is a common denominator, especially the identification of characteristics of the environment that influence behaviour. Urban planning research is variously known as New Urbanism, Smart Growth or Liveable Neighbourhoods to list a few of the labels, however, irrespective of the label all of these groups share a common concern about urban sprawl and the resulting impact on the movement of people within urban spaces. Transport planners are also concerned with the impact of the built environment and sprawl on air quality, public transport usage and walk and cycle behaviour. These research interests have resulted in a considerable literature with Ewing et al. (2003) reporting more than 50 studies in the last decade on environmental influences on utilitarian travel such as journey to work, shopping or school. Saelens, Sallis and Frank (2003) recently completed a study of 18 transport and planning studies which examined the environmental correlates of walking and cycling and grouped the factors into two main classes, proximity (the way land is used, distance and density) and connectivity (directness of travel). The majority of transport studies apply neighbourhood density, land use mix, street network measures and various access factors to classify neighbourhoods as traditional, transit oriented, neo-

traditional and automobile dominated neighbourhoods. These classifications share a goal of understanding how the neighbourhood impacts on the way people move around either by car, public transport, walking or bicycling. Some of the key work in this area has been completed by Handy et al. (2002); Handy and Clifton (2001); Handy (1993, 1996); Cervero and Kockelman (1997); Cervero and Radisch (1996); Cervero and Gorham (1995); and Grant (2004). More recently, Saelens, Sallis and Frank (2003); Frank and Engelke (2001); and Barton (2004) have started to examine the relationship between transport and planning research, health and physical activity research and the impact the built environment has on population health.

1.1 Study Aims and Objectives

This convergence of interest is leading to more collaborative research between disciplines to better understand both the health issues and the built environment influences. One such collaboration is the Physical Activity in Localities and Community Environments (PLACE), a National Health and Medical Research Council funded project by the School of Population Health at the University of Queensland, the University of New South Wales and the National Centre of Social Applications of GIS (GISCA), University of Adelaide. The aim of the PLACE project is to build an objective walkability index based upon the identification of factors from the research and apply this to Adelaide, a large urban city in Australia using geographic information systems (GIS).

Walkability for the purpose of this study is defined as whether an areas environment is supportive or non-supportive of walking behaviours calculated from a range of environmental characteristics identified in the literature as promoting walking. Once the walkability index is calculated it will be used to identify areas that are highly supportive of walking or areas that are poorly supportive of walking. These areas will be used for a random survey of residents to learn about their actual levels of physical activity, perceptions of their local environment and as a validation of the walkability measure.

The present study is one part of the PLACE project and has the specific aim of constructing an objective index of walkability for Adelaide with the factors identified from the research literature, namely, population density, land use mix, street network connectivity and retail opportunity using GIS. Specifically, this study will build upon the work from the US (Frank et al. 2005) in delimiting cities into walk friendly or unfriendly, adapted to Australian data to provide the basis for an index that can be applied to Australian cities to highlight the variations across cities and between cities. Adelaide was chosen for this research for two main reasons, first, the variation in urban form across the city, and second, the quality and availability of data for GIS modelling. Both of these factors are essential for identifying walkability differences across space. GIS is used in this study because of the capacity to integrate large disparate data based on the spatial element. In many of the data sets used in this study the only common factor is that they share a location and without GIS it would be difficult to integrate and model these data to form a measure of walkability.

The detailed methodological approach adopted for this research is presented in Chapter 3 and the construction of the different elements leading to the final walkability index for Adelaide are presented in Chapter 4. Chapter 5 considers the usefulness of the walkability index and considers possible enhancements or variations as part of a process of developing a more detailed index. To set the context for this study, the next chapter provides an examination of the body of research pertaining to health issues, overweight, obesity and the health benefits of physical activity, studies of health implications and associations of environmental influences on physical activity plus the considerable research by transport and urban planners on the impact of built form on travel behaviour.

CHAPTER 2 LITERATURE REVIEW

OBESITY, PHYSICAL ACTIVITY AND PLANNING AND TRANSPORT RESEARCH

To set the context for the walkability index the literature review starts by looking at the growing numbers of overweight and obese persons, especially in the US and Australia. Increasing numbers of obese persons and the associated health costs are outlined to highlight the potential savings of reducing the numbers of obese in the population. Being physically active is one solution to reduce obesity and this forms the basis of the next section of the review. Health researchers investigating physical activity are concerned with two main research areas, individual factors and environmental factors. It is the later area of research that is of most importance to this study and therefore this section of the review is more detailed and comprehensive, because the identification of suitable walkability characteristics is driven by the results of studies included in this section. This section of the literature review focuses on the growing nexus between health, transport and urban planning research and the influences of the built environment on walking behaviours. This section concludes by identifying the set of characteristics that are used to create the walkability index for this study.

2.1 Overweight and Obesity

Body mass index[1] (BMI) is the recognised measure of overweight and obesity, although other measures are also used such as waist circumference, waist to hip ratio and skin fold. The proportion of the population overweight or obese in western countries is a major problem and has formed the basis of numerous studies and reports, CDC (2004); ABS (2003a); AIHW (2003); Cameron et al. (2003); Mokdad et al (2003); ABS (2002); AIHW (2002); AIHW (2003); Contaldo and Pasanisi (2003); Flegal et al. (2002); Mokdad et al. (2001); Mokdad et al. (1999); WHO (1998); ABS (1998) and ABS (1995).

Many agencies have established web sites to disseminate data and promote healthy lifestyles (American Obesity Association www.obesity.org; Australasian Society for the Study of Obesity www.asso.org.au; The International Association for the Study of Obesity; www.iotf.org; North American Association for the Study of Obesity www.obesityresearch.org; the Weight Control Information Network www.niddk.nih.gov; World Health Organisation www.who.int/topics/obesity/en/; The US Department of Health and Human Services Centre for Disease Control, www.cdc.gov). These web sites provide research reports and statistics on rates of overweight and obesity from many western countries.

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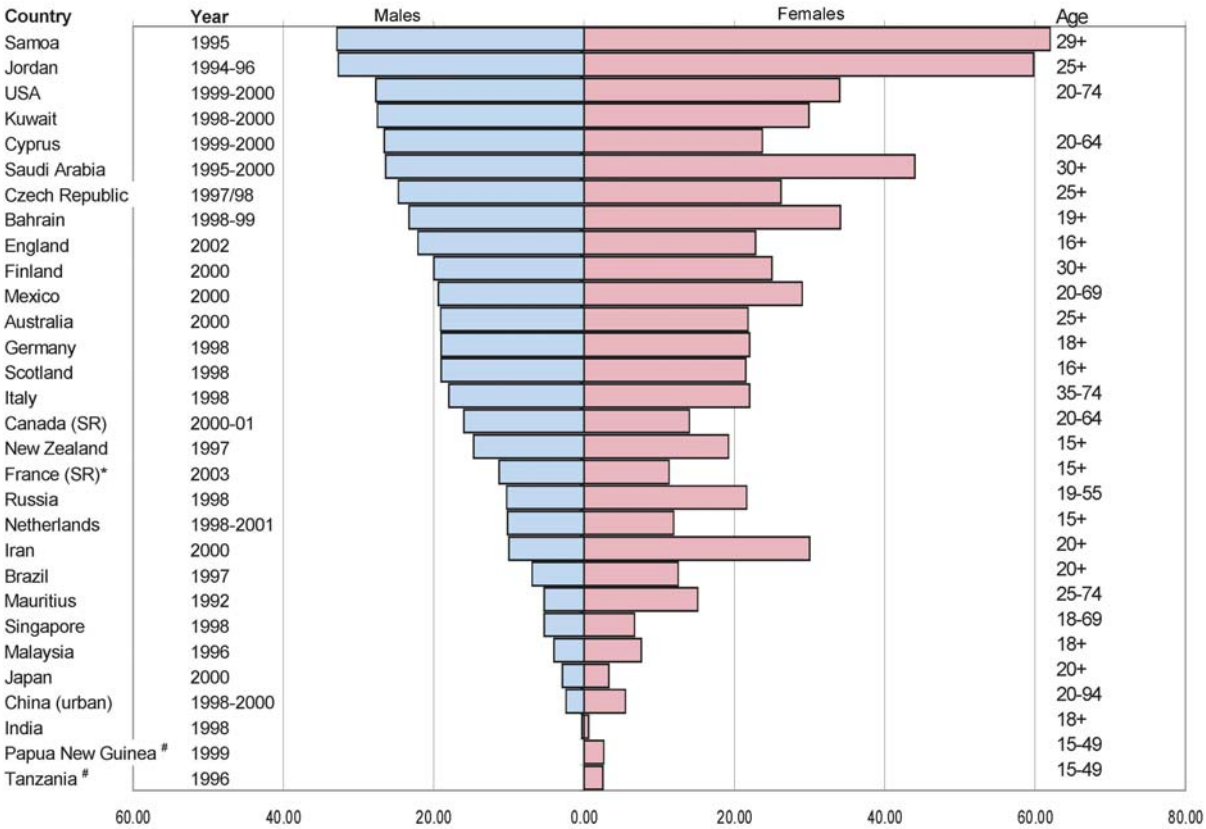
[1] BMI is calculated as the weight in kilos divided by the height squared (BMI = wt/(ht^2). The standard for overweight is a BMI of >= 25 and less than 30, obesity is a BMI of greater than 30.

Data from the International Obesity Task Force reports obesity levels for a range of countries for the early 1990s to 2003 (Figure 2.1). Noticeably, the US was 3rd on the list and Australia was 12th. The highest level was for urban Samoans, especially the women. Obesity levels are reported to be 20% or higher for many of the developed nations, such as Scotland, Germany, Finland, England and the Czech Republic. Also noteworthy is the high levels of obesity in the Middle East, Jordan, Kuwait and Saudi Arabia, especially with the women. The US and Australia are the main interest for this research and the next two sections report on obesity levels in these countries.

Figure 2.1: Obesity Levels (BMI), Selected Countries 1996 and 2003



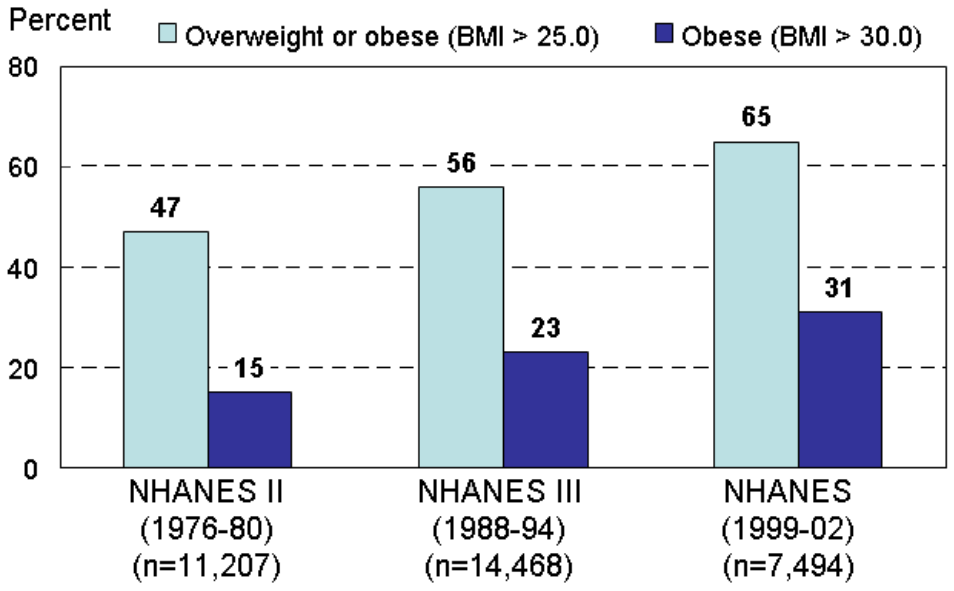
SR - self report.
* males and females combined
# No data for Males

Source: International Obesity Task Force (n.d.).

2.1.1 US Obesity

For the US, where obesity is considered to be one of the country's major health issues (Surgeon General's Report 1996), the proportions of overweight and obese has continued to increase. In 1999–2000, an estimated 31% of U.S. adults aged 20 years and older, approximately 59 million people, were overweight or obese (CDC 2004). Since the 1976-80 data on overweight and obesity data was collected, the percentage of adults aged 20-74 years reported as obese, has doubled between from approximately 15% to an estimated 31% (see Figure 2.2).

Figure 2.2: Percent of Overweight and Obese Persons, US 1988-2000.



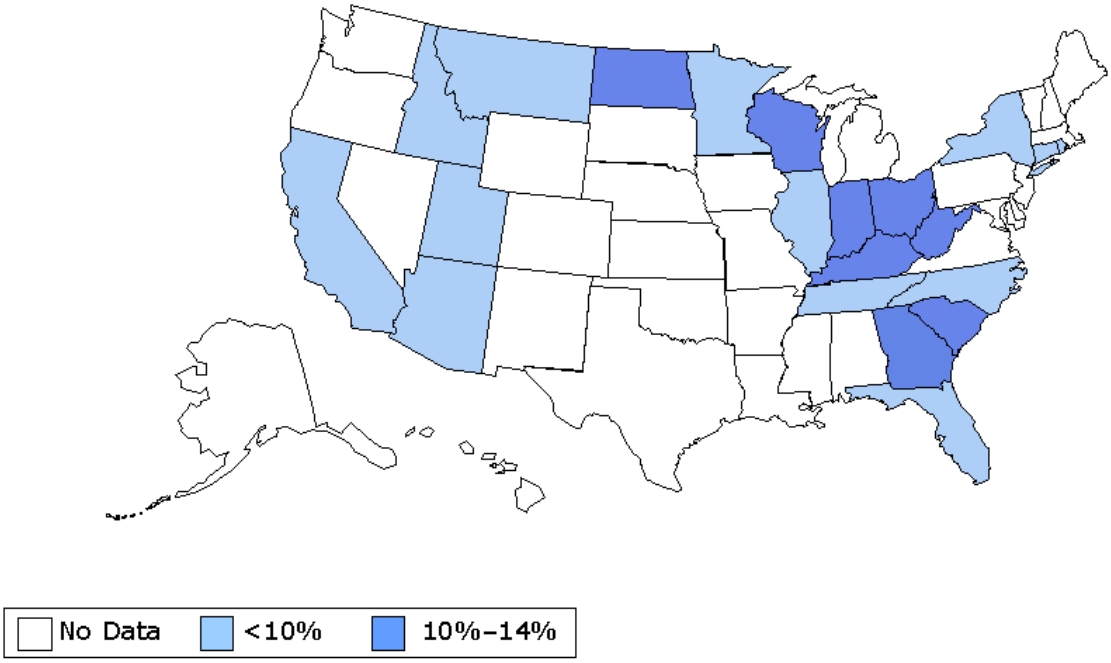
*Age-adjusted by the direct method to the year 2000 U.S. Bureau of the Census estimates using the age groups 20-39, 40-59, and 60-74 years.

Source: CDC (2004).

Some of the more revealing data from the US are a series of state based obesity maps with the percent of the population with a BMI of 30 or more

recorded annually since 1980. For this report, only the 10 yearly data are included (1980, 1990, 2000 and 2003), plus 2003 to provide the latest data. What is important about these maps is they display not only the increasing percentage of the US population that is obese, but also the distribution across the US (Figures 2.3 to 2.6). It is important to recognise that when reporting national level data, that this masks the variations that occur across space. Figures 2.3 to 2.6 show that although the overall trend of increasing levels of obesity are evident across the US, some states report higher levels than other states. From a planning perspective, the state level data allows resources to be targeted to those states with higher levels of obesity.

Figure 2.3: Obesity Trends, US, 1980.

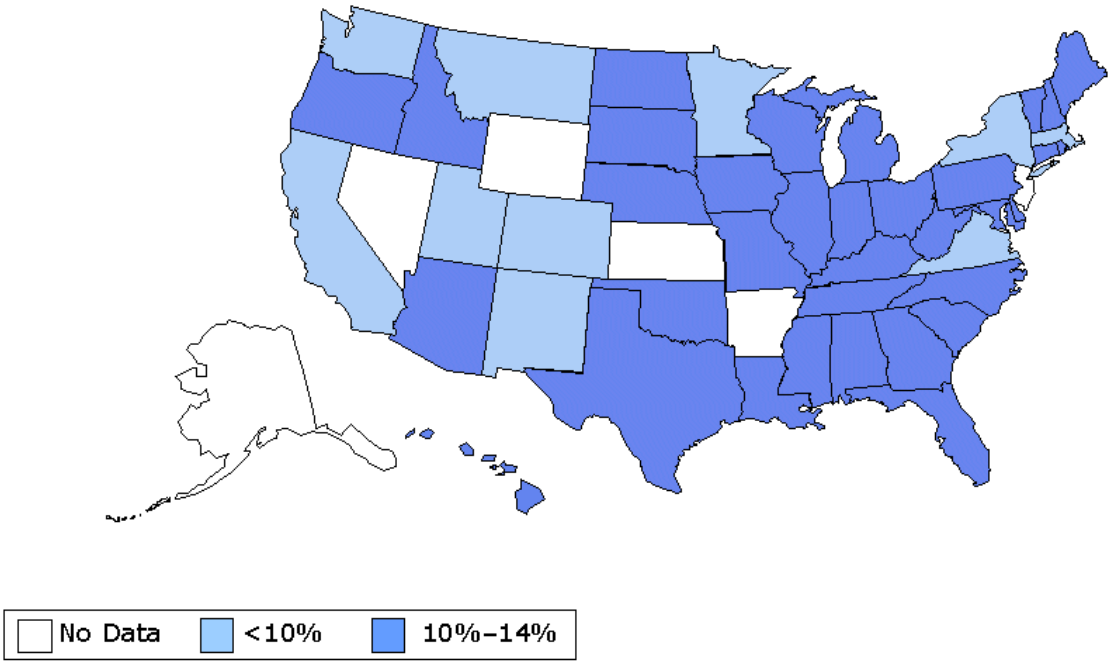


Source: CDC (n.d.).

The 1980 data displays overall low levels of obesity across the US with less than 14% of the adult population obese in those states with obesity data. By

1990 more of the states obesity date are available and most states are between 10%-14% obese (Figure 2.4).

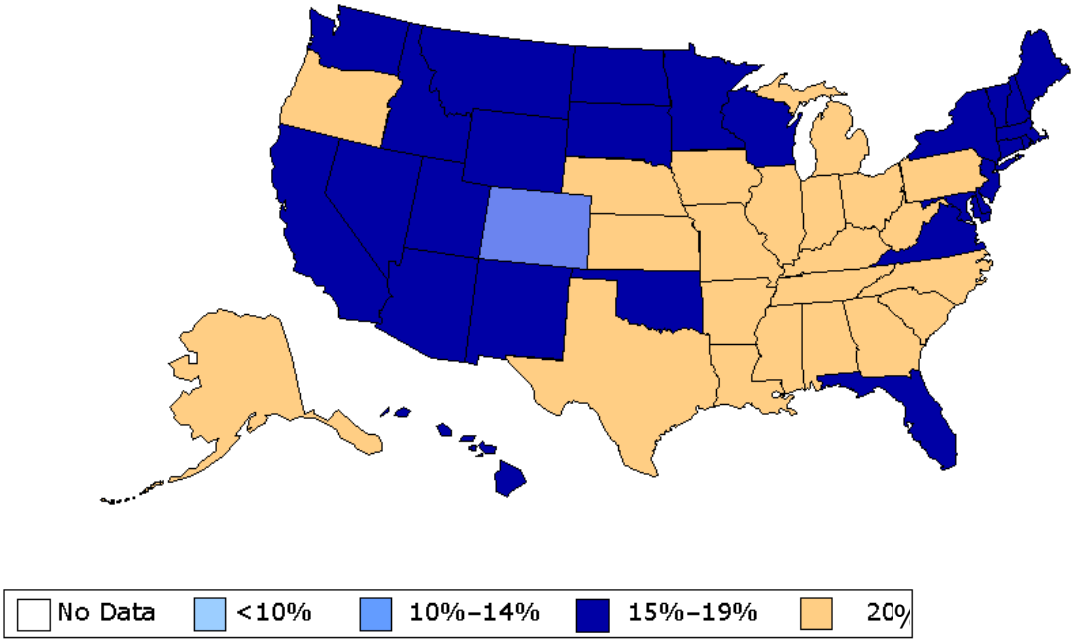
Figure 2.4: Obesity Trends, US, 1990.



Source: CDC (n.d.).

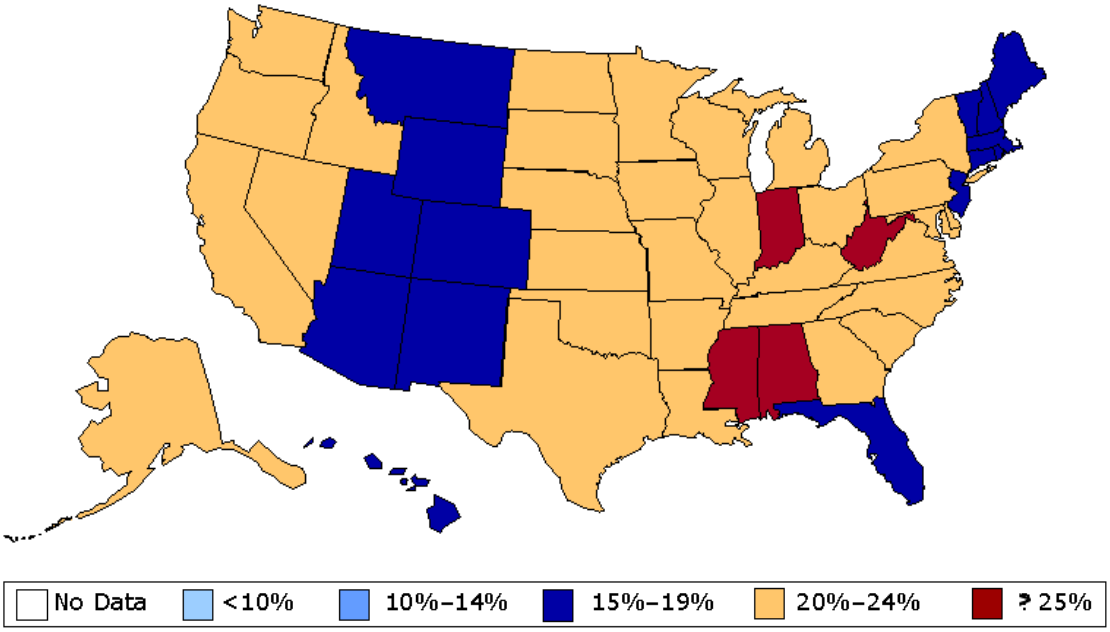
By 2000 the proportion of obese adults had continued to rise with most states at least 15%-19% obese and many up to 20% obese (Figure 2.5). By 2003 most states in the US reported that between 20%-24% of the adult population are obese with a small number of states reporting more than 25% obese (Figure 2.6).

Figure 2.5: Obesity Trends, US, 2000.



Source: CDC (n.d.).

Figure 2.6: Obesity Trends, US, 2003.

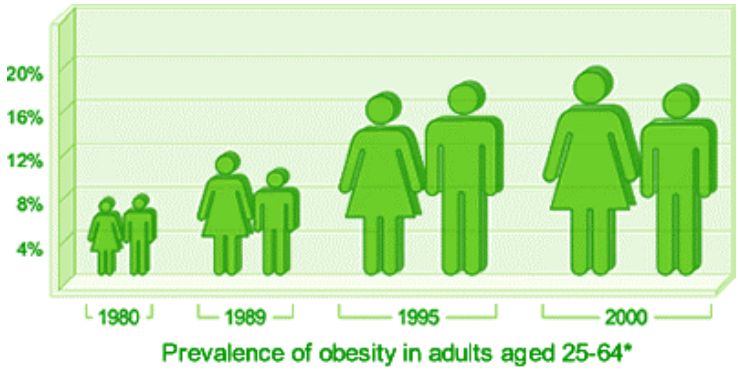


Source: CDC (n.d.).

2.1.2 Australian Obesity

The situation in Australia follows a similar pattern with the proportion of overweight and obese persons increasing over the 1980 to 2000 (Figure 2.7).

Figure 2.7: Percent of Obese Australian Adults, 1980 – 2000.

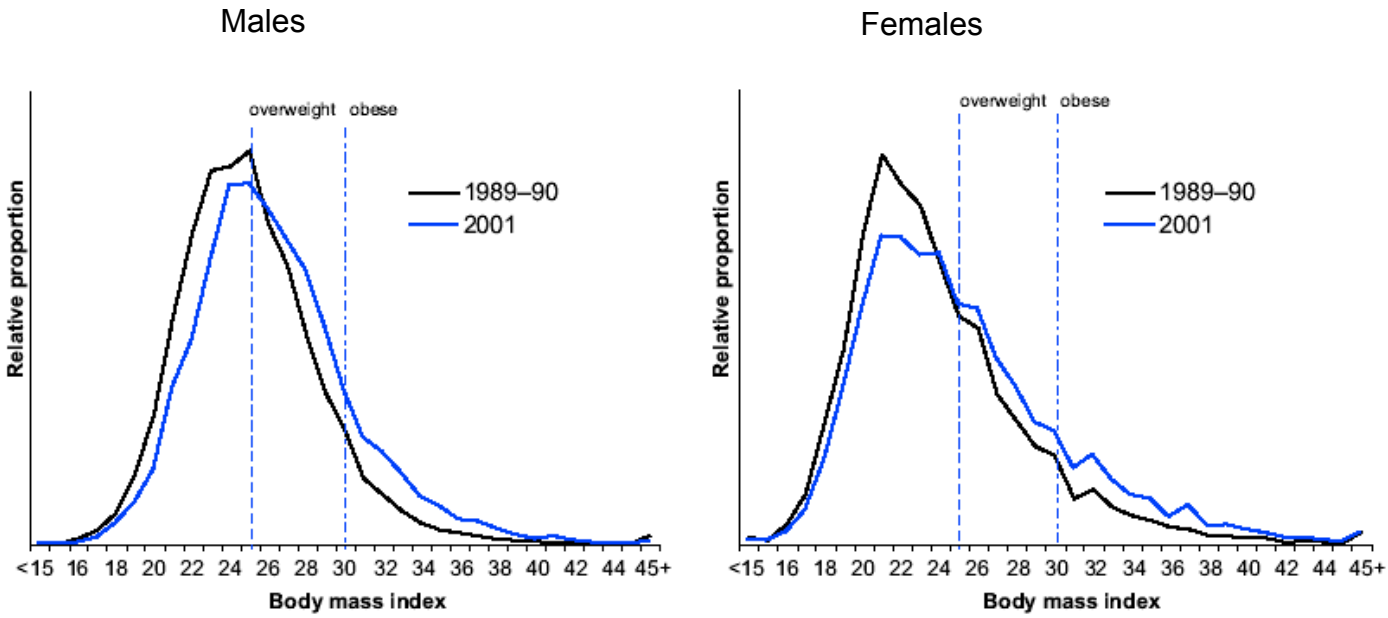


Source: Australasian Society for the Study of Obesity (n.d.).

The Australian Institute of Health and Welfare (2003) reported that the prevalence of obesity (BMI >=30) for adults (aged 18 or over) increased from 9.5% in 1989-90 to 16.7% in 2001. Over the same period, overweight (BMI >= 25 <30) adults increased from 30.4% to 34.4% for the same period (AIHW, 2003).

Data from the 1989–90, 1995 and 2001 National Health Surveys show an alarming increase of overweight and obesity levels among Australian adults. In 2001 an estimated 51.1% of Australians aged 20 years and over were overweight (BMI > 25). This is a marked increase from 1989–90 when the prevalence of overweight was 40.0%. Figure 2.8 displays the change in BMI for males and females from 1989-90 to 2001.

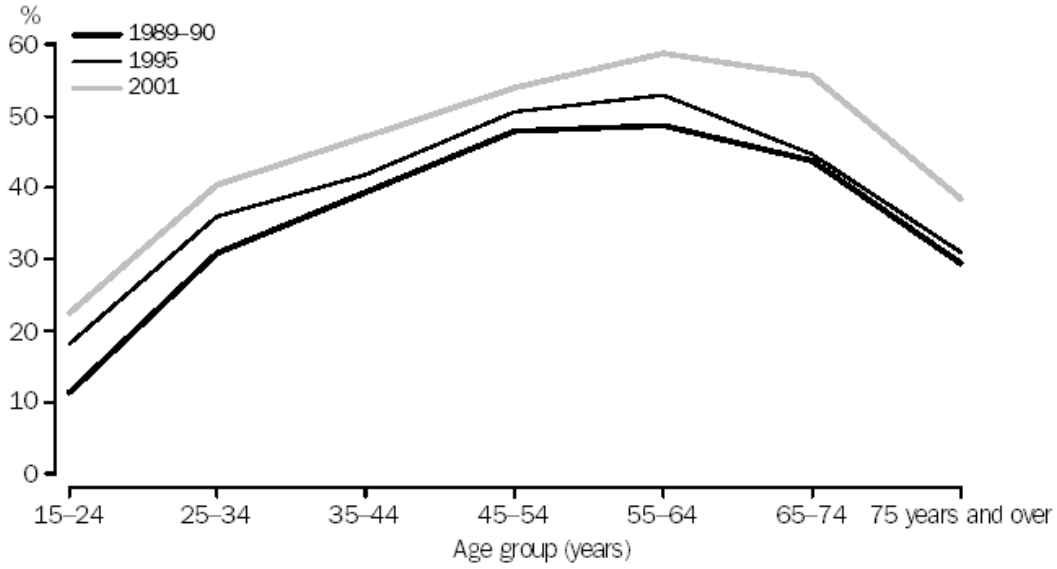
Figure 2.8: Australian Adult BMI, Males and Females, 1989-2001.



Source: AIHW (2003, p4).

BMI, as displayed in Figure 2.8 is showing a shift in the distribution towards higher BMI values, suggesting that the Australian population has gained weight. Figure 2.8 shows that the increased levels of obesity is occurring in both the male and female populations, although, the AIHW (2003) suggests that due to the self-report nature of these data, these figures may underestimate the true extent of overweight and obesity in Australia as people under report their weight. The Australian Bureau of Statistics (2003a) in its report of the National Health Survey (NHS) 2001 also report higher levels of BMI in Australia, and also show that the gain in weight is not only across all of the Australian population but also across all the age groups (Figure 2.9).

Figure 2.9: BMI (>=25), Increases Australian Adult Population 1989-90 to 2001.



Source: ABS, Catalogue 4812.0 (2003a, p. 17).

The important aspect that is evident from Figure 2.9 is that BMI is increasing across all of the age groups and therefore this is not a cohort-based outcome. As all the age groups are increasing, this will potentially continue to increase the number of obese persons in Australia into the foreseeable future. Further evidence of the obesity epidemic is provided by results from the recent Australian Diabetes, Obesity and Lifestyle Study (AusDiab) on obesity, reported by Cameron et al. (2003). The AusDiab study was a household interview of eligible adults aged 25 years or older followed by a physical examination at specified survey sites. A total of 20347 eligible people completed the household interview but only 11247 attended the physical examination at local survey sites (response rate, 55%).

The results of the survey are presented in Table 2.1, which displays the BMI and waist circumference data by age group and sex for the survey respondents.

Table 2.1: Age-specific prevalence (%) of (A) overweight and (B) obesity defined by body mass index (BMI) (n= 11067) and by waist circumference (n=11059) among Australian adults

	25–34 y	35–44 y	45–54 y	55–64 y	65–74 y	75+ y	Total
A	**Age-specific prevalence (%) of overweight**						
BMI*							
Men	43.7	46.8	51.1	48.9	53.6	50.8	48.2
Women	22.6	25.7	32.1	35.4	37.4	36.4	29.9
Total	33.5	36.3	41.7	42.2	44.8	42.4	39.0
Waist circumference†							
Men	26.6	25.7	31.0	31.0	30.7	27.5	28.5
Women	19.6	21.8	21.5	25.6	27.7	22.8	22.6
Total	23.3	23.8	26.3	28.3	29.1	24.7	25.5
B	**Age-specific prevalence (%) of obesity**						
BMI‡							
Men	17.4	17.8	20.8	25.5	19.9	12.7	19.3
Women	12.4	19.5	26.9	32.8	29.4	15.6	22.2
Total	15.0	18.6	23.8	29.1	25.1	14.4	20.8
Waist circumference§							
Men	14.0	24.9	27.6	36.0	40.7	36.5	26.8
Women	17.2	25.8	38.3	48.0	51.2	42.3	34.1
Total	15.5	25.4	32.9	42.0	46.5	39.9	30.5

* Overweight defined as a BMI of 25.0–29.9 kg/m^2.
† Overweight defined as a waist circumference of 94.0–101.9 cm in men and 80.0–87.9 cm in women.
‡ Obesity defined as a BMI of ≥ 30.0 kg/m^2.
§ Obesity defined as a waist circumference of ≥ 102.0 cm men and ≥ 88.0 cm in women.

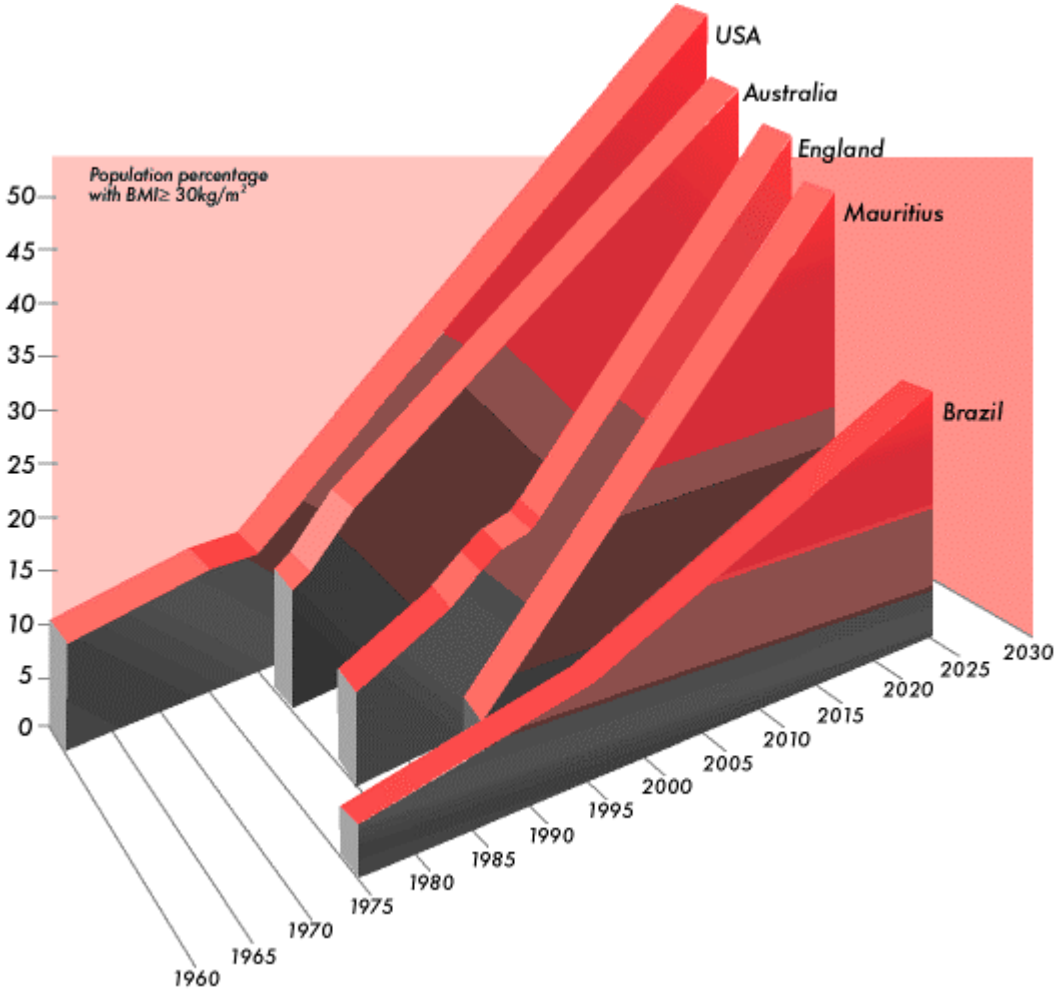
Source: Cameron et al. (2003, p. 428).

The BMI overweight and obesity results were 39.0% and 20.8 and 30.5% and 25.5% by waist circumference measurement (Cameron et al. 2003). By either

measure, approximately 60% of the population was overweight or obese (Table 2.9).

In common with the US and many other western countries, the percentage of the adult population that is overweight or obese is a serious health issue that is worsening. According to the International Obesity Task Force (n.d.), the percent of the population that is obese could be as over 50% by 2025 in the US, Australia and England (Figure 2.10).

Figure 2.10: Percentage of the Population with a BMI of 30 or Greater, Selected Countries, 1960 – 2025.



Source: International Obesity Task Force (n.d.).

Australia and the US face a serious health issue that has worsened over the past 20 years as is evident from the levels reported in this section. As the increases have occurred in both the male and female populations and across all age groups, the impacts of the growing numbers of obese is likely to continue. The costs associated with the obesity epidemic are presented in the next section to emphasize the direct costs associated with obesity and the potential health saving that could occur if the factors associated with obesity are better understood, especially the impact of the environment on physical activity.

2.2 Direct Medical Costs of Obesity

Australia, the US and many western countries have a significant proportion of their population either overweight or obese. As stated above, obesity is linked with a number of major diseases and therefore the cost of obesity can be estimated. The costs associated with overweight and obesity have two components, direct medical costs and indirect costs (Wolf and Colditz 1998; Wolf 1998). The direct medical costs may include preventive, diagnostic, and treatment services related to obesity are more readily calculated. Finkelstein, Fiebelkorn, and Wang (2003) reported that the direct costs associated with overweight and obesity in the US for 1998 was 9.1% of total US medical expenditure or approximately $78 billion (Table 2.2).

Table 2.2: Aggregate Medical Spending, in Billions of Dollars, Attributable to Overweight and Obesity, by Insurance Status and Data Source, 1996–1998

Insurance Category	Overweight and Obesity		Obesity	
	MEPS (1998)	NHA (1998)	MEPS (1998)	NHA (1998)
Out-of-pocket	$7.1	$12.8	$3.8	$6.9
Private	$19.8	$28.1	$9.5	$16.1
Medicaid	$3.7	$14.1	$2.7	$10.7
Medicare	$20.9	$23.5	$10.8	$13.8
Total	$51.5	$78.5	$26.8	$47.5

Note: Calculations based on data from the 1998 Medical Expenditure Panel Survey merged with the 1996 and 1997 National Health Interview Surveys, and health care expenditures data from National Health Accounts (NHA). MEPS estimates do not include spending for institutionalised populations, including nursing home residents.

Source: Finkelstein, Fiebelkorn, and Wang (2003, p. 223).

The International Obesity Task Force (n.d.) report on costs for a range of countries, and even though these data are not as current as the US data above, the direct medical costs of obesity are significant (Table 2.3). It should be stressed, these are indicative costs only (Table 2.3) and even though Table 2.2 is more up to date, these tables do not take account of indirect costs, such as work sick days and therefore the cost implications of the obesity epidemic in western countries is far more significant and any reduction in obesity will save the respective government a considerable sum from the health budget.

Table 2.3: Medical Spending, in Billions/Millions of Dollars, Attributable to Obesity for Selected Countries.

Country	Year	Obesity (BMI)	Direct Costs	% National Health care costs
US	1986	> 29	US $39.3 billion	5.5%
US	1988	> 29	US$44.6 billion	7.8%
Canada	1997	>27	CDN$1.8 billion	2.4%
Australia	1989/90	> 30	AUD$464 million	> 2%
Netherlands	1981-89	> 25		4%
France	1992	> 27		2%

Source: International Obesity Task Force (n.d.).

Table 2.2 and 2.3 display the significant direct expenditure associated with dealing with obesity. With the significance of both the number of people overweight and obese, and the magnitude of the associated costs, it should not be a surprise that health professionals have been researching the influences of the obesity epidemic with the aim of reducing the numbers of overweight and obese persons. Reductions in the direct medical costs associated with obesity offer considerable savings to the health budget. One of the methods identified to reduce the numbers of obese or overweight persons is to get the population more physically active (US Surgeon General 1996). As a result the health profession has been promoting get active programs and the researchers have been investigating what influences people to be physically active (or inactive). The next section reviews the health professional physical activity literature, in particular, those studies

highlighting characteristics that have been associated with physical activity or inactivity.

2.3 Physical Activity

Research into the links between physical activity, obesity and health are too numerous for a complete listing, however, see for example, Bauman (2004); Sallis et al. (2004); Sallis, Bauman and Pratt (1998); Sallis et al. (1997); Wendel-Vos et al. (2004); Ewing et al. (2003); Bauman et al. (2002); Pikora et al. (2002); Reidpath et al. (2002); Ball et al. (2001); Brownson et al. (2001); Giles-Corti and Donovon (2001); Troped et al. (2001); Bauman, Owen and Leslie (2000); and Sparling et al. (2000). Moderate physical activity as been identified as one of the best investments for individual and community health (Bauman et al. 2002), and plays a crucial role in the prevention and management of a range of chronic diseases (Brown 2004; Giles-Corti and Donovon 2001;Troped et al. 2001; Owen et al. 2000). Evidence from epidemiological research based upon quality cohort studies, similar in design to studies that have provided four decades of evidence about the risks of tobacco, provide remarkably consistent results on the associations of inactivity and disease outcomes (Bauman, Owen and Leslie 2000).

Current public health recommendations emphasize the benefits of accumulating 30 minutes of moderate intensity physical activity daily (Sallis et al. 2004). Walking is the most common form of adult physical activity (Saelens, Sallis and Frank 2003; US Surgeon General's Report 1996) as

walking can be done at almost any age and can be done for transport, health or leisure purposes (Sallis et al. 2004). Consequently, as the goal of many state and national health agencies is to promote physical activity, particularly walking for the health benefits, Healthy People 2010 (US Department of Health and Human Services 2000) targeted a 50% increase in walking trips for adults for trips of less than 1 mile (Saelens, Sallis and Frank 2003). Despite the national programs promoting healthy lifestyles, about one-half of the Australian adult population was insufficiently active for health gain and similar results are reported for other industrialised countries (Bauman et al. 2002; Troped et al. 2001; Owen et al. 2000; Sallis, Bauman and Pratt 1998).

Physical activity such as walking is a simple and effective means of reducing the health burden in western countries and therefore, factors that influence physical activity has been the subject of considerable research. Two main streams of research have emerged, individual and community level influences and the environmental influences of physical activity. The first stream of study is not directly pertinent to this research and is not included in this review. The second stream is the basis for this study and provides part of the rationale for creating an index of walkability.

2.3.1 Environmental Influences of Physical Activity

A number of different studies have looked at environmental influences and a range of factors has been correlated with physical activity. Ball et al. (2001) identified the aesthetic appeal of the environment, convenience and walking

companions as correlated with higher walking rates. Behavioural settings associated with physical activity were proposed by (Owen et al. 2000) such as community, home, work, educational, and transport, with a series of sub-characteristics:

Community

- Public open spaces
- Sports facilities
- Retail facilities
- Social setting (cafes etc)

Home

- Indoor
- Outdoor

Occupational

- Office based
- Trade and industrial
- Service industry

Educational

- School
- Tertiary

Transport

- Roads
- Walking and cycling paths
- Subways

Wendel-Vos et al. (2004) identified a range of factors, including access to walking paths, cycling paths and parks plus safety as factors of the physical environment that may influence walking or bicycling during leisure and commuting plus the amount of green and recreation space within 300 and 500 metres of survey participants homes.

Sallis, Bauman and Pratt (1998) included policy and environmental factors such as natural and constructed environments with policies related to incentives to promote activity and policies for the provision of infrastructure supportive of physical activity. In this study, Sallis, Bauman and Pratt (1998) included many factors: such as weather and geography under natural environmental factors; the information environment; suburban factors, including walk and bike trails that connected home to shopping centres, parks and recreation centers; the separation of buildings from parking lots by green space; making stairways more open and accessible; and accessible transport infrastructure. Linked with these factors, Sallis, Bauman and Pratt (1998) also include a raft of policies to provide or improve or promote these facilities in support of physical activity.

Sallis et al. (1997) reported on the capacity of the environment to facilitate or hinder physical activity, where environments rich in resources relevant to physical activity, such as sidewalks, parks, exercise classes and health clubs make it easier for people to be physically active, whereas environments that lack relevant resources or pose barriers such as inclement weather or high

crime rates may act to reduce the probability that residents will be physically active.

The development of an audit instrument for measuring environmental factors may influence walking or cycling in local neighbourhoods was reported by Pikora et al. (2002); factors included the presence, surface and condition of footpaths, path continuity, route directness, street widths, vehicle parking, traffic volume, speed and calming infrastructure.

A study on Environmental and Individual Determinants of Physical Activity (known as the SEID project) examined the relative influences of individual, social and physical environmental determinants of recreational physical activity in a part of Perth, Western Australia, (Giles-Corti and Donovon 2001). This study highlighted the importance of access to facilities and reported that the most frequently used facilities were the streets (45.6%), public open space (28.8%) and the beach (22.7%).

Humpel et al. (2002) reported the results of a survey of 800 persons and found an association between higher walking behaviour and coastal locations, while the results of a study by Troped et al. (2001) on the use of a community rail-trail found that physical barriers such as travel distance and hilly terrain should be included in the planning of community trails, if the trails were to be more effective. Personal barriers such as lack of time, feeling too tired, getting exercise at work and no motivation to exercise were reported by Brownson et al. (2001) as well as the presence of environmental characteristics such as

footpaths, enjoyable scenery, hills and heavy traffic. The density of fast food outlets was positively correlated with lower socio-economic status (SES) areas in Melbourne by Reidpath et al. (2002) in an interesting twist on how the characteristics of the local environment might influence overweight and obesity rates.

The above précis of physical activity research is not meant as an all-encompassing treatment, but is meant to highlight the varied response to the question of how the physical environment can influence physical activity. There are a number of themes identified, access to foot and bike paths, aesthetics, a feeling of safety, public transport infrastructure and the home, work and play environment have all been linked with physical activity. Humpel, Owen and Leslie (2002) reviewed 18 studies including the studies outlined above and classified the research into a number of groups. These groups were proposed to provide a common framework that could be applied to physical activity research to assist in the identification of relationships between physical activity behaviour and physical environmental attributes. This study grouped the studies into five classes; accessibility, opportunity for activity, weather, safety and aesthetics (Table 2.4).

Table 2.4: Associations Between Environmental Variables and Physical Activity.

Environmental Variable	*Associations*
Accessibility of Facilities	
A cycle path is accessible	+
Busy street to cross	-
Busy street to cross [a]	0
Negotiate steep hill	0
Negotiate steep hill [a]	-
Access to facilities (local park)	+
Facilities on frequently traveled route	+
Density of pay and free facilities [a]	+
Neighborhood residential	-
Number of convenient facilities	0/0
Lack of facilities	- / -
No facility nearby (women)	-
Available facilities inadequate	-
Access to built facilities [a]	0
Access to natural facilities [a]	0
Distance to bikeway	-
Distance to bikeway [a]	-
Park or beach in walking distance	+
Shops are in walking distance	+
Opportunities for activity	
Presence of sidewalks	0 / 0
Home equipment	0 / + / +/ +/0
Lack of equipment	- / -
Awareness of facilities	+
Satisfaction with recreation facilities	+
Neighborhood environment	0/+
My area offers opportunities for physical activity	+
Local clubs and others provide opportunities	+
Coastal residence	+
Functional environment (footpath/shop)	0
Weather	
Poor weather	0
Lack of good weather	0
Safety	
Footpaths are safe	+
How safe to walk or jog alone in day	0 / 0 / 0
Lack a safe place to exercise	0 / 0
High levels of crime	0 / 0
Unattended dogs	+ / 0
Streetlights	0 / 0
How safe from crime is your neighborhood	+
Heavy traffic	0 / 0
Aesthetics	
Neighbourhood friendly	+
Pleasant near home	+
Local area is attractive	+
Enjoyable scenery	+ / +
Hills	+ / 0
Living environment	+
Appeal (traffic/trees)	0

[a] objectively assessed by Geographic Information System or other objective data
\+ significant positive association found with physical activity
\- significant negative association found with physical activity
0 no association found with physical activity

Source: Humpel, Owen and Leslie. (2002, p. 196).

The importance of the Humpel, Owen and Leslie (2002) review is twofold, first the list of factors associated with physical activity and second, an indication of whether the factors are positively correlated, did not impact or are negatively associated (Table 2.4). Access was important in a few cases, particularly bike and footpath access, parks, the beach and local shops. Steep hills, a lack of facilities nearby and distance were all negatively correlated with physical activity (Humpel, Owen and Leslie 2002). Aesthetics was important in most of the reviewed studies, but weather and most of the safety factors reviewed did not have an association with physical activity. Humpel, Owen and Leslie (2002) point out that in some cases, the variables are groups or associations of physical environmental items and not individual relationships between a variable and physical activity and that the five groups identified were not proposed as definitive constructs, but as labels of groupings that can assist in understanding the relationships between factors and the influence on physical activity.

Humpel, Owen and Leslie (2002) conclude that the research on environmental influences has considerable promise for identifying influences on physical behaviour. What the research described above does not include is the influence of the built environment and how this may be impacting upon peoples capacity and ability to walk or cycle. The next section reviews the work of the transport and town planning professions, as this research is crucial for this study in the identification of built environment characteristics that have been positively correlated with influencing walk activity.

2.4 The Built Environment and the Influence on Physical Activity: Evidence from Transport and Planning Studies

Historically, town planning was introduced to improve health conditions in European cities, especially overcrowding and sanitation, (Barton 2004, Grant 2004). Haussmann's plan for Paris in 1850 was intended to improve airflow and sanitary conditions (Saalman 1971 cited Frank and Engelke 2001). Similar concerns were behind Frederick Olmstead's low-density residential neighbourhoods combined with parks and open space (Grant 2004). The 1926 Supreme Court ruling of Euclid, Ohio v Ambler Realty that resulted in the Zoning Enabling Act was predicated upon the health, safety and welfare impacts of land use decisions (Beuscher, Wright and Gitelman 1976, cited Frank and Engelke 2001, Jackson and Kochtitzky n.d.). The early history of planning was fundamentally a desire to improve health in the early industrial cities of Europe and planning and public health professionals share a common heritage (Frank and Engelke 2001).

While the planning and transportation research questions differ from the public health professionals, the physical environment is the common denominator, especially the identification of characteristics of the environment that influence behaviour. Factors identified from the planning and transport literature are reviewed to identify characteristics that are correlated with walk or cycle supportive areas.

Typically, the urban planning research into the influence of built environments is part of what is variously termed New Urbanism, Smart Growth or Liveable Neighbourhoods. Irrespective of the label, all of these share a concern about the negative impact of urban sprawl and what this is doing to the interaction within urban spaces. Transport planners are also concerned about the impact of the built environment and sprawl and especially the impact on automobile trips, vehicle miles (kilometres) traveled, public transport usage and walk and cycle behaviour (Barton 2004; Schlossberg and Brown 2004; Timmermans 2004; Ewing, Pendall and Chen 2003; Ewing et al. 2003; Rajamani et al. 2003; Handy et al. 2002; Handy and Clifton 2001; Pucher and Dijkstra 2000; Cervero and Kockelman 1997; Kitamura, Mokhtarian and Laidet 1997; McNally and Kulkarni 1997; Cervero and Radisch 1996; Ewing, Haliyur and Page 1996; Handy 1996; Cervero and Gorham 1995; JHK and Associates 1995; Friedman, Gordon and Peers 1994; Handy 1993; Parsons Brinckerhoff Quade and Douglas Inc. 1993 and Morris and Kaufman n.d.). Not surprisingly, this literature has resulted in the recognition that the built environment can be linked with health behaviour (Sallis et al. 2004; Vandegrift and Yoked 2004; Ewing et al. 2003; Berrigan and Troiano 2002; Handy et al. 2002; Frank and Engelke 2001; Giles-Corti and Donovon 2001; Stafford et al. 2001; and Sallis et al. 1997). Ewing et al. (2003) report that there have been more than 50 studies in the last decade on the environment and influences on utilitarian travel such as journey to work, shopping or school. This review will include some of the key transport or planning studies on how the built environment influences walking behaviour as part of the process of identifying those

characteristics that will most usefully contribute to how an area can be objectively classified as walkable.

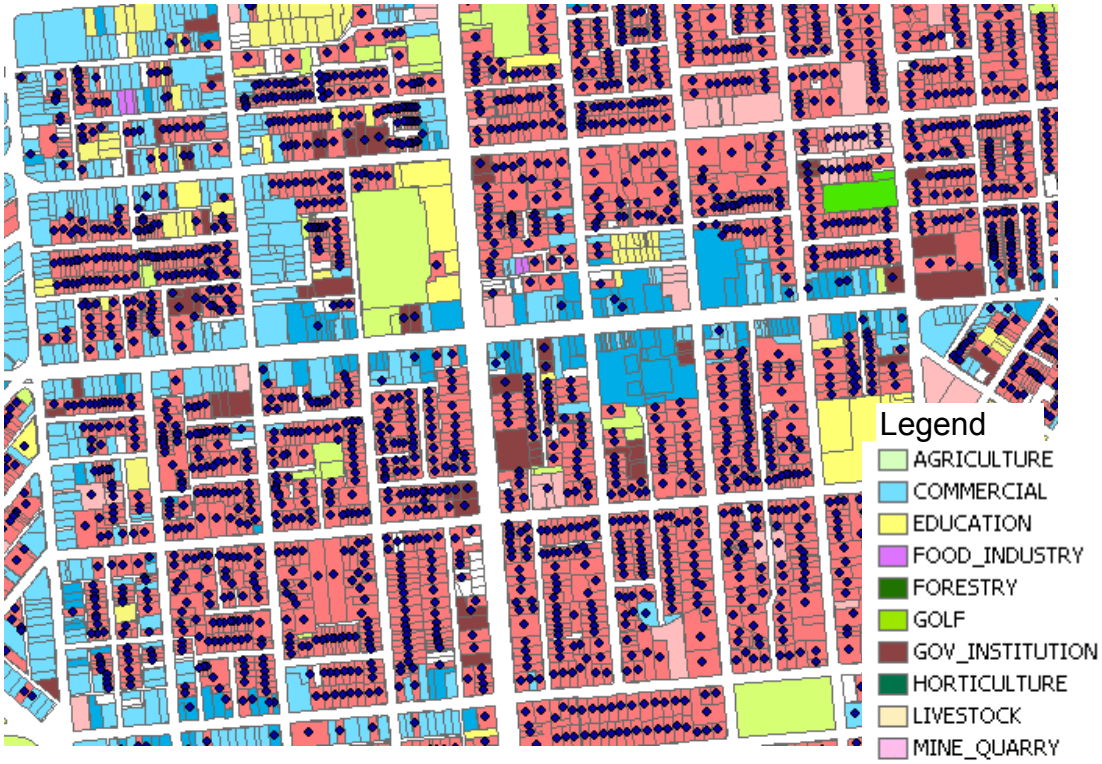
A useful starting point is a review of walking for transport completed by Saelens, Sallis and Frank (2003) who examined the environmental correlates of walking and cycling from transportation and planning studies. The Saelens, Sallis and Frank (2003) review was designed to highlight the links between health and planning research, introduce some of the planning findings and start a more collaborative approach to future research. A key to this review is the recognition that transport and planning researchers have long understood that neighbourhood design and land use may affect transport choice, such as automobile, public transit or walking/cycling (Saelens, Sallis and Frank 2003).

The factors associated with the choice between motorised or non-motorised transport were classified into two fundamental groups, proximity (the way land is used, distance and density) and connectivity (directness of travel). Proximity is characterised by two land use variables, density and land use mix. Density relates to the number of people, dwellings, jobs, or buildings per unit area to name a few. Land use mix is the integration of different land uses, such as residential, retail, commercial, industrial or recreation per unit area. Connectivity is characterised as the ease of moving between origins (e.g., households) and destinations (e.g., stores and employment) within the existing street and sidewalk/pathway structure, (Saelens, Sallis and Frank 2003).

In the transport and planning research, street connectivity is classified as high with a traditional grid street pattern and low in the typical modern suburbs characterised by curvilinear streets and numerous cul-de-sacs, limiting route choices (Figure 2.11). Figure 2.11 highlights two areas from the Adelaide study area, a more traditional grid pattern with mixed land use and a newer area with less land use mix and a street network characterised by cul-de-sacs and curvilinear streets.

Density, land use mix and the connectedness of the street network are the characteristics that the urban and transport planners have explored in relation to the way the urban environment influences non-motorised transport and the research has the capacity to inform the physical activity research into environmental influences. These characteristics are the key to the design and construction of the walkability index in this study and are the focus of this section of the literature review.

Figure 2.11: Examples of Density, Land use Mix and Street Networks



Good land use mix, density and grid street network.

Poor land use mix, density and curvilinear street network.

Source: DCDB-LOTS; Planning SA Zoning.

In a number of studies higher density, more land use mix and good street connectivity was used to characterise high walkable areas and lower population density, more uniform land use (e.g., residential), and poor street connectivity to characterise low walkable areas (Saelens, Sallis and Frank 2003). Residents from the identified areas are sampled and asked to keep a travel behaviour log and record their walking trips and the results are presented in Table 2.5.

Table 2.5: Estimated average walking and\or cycling trips per week among residents of high walkable versus low walkable neighborhoods

Geographic location	High walkable neighbourhoods				Low walkable neighbourhoods			
	Non-work Errand Exercise		**Work**	**Total**	**Non-work** Errand Exercise		**Work**	**Total**
San Francisco Bay area & Los Angeles	----		0.9	----	----		0.3	----
San Francisco Bay area	1.4		0.7	----	0.4		0.1	----
Palm Beach County, FL	----		----	0.2	----		----	0.3
San Francisco Bay area	2.8		0.4	3.6	2.0		0.3	2.4
San Francisco Bay area	1.9	2.7	----	----	0.7	2.6	----	----
Austin, TX	1.5	2.4	----	----	0.3	2.0	----	----
Austin, TX	----		----	4.3	----		----	0.8
San Francisco Bay area	----		----	6.8	----		----	1.1
Orange County, CA	----		----	2.2	----		----	2.1
Portland, OR	----		----	2.1	----		----	0.5

Note. Estimates are for walking trips, unless otherwise noted.
---- Not estimated in the study
* Comparison of neighbourhoods with highest versus lowest pedestrian-friendly characteristics on percentage of combined walking/cycling trips
** Comparison of average of neighborhoods with three highest versus three lowest ratings of pedestrian-friendliness on combined estimate of walking and cycling trips.
Source: Saelens, Sallis and Frank (2003, p. 89).

The results of the 10 studies listed in Table 2.5 supported the relationship between neighbourhoods classified as walkable and higher rates of walk trips with the high walkable neighbourhood residents recording approximately 2 times more walking trips per week than the low walkable neighbourhood residents (3.1 versus 1.4 trips, Table 2.5). One limitation of these results was a lack of a common objectively consistent index of walkability to classify neighbourhoods into walkability classes.

Population density was one of the most consistently positive correlates of walking trips with the 1995 Nationwide Personal Transportation Survey (NPTS), travel by walking/cycling was approximately five times higher in the highest versus lowest density areas (Saelens, Sallis and Frank 2003). A study of 32 cities around the world revealed a positive association between city population density and the percentage of workers walking or cycling to work (Newman and Kenworthy, 1991).

Land use mix, especially the proximity of shopping, work, and other non-residential land use to housing, appears related to greater walking/cycling among residents (Saelens, Sallis and Frank 2003). All of the studies reviewed by Saelens, Sallis and Frank (2003) supported the relationship between neighbourhood environment characteristics and walking and cycling for transport. While the strength of the associations varied, it does support the importance of understanding how proximity and connectivity characteristics of urban areas impact upon walking behaviours. It was reported that residents of

the walkable neighbourhood took 1-2 more trips per week or 15-30 minutes more walking per week than residents in the low walkable neighbourhoods. Further, although all of these studies were not directly comparable, the results were remarkably consistent in reporting a positive relationship between areas with higher population density, a greater mix of land uses and a well connected street network.

Saelens, Sallis and Frank (2003) concluded that there is substantial evidence that environmental variables, whether assessed objectively or subjectively, are consistently related to physical activity and that well-specified procedures for determining walkability and neighbourhood selection are required to allow for translation across neighbourhoods and regions. The emergence of GIS as a tool to objectively collect and manage data is also listed as a area of further potential in the task of creating an index of walkability that can be applied across urban areas and allow for better comparison research on the impacts of urban form on walking behaviour. The Saelens, Sallis and Frank (2003) review was one of the first to bring the results of transport and planning research to the attention of the health professionals concerned with physical activity. While the health research is useful as context for this study, it does not provide the detailed identification of characteristics necessary for the construction of an objective index of walkability. The transport studies provide a more detailed treatment and some of the more important transport and planning studies are reviewed to list the characteristics identified with more walk or cycle behaviour.

Parsons Brinckerhoff Quade and Douglas Inc. (1993) in a report on the pedestrian environment in Oregon as part of the land use, transport and air quality (LUTRAQ) research in Portland, reported a 10% reduction in vehicle miles traveled (VMT) could be achieved with a region wide increase in the quality of the pedestrian environment. The factors they used to classify the walkability of neighbourhoods were:

- Ease of street crossing;
- Sidewalk continuity;
- Street connectivity; and
- Topography.

In a study of the differences between transit and automobile neighbourhoods, Cervero and Gorham (1995) characterised neighbourhoods as transit oriented and post war. Transit oriented neighbourhoods were pre world war two and built around transit routes, with mixed land uses. Post war neighbourhoods were basically designed around the use of the private car in the era of the freeway, conceived as discrete developments with residential areas, solely residential, industrial, solely industrial and commercial, solely commercial Cervero and Gorham (1995). The link between these discrete areas was the hierarchical road network with the limited access highway at the top and the local street epitomized by the cul-de-sac at the bottom. The road hierarchy and the cul-de-sac works for car dominated trips but fail the pedestrians; pedestrians often have to walk long distances. Thus, many modern suburbs

limit travel choice by physically designing out all but the automobile option (Cervero 1989, Beimborn et al.1991).

As the post war neighbourhoods were being classed as car friendly, older neighbourhoods were recognised as being more pedestrian friendly as they were generally of a higher density, had a greater mix of land uses and were designed around a more grided street network. These older neighbourhoods have been called traditional neighbourhoods or transit oriented development (TOD).

Cervero and Gorham (1995) studied the differences in VMT of the two neighbourhoods. This study used the following factors to classify the TOD versus the automobile neighbourhoods in Southern California:

TOD

- Initially built upon a transit line or station;
- Grided (> 50% 4 way intersections);
- Built before 1945;

Automobile

- Laid out without regard to transit, generally in areas without transit;
- Random street pattern (> 50% either 3 way or cul-de-sacs); and
- Built after 1945.

Cervero and Gorham (1995) concluded that the neighbourhood does influence commuting behaviour, specifically, the TOD areas had higher walking and bicycles trips and less people driving alone to work. Automobile neighbourhoods had higher rates of persons driving to work and lower bicycle and walk trips to work

In a later study, Cervero and Radisch (1996) compared travel choices between a pedestrian and an automobile oriented neighbourhood in San Francisco and used a more detailed set of characteristics to classify neighbourhoods. These were:

Pedestrian-oriented neighbourhoods

- Older;
- High housing density with greater number of apartments and attached housing units;
- More blocks and intersections;
- Mixed-use of land;
- Grid-like street patterning;
- More 4-way and fewer “T” intersections and cul-de-sacs;
- Traditional design qualities;
- Integrated network of sidewalks and pedestrian paths;
- Shade trees in planting strips;

Auto-oriented neighbourhood

- Post World War community;

- Lower housing density;
- Dominated by suburban tract;
- Spacious community designs/large-lot tract housing;
- Curvilinear streets;
- Wider streets;
- Sidewalks in commercial core, but sporadic elsewhere;
- Coarsely grained land-use mix;
- Very little mixing within land-use zones;
- No mixing vertically within structures;
- Poor pedestrian connections; and
- Auto-oriented retail strips and plazas.

The results from this study showed that residents in the pedestrian neighbourhoods averaged about 10% more walk trips for non-work purposes. The identification of characteristics is starting to become more detailed a move from a more general classification of older walk friendly and newer automobile friendly into a recognition of the factors that make the distinction between walk and non walk neighbourhoods.

In a 1997 study, Cervero and Kockelman continued to develop the classification and broadened the characterisation of neighbourhoods to the concept of the 3Ds, density, diversity and design. To test the relationships between the built environment and travel demand, Cervero and Kockelman (1997) used the 1996 Bay Area Travel Survey in San Francisco within the framework of the urban design philosophies of new urbanism. The aim of this

study was to identify the impact of urban design on travel choices and trips with a view to reducing motorised trips, increasing the share of non-motorised trips, reducing trip distances for motorised trips and increasing vehicle occupancy. To classify the neighbourhoods using the 3Ds, a series of sub factors were used. Cervero and Kockelman (1997) state that it is important to recognise that the 3Ds are not simple lists of factors which alone fully portray each dimension, but a series of factors which taken together more completely characterise the dimension. Further, due to extreme multicolinearity Cervero and Kockelman (1997) contended that it was futile to attempt to isolate the unique contribution of each and every variable that measures some fine aspects of the built environment. The factors used in this study included:

Density

- Population per developed acre;
- Employment per developed acre;
- Accessibility to jobs (gravity model);

Diversity

- Dissimilarity index (different land use in hectare grid cells);
- Entropy for land use in hectare grid cells;
- Vertical mixture of land uses on one parcel;
- Per developed acre intensities of land use (residential, commercial, office, industrial, institutions, parks and recreation);
- Activity centre mix – entropy of commercial land use categories computed across all activity centres within a zone;

- Proportion of activity centres with more than one category of commercial retail uses;
- Proportion of activity centres with stores classified as convenience, auto-oriented, entertainment/recreation, offices, institution, supermarkets;
- Commercial intensities measured as per developed acre rates of convenience stores, retail services, supermarkets, eateries, entertainment; auto-oriented; mixed parcels;
- Proximities to commercial-retail uses – proportion of developed acres within ¼ mile of convenience store, retail service use;
- Proportion of residential acres within ¼ mile of convenience store, retail service use;

Design

- Predominant street pattern (grid, curvilinear);
- Proportion of 4 way intersections per developed acre;
- Freeway miles within or abutting tract;
- Number of freeway under/over passes;
- Number of blocks;
- Number of cul-de-sacs;
- Average of arterial speed limits;
- Street widths;
- Pedestrian and cycling provisions – proportion of blocks with footpaths;
- Planting strips;
- Street trees;
- Overhead street lights;

- Bicycle lanes;
- Mid-block crossings;
- Proportion of crossing with signal control;
- Average of block length;
- Average of sidewalk width;
- Average distance between street lights;
- Average slope;
- Average of pedestrian green lights at signalised intersections;
- Bicycle lane per developed acre; and
- Proportion of commercial-retail and service parcels with off street parking between the store and the road, on-street front or side parking, on-site drive-ins and drive-throughs.

Results of the study lend some degree of credibility to the claims of new urbanists that compact, mixed use, pedestrian friendly design can degenerate vehicle trips, reduce VMT per capita and encourage non-motorised travel (Cervero and Kockelman 1997). The list of factors used by Cervero and Kockelman (1997) for this study is large compared with the earlier studies, and represents the recognition that the built environment is not simply characterised as walk friendly or unfriendly, but is in fact based on a large number of factors.

In a travel study of 16000 records in the Palm Beach County, Florida different neighbourhoods were tested for differences in trip frequencies, modal choices, trip chaining, trip length and overall vehicle hours of travel (Ewing,

Haliyur and Page 1996). The characteristics used to classify traditional neighbourhoods, suburban planned unit developments, and sprawling suburbs are provided in Table 2.6.

Table 2.6: Neighbourhood Characteristics.

Terms	Features
Traditional neighbourhood	Higher residential and employment density Rectilinear grided and narrow streets High residential and destination accessibility Commercial downtown area Tree-lined streets with sidewalks Nearby employment centres
Suburban planned unit development (PUD) neighbourhoods	Curvilinear streets, loop roads and cul-de-sacs High residential development Lower employment density Many collector roads with meandering sidewalks Lower destination/employment accessibility Subdivision and PUD streets Arterials Accessibility of shopping centres, schools, recreation facilities Attached and multi-family housing
Twin-strip cities	Lower destination/employment accessibility Lower employment density Streets strictly for automobiles Limited landscaping, medians, sidewalks, pedestrian amenities Limited recreation facilities Mixed land-use (residential areas running up to edges of commercial strips)
Sprawling suburbs	Low residential and employment density Large lot, single-family homes Low multi-family dwellings Limited recreation facilities Limited facilities (schools, recreation, shopping

Source: Ewing, Haliyur and Page (1996).

The results of this study were supportive of the relationship, but not as strongly as would be expected in some cases. Ewing, Haliyur and Page (1996) suggested that Americans would drive even if the trips were short and that even though the traditional neighbourhoods did reduce vehicular travel, urbanites drove a lot whether they needed to or not, and sprawl dwellers could reduce the amount of driving they did through careful trip scheduling (Ewing, Haliyur and Page 1996). The factors identified by Cervero and Kockelman (1997) are similar to those of Ewing, Haliyur and Page (1996) and are the start of a common set of factors that are used for classifying walk friendly neighbourhoods in a number of studies.

A study by Friedman, Gordon and Peers (1994) compared household travel data for the San Francisco Bay area for suburban versus traditional neighbourhoods. Like many of the transit-based research, urban form characteristics were used to identify neighbourhoods that were considered automobile dependant and those that were more transit and walk supportive. The characteristics employed in the Friedman, Gordon and Peers (1994) study are presented in Table 2.7. This study was looking to identify increased transit usage in the neotraditional neighbourhoods. The similarity of factor choice is important, with street pattern, land use mix and retail access again listed as important in classifying neighbourhoods into areas of higher walk trips and lower walk trips.

Table 2.7: Neighbourhood Delimitation.

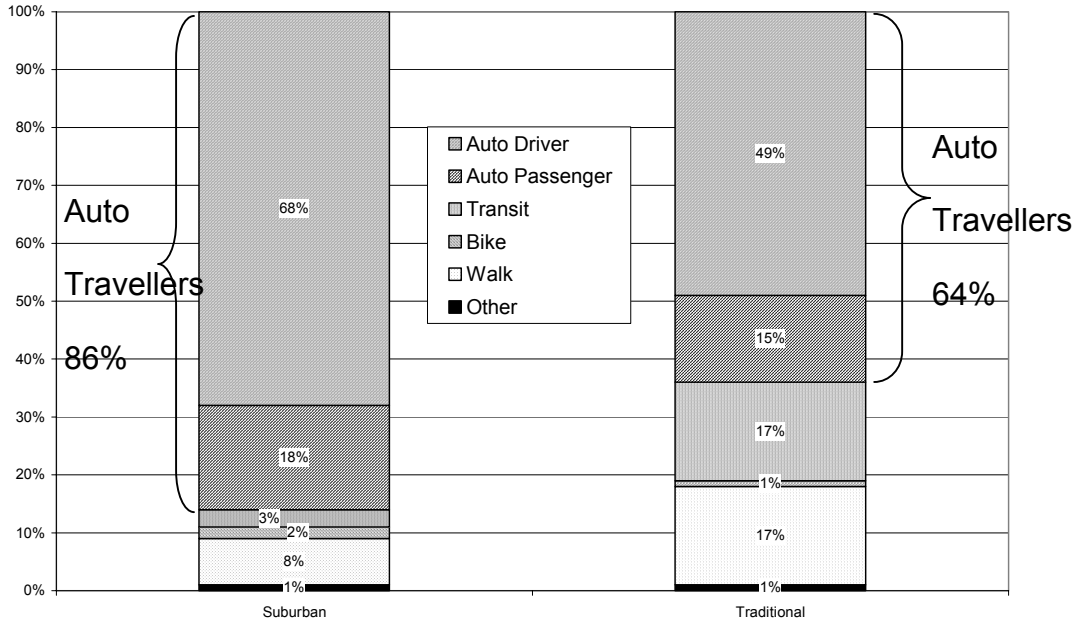
Term	Definition
Neotraditional neighbourhood design	Pre-World War II small-town development patterns A neighbourhood or town centre district with considerable pedestrian access and consisting of mixed commercial and office uses Connected grid street patterns that enhanced accessibility along alternate routes between the town centre and adjacent residential neighbourhoods Proximity between different land uses, which provided increased pedestrian access to local residents Relatively narrow residential streets with on-street parking and tree canopies Small home lots with accessible public parks and recreational areas
Standard suburban communities	Developed since the early 1950s with segregated land use (i.e. minimal pedestrian access between residential and non-residential uses) Have a well-defined hierarchy of roads Concentrate site-area access at a few key points via main arterial roadways Have relatively little transit service
Traditional communities	Mostly developed before World War II Have a mixed-use downtown commercial district with significant on-street curb-side parking Have an interconnecting street grid and residential neighbourhood in proximity to non-residential land uses

Data source for defining standard suburban and traditional communities obtained via Census tracts and zones used in The Bay Area Transportation Survey (BATS)
Source: Friedman, Gordon and Peers (1994).

The results from this study revealed significant differences with higher total trip rates and automobile trip rates for suburban communities, and higher rates of walking in neotraditional and traditional communities (Figure 2.12). It is clear from Figure 2.12, that the automobile was the dominant transport mode with 68% of trips as drivers and 86% when combined with the

automobile passengers. In the neotraditional neighbourhood, automobile travel was lower, but importantly, walking rates were much higher.

Figure 2.12: Mode Choice comparison for all trip types in San Francisco Bay Area: Representative Samples for Suburban Communities and Traditional Communities.



Source: Friedman, Gordon and Peers (1994 p. 69).

Another study that looked at neotraditional neighbourhoods and travel behaviour was Handy's (1993) analysis of San Francisco Bay resident's travel patterns. The study applied spatial measures to delineate the neighbourhoods to study. The spatial characteristics included measures similar to other studies described in this review as well as local and regional access measures for retailing. Of importance to the development of walking measures, Handy (1993) applied a range of factors for network access, these included:

- Area;
- Road miles;

- Road miles/area;
- Blocks;
- Intersections;
- Number of 3 way intersections;
- Number of 4 way intersections;
- Number of cul-de-sacs;
- Blocks per square mile;
- Intersections per square mile;
- Number of 3 way intersections per square mile;
- Number of 4 way intersections per square mile;
- Number of cul-de-sacs per square mile;
- Blocks per road mile;
- Intersections per road mile;
- Number of 3 way intersections per road mile;
- Number of 4 way intersections per road mile;
- Cul-de-sacs per road mile; and
- Percent 3 and 4 way intersections.

The importance of this work is the detailed list of factors used to quantify the street pattern, which in many of the studies is based on whether the street pattern is grided or curvilinear. Another important development in this study was the recognition of the importance of access to retail with Handy (1993) using access to retail at the local level as well as the regional level to differentiate between access and trips locally versus regionally. The study did not support the belief that neo-traditional development will reduce work trips,

but did find that neo-traditional residents were significantly more likely to make walking trips to local retail. What was not clear was whether these trips were in place of automobile or additional to automobile trips. While the results did not support the urban form influence on travel behaviour per se, it did in part, support the influence a more compact urban form has on walking behaviour.

Using a similar methodology, Handy (1996), investigated the influence of urban form on pedestrian choices in Austin neighbourhoods, classifying the neighbourhoods using measures of network connectivity, land use mix and retail access (Table 2.8). Three distinct neighbourhoods were identified for six neighbourhoods in Austin Texas. The street network was again classified using aspects of connectivity, such as:

- Street kilometres;
- Ratio of street kilometres to land area;
- Estimated street area;
- Ratio of street area to land area;
- Percent of T intersections;
- Percent of 4 way intersections;
- The ratio of intersections to street kilometres; and
- Ratio of cul-de-sacs to street kilometres.

Table 2.8: Neighbourhood Delineation Characteristics, Austin Texas.

Terms	Characteristics
Traditional neighbourhoods	Developed between 1900-1949 Located beyond the downtown area Rectilinear grids Greater number of "T" intersections as opposed to 4-way intersections Multiple bus routes Majority of neighbourhoods within 0.4km of a bus stop Narrow streets High level of shade from tree canopy Garage at back of and detached from most houses or located on a rear alley Most houses have front porches Great variation in house designs Most houses within walking distance from commercial activity Commercial development is pedestrian oriented Most commercial areas have more complete and higher-quality sidewalk infrastructure
Early-modern neighbourhoods	Developed between 1950 and 1970 Located within 3 miles of downtown Curvilinear layouts Greater number of "T" intersections as opposed to 4-way intersections Multiple bus routes Majority of neighbourhoods within 0.4km of a bus stop Narrow streets Medium level of shade from tree canopy Garage at back of and detached from most houses or located on a rear alley Medium variation in house designs Most houses within walking distance from commercial activity Commercial development is automobile oriented Commercial areas less complete and lower-quality sidewalk infrastructure
Late-modem neighbourhoods	Developed after 1970 Located 10-15 miles from downtown Combination of rectilinear grids and curvilinear layouts High ratio of cul-de-sacs to street kilometres Greater number of "T" intersections as opposed to 4-way intersections Low level of transit service Wide streets Low level of shade from tree canopy Residential sidewalk infrastructure more complete and in better condition Garage close to front of houses Limited variation in house designs Minority of houses within walking distance from commercial activity Commercial development is automobile oriented Commercial areas less complete and lower-quality sidewalk infrastructure

Source: Handy (1996).

Data from this study supported the suggestion that certain aspects of urban form can play an important role in encouraging walks to a destination, with more people walking to work and to shopping in traditional neighbourhoods than the early modern or late modern.

In a more recent study, Handy and Clifton (2001) used the Austin Texas neighbourhoods to test the strategy of providing local shopping as a means of reducing automobile trips. This study was built upon the premise that if shopping is provided locally, then residents will choose to walk to local shops rather than use the automobile. Travel choice for residents from six neighbourhoods, classified with the measures presented in Table 2.8, were investigated to determine if residents made use of the local shopping available to them. This study did support the notion that residents would walk to local shopping opportunity and that the traditional neighbourhood resident was more likely to walk to shopping. While the rates and miles saved was not high, approximately 3.4 miles saved per month, Handy and Clifton (2001) concluded it was better than nothing and while local shopping did not show great promise as a strategy for reducing automobile use, it did show promise as a strategy for enhancing quality of life in neighbourhoods, at least partly by making driving once again a matter of choice.

Kitamura, Mokhtarian and Laidet (1997) suggest the correlation between land use and travel demand is supported by ample evidence, with study after study displaying the relationship between household automobile ownership and residential density. In a study of travel patterns in five neighbourhoods in San

Francisco, Kitamura, Mokhtarian and Laidet (1997) applied high or low density, land use mix, street connectivity, business connections, topography and public transit access to classify the neighbourhoods. The study did support the association between neighbourhood characteristics and amounts of travel and modal split, but more importantly, this research continued to support the use of density, land use mix, street connectivity and access for classifying neighbourhoods.

In another land-use transport system travel behaviour study, McNally and Kulkarni (1997) applied a range of density, land use mix, connectivity and access measures to classify neighbourhoods in Orange County, California. Neighbourhoods were classified as traditional, mixed or planned unit development; the characteristics and some neighbourhood averages are presented in Table 2.9. The work of McNally and Kulkarni (1997) is valuable because it presents a classification of neighbourhoods based on a range of characteristics and the average values for these characteristics. Support for the walkability concept are provided by these measures and distinguish between areas that are automobile dependent and those that are more walking supportive. From Table 2.9, the traditional neighbourhood had, on average, half the number of cul-de-sacs, more then twice the number of four way intersections, higher density and better access to commercial and other land uses.

Table 2.9: Characteristics for Classifying Neighbourhoods.

Index	Description	Traditional	Mixed	PUD
INT1	number of cul-de-sacs	83.20	81.10	167.30
INT3	number of 3-way intersections	298.00	235.10	445.30
INT4	number of 4-way intersections	207.20	100.80	88.00
INT	total number of intersections	588.40	417,40	700.60
ENT	number of access points	56.40	39.80	17.90
ENTM	number of major access points	7.80	8.50	6,70
R-INT1'	ratio or INT1 to INT	0.14	0.20	0.24
R-INT3	ratio of INT3 to INT	0.50	0.56	0.63
R-INT4'	ratio of INT4 to INT	0.36	0.24	0.13
R-INT43	ratio of INT4 to INT3	0.77	0.45	0.31
D-INT*	intersection density (intersections/acre)	278.01	184.54	182.75
R-ENT"	ratio of ENT to development perimeter	0.47	0.39	0.10
R-ENTM	ratio of ENTM to development perimeter	0.07	0.17	0.04
SFRES	single family residential area to total area	0.16	0.22	0.10
MFRES	multi-family residential area to total area	0.14	0.16	0.16
RES	residential area to total area	0.30	0.38	0.26
MALL	shopping complex area to total area	0.00	0.02	0.00
STRIP	strip commercial area to total area	0.18	0.08	0.04
GENC	general commercial area to total area	0.04	O.05	0.03
OFFICE	office-commercial area to total area	0.03	0.04	0,06
COM*	commercial area to total area	0.25	0.18	0.14
PI	public/institutional to total area	0.09	0.14	0.12
T	transportation to total area	0.01	0.06	0.01
U	uncommitted to total area	0.14	0.04	0.32
DENS'	population density	13285.51	8292.01	4729.41
ACR	access to residential land uses	81.80	41.60	53.10
ACC	access to commercial land uses	87.00	46.60	43.40
ACO	access to other land uses	170.70	100.90	105.60
R-ACR	ratio of ACR to area	42.06	17.74	16.40
R-ACC	ratio of ACC to area	46.11	20.05	12.90
R-ACO	ratio of ACO to area	94.64	42.43	30.61

' Indicates indices used in clustering

Source: McNally and Kulkarni (1997, p. 106).

Transit oriented development is another term used for labeling neighbourhoods that are designed to integrate transport and land use. Schlossberg and Brown (2004) compared transit oriented developments (TOD) based on walkability indicators and provides further support of the use of the street network for classifying neighbourhood connectivity,

> *"In most locations, the capacity to walk is based upon the same infrastructure as the ability to drive: the street network. While not all streets include sidewalks and not all walking paths are adjacent to streets, the street network provides a reasonably comprehensive proxy for the capacity to walk within a neighbourhood. "(p.2).*

Further, although there are limitations (footpath access/provision, road widths, traffic volumes) Schlossberg and Brown (2004) contend that the street network remains the most accessible proxy data for walking in any jurisdiction and can thus provide a reasonable planning and evaluation foundation for walking studies.

In many studies, Bernick and Cervero (1997), Handy (1995) and Krizeck (2000) positive relationships between traditional neighbourhoods and walk trips were identified, therefore a walkable neighbourhood is likely to result in more walking trips (Schlossberg and Brown 2004). The measures used to classify the TODs, include block size, intersection density, route directness, land use barriers, commercial density, intensity and choice. Schlossberg and

Brown (2004), concluded that access, connectivity and choice are key elements in understanding the pedestrian environment and all can be derived using various elements of the street network.

The increasingly adverse effects of automobile use on traffic congestion and air pollution, combined with the limited financial ability to continually invest in transportation infrastructure has led to the consideration of non-transport strategies for managing and influencing travel demand (Rajamani et al. 2003). In a study for the Portland Metropolitan Area that applied composite indices such as land use mix and accessibility as well as more disaggregate measures, such as the actual land use types, Rajamani et al. (2003) assessed the impact of urban form to measure non-work trip mode choice. The land use measure in this study went beyond just an entropy measure, and suggested that actual land use mix and distribution was more informative in relation to influencing transport choices. The results indicated a clear relationship between mode choice decisions and urban form, specifically, mixed uses and higher residential densities promoted walking (Rajamani et al. 2003).

The findings of the transport oriented research have consistently identified density, proximity (land use mix and access) and connectivity as key factors in defining neighbourhoods for the purposes of research into transport planning issues. The same factors are also identified by the urban planning profession in research reports and policy guidelines as important for providing more environmentally sustainable urban areas. Jackson and Kochtitzky (n.d.) in a

report for the Centres for Disease Control and Prevention on the Impact of the Built Environment on Public Health suggested that health professionals tend to focus on influences such as poor diet or the need to exercise, but rarely do they consider less traditional factors such as housing, land use patterns, transport choices or architectural or urban design decisions as potential health hazards.

Jackson and Kochtitzky (n.d.) listed a range of public health criteria for land use and urban design from the health and quality of life perspective, including:

- Relationship between land use and air quality – respiratory health;
- Built environment (settlements, streets, open space, infrastructure) impact on physical activity;
- Impact of urban design on number of pedestrian injuries and deaths; and
- Impact land use has on water quality and incidence of disease outbreaks.

A report by Morris and Kaufman (n.d.) links New Urbanism with travel demand and reports that in the City of Portsmouth, NH Traffic/Trip Generation Survey (1991) New Urbanism neighbourhoods, when compared with Conventional neighbourhoods, generated about 57% of total vehicle miles traveled compared to Conventional suburbs and that Traditional neighbourhoods reduce peak-hour traffic by around 64-72%. The criteria for defining the New Urbanism neighbourhood included high amenity walkable mixed-use communities with higher densities, interconnected streets, viable public

transport, social diversity, cultural appropriateness and exemplary environmental management.

Another planning based report, Healthy Urban design: Maryland's Smart Codes and the Pedestrian Environment (Clifton, Livi and Harrell 2004) offers guidelines for developing healthy urban and pedestrian environments. This report makes the connection between the increases in overweight, obesity and the decline in the numbers of people who walk to work and other destinations and linked this decline with the planning profession that designed the built environment around car dominance.

While the physical activity outcomes were not part of the thinking behind Smart Growth, improvements to the pedestrian environment are gaining interest with public health researchers. Maryland legislation of 1997 (Clifton, Livi and Harrell, 2004) directs the state to target programs that are consistent with the Smart Growth tenets:

- Mixed land uses;
- Compact building design;
- Create housing opportunities and choices;
- Foster distinctive attractive communities with a strong sense of plan;
- Preserve open space, farmland, natural beauty and critical environmental areas;
- Strengthen and direct development to existing communities;
- Make development decisions predictable, fair and cost effective;

- Encourage community and stakeholder collaboration in development decisions;
- Create walkable communities; and
- Provide a variety of transport options.

Along similar lines, Grant (2004) presented a paper at the 2004 International Planning Symposium on Incentives, regulations, and Plans – the Role of States and Nation-States in Smart Growth Planning. This paper stressed that the move to segregated development, facilitated by public transport and later the automobile, led to the building of segregated residential suburbs to improve the health in cities. Further, to improve the health in cities, zoning was introduced in the 1920s to separate land uses. As a result of zoning the concept of segregated land uses was established which resulted in much of the post war urban sprawl with largely segregated enclaves of housing, zones of commercial, pods of offices and large industrial areas (Grant 2004).

There was some recognition of the problems widespread commuting was causing in the 1960-70s; action was called on to clean up the air and water, although, the influence of the built environment was not yet considered. With a dawning of the connection that urban form was one of the contributing factors in the demise of walking and the rise of the automobile trip, planners started to consider the concept of mixed land use as part of a strategy to reduce energy demands and enhance the liveability of cities (Grant 2004).

Smart Growth appeared in the late1990s and mixed use was promoted as part of the solution to better manage sprawl. The basic message for Smart Growth was to mix:

- Increasing intensity (mixing housing types);
- Increasing diversity (mix commercial with residential); and
- Integrating formerly segregated uses (light industry in residential areas).

With the growing recognition that sprawl was part of a larger problem, more researchers examined the links between urban sprawl and traffic, air pollution, central city poverty and degradation of scenic areas, Ewing, Pendall and Chen (2003). In a major study on 83 US cities Ewing, Pendall and Chen (2003) defined sprawl as low density, segregated land uses, lack of thriving central areas and limited travel choices. These characteristics were measured using these factors:

- Residential density;
- Neighbourhood land use mix;
- Strength of centres; and
- Accessibility of street network.

Ewing, Pendall and Chen (2003) also considered whether any one factor was more influential than the others and therefore should be weighted in the sprawl index, but concluded that a rational for weightings could not be found in the literature and the measures were summed.

Overall, the sprawl index displayed strong and statistically significant relationships to six outcome variables. As the index increases (sprawl decreases) average vehicle ownership, daily VMT per capita, annual traffic fatality rate and maximum ozone level decreases to a significant extent and shares of work trips by transit and walk modes increase to a significant extent. These relationships are not independent of each other, Ewing, Pendall and Chen (2003). In this study, density displayed the strongest and most significant relationship to travel and transportation outcomes, whereas, land use did not significantly affect public transportation or walk mode shares for commute trips.

In a report that moves beyond the consideration of sprawl to a more holistic view of the city, Barton (2004) writes about the anatomy of healthy cities as part of the World Health Organisation's (WHO) Healthy Cities Project. This report starts by recognising that the environment in which we live is a significant determinant of health and continues to suggest that the design and development of cities are unhealthy, cultivating the so-called diseases of civilization, Barton (2004).

Barton (2004) raises the concern that planning theory and planning education do not challenge this situation. Problems commonly identified in the World Health Organisation's (WHO) Healthy Cities Project included, traffic generation, pollution, rigid zoning, increased social polarisation, the loss of open space and the focus on short-term profits at the expense of

environmental quality. This led Barton (2004) to suggest that planning theory and current practice are largely health blind.

Within this context of cities being bad for health and a planning process that did not integrate health and transport issues, WHO started the Healthy Cities movement in the late 1980s with the aim of increasing cooperation and moving to more sustainable city development. The Healthy Cities movement is built upon the recognition that urban spatial and transport planning significantly influences the determinants of health (Duhl and Sanchez 1999). WHO advocate a series of planning objectives which consider how the propensity to exercise, especially walking is affected by transport planning and urban design, living conditions, such as equitable access to housing, services, food and work and the quality of air and water.

In a paper presented to the 14th International Pedestrian Conference, Bolder Colorado, Bradshaw (1993) proposed a rating system for classifying neighbourhood walkability. Similar to many of the studies presented above, Bradshaw's (1993) basic walkability characteristics included:

- Foot friendly – man made physical environment with sidewalks, small intersections, narrow streets, clean, good lighting and absence of obstructions;
- A full range of useful, active destinations within walking distance, shops, services, employment, professional offices, recreation, libraries etc;

- A natural environment that moderates the extremes of weather with no excessive air pollution, noise or the dirt stains and grime of motor traffic; and
- A diverse local culture that increases contact between people.

To actually measure some of these characteristics, Bradshaw (1993) included a set of quantitative measures:

- Density, persons per acre;
- Parking spaces off-street per household;
- Number of sitting spots per household;
- Chance of meeting someone while walking;
- Age child allowed to walk alone;
- Women's ranking of safety;
- Responsiveness of transit service;
- Number of neighbourhood places of significance;
- Acres of parkland; and
- Sidewalks.

In common with the plethora of studies and reports reviewed above, Bradshaw (1993) included aspects of proximity and connectivity as the factors that should be measured to delimit areas that are more walk friendly.

2.5 Factors Identified from the Literature

The epidemic of overweight and obesity in the developed countries has generated a research response in an attempt to understand the factors that have created such a major health crisis (CDC 2004; Vandegrift and Yoked 2004; ABS 2003a; AIHW 2003; Cameron et al. 2003; Contaldo and Pasanisi 2003; Mokdad et al. 2003; ABS 2002; AIHW 2002; Bauman et al. 2002; Flegal et al. 2002; Mokdad et al. 2001; Bauman, Owen and Leslie 2000; Sparling et al. 2000; Mokdad et al. 1999; ABS 1998; Heart Foundation 1996; ABS 1995). Health professionals have reported on links between sedentary lifestyles and physical inactivity and this in turn has led to more research effort into understanding why people were inactive (Bauman 2004; Brown 2004; Wendel-Vos et al. 2004; Humpel, Owen and Leslie 2002; Humpel et al. 2002; Reidpath et al. 2002; Ball et al. 2001; Owen et al. 2000; Sparling et al. 2000; Sallis, Bauman and Pratt 1998; Sallis et al. 1997). Two major areas of study were pursued, individual factors and environmental factors. It is the latter area of research that is of interest for this study, particularly the work on identifying characteristics of the environment that are correlated with physical activity, particularly walking (Vandegrift and Yoked 2004; Ewing et al. 2003; Kirtland et al. 2003; Saelens, Sallis and Frank 2003; Berrigan and Troiano 2002; Handy et al. 2002; Pikora et al. 2002; Brownson et al. 2001; Giles-Corti and Donovon 2001;Troped et al. 2001). The links between urban form and walking behaviour have become of interest to the health professional, recognising that certain characteristics of where people live may encourage or discourage walking. The complimentary research work from transportation and town

planners is of importance, as these professions have spent many years researching how the built environment influences travel choices, especially non-automobile travel (Grant 2004; Schlossberg and Brown 2004; Timmermans 2004; Ewing, Pendall and Chen 2003; Main 2003; Rajamani et al. 2003; Handy and Clifton 2001; Cervero and Kockelman 1997; Kitamura, Mokhtarian and Laidet 1997; McNally and Kulkarni 1997; Cervero and Radisch 1996; Ewing, Haliyur and Page 1996; Handy 1996; Cervero and Gorham 1995; JHK and Associates 1995; Friedman, Gordon and Peers 1994; Handy 1993; EDA Collaboration Inc. n.d.; Morris and Kaufman n.d.).

The review of literature has identified a range of characteristics that are correlated with higher rates of walking and these have been grouped as the 3Ds (Cervero and Kockelman 1997) or proximity and connectivity (Sallis et al. 2004; Saelens, Sallis & Frank. 2003; Frank and Engelke 2001). Consistently, density, land use mix, the street network and retail access are linked with definitions of neighbourhoods as either supporting walking behaviour or automobile dominated. Although there are numerous specific measures within these more broad groupings, many of the measures are repeated from one study to the next (Table 2.10). Table 2.10 does not list the individual measures used by these authors but the broad groupings. Within these broad groupings are various levels of detail used to measure the actual factors; these more detailed factors are used in Chapter 4 when designing the walkability index. The classification of factors and the positive relationship between these factors and walking behaviour identified in these studies is valuable for the current study.

Table 2.10: Factors Identified in Studies Related to Walking Behaviour.

Factors	Authors
Density: population or dwelling	Sallis et al. 2004; Timmermans 2004; Ewing, Pendall and Chen 2003; Ewing et al. 2003; Main 2003; Rajamani et al. 2003; Saelens, Sallis and Frank 2003; Saelens et al. 2002; Berrigan and Troiano 2002; Handy et al. 2002; Allan 2001; Frank and Engelke 2001; Sallis, Bauman and Pratt 1998; Cervero and Kockelman 1997; Kitamura, Mokhtarian and Laidet 1997; McNally and Kulkarni 1997; Cervero and Radisch 1996; Cervero and Gorham 1995; JHK and Associates 1995; Bradshaw 1993; Morris and Kaufman n.d.
House Age	Ewing et al.2003; Berrigan and Troiano 2002; Handy and Clifton 2001; Cervero and Gorham 1995
Land Use Mix	Grant 2004; Sallis et al. 2004; Ewing, Pendall and Chen 2003.; Ewing et al. 2003; Rajamani et al. 2003; Saelens et al. 2003; Saelens, Sallis and Frank 2003; Handy et al. 2002; Berrigan and Troiano 2002; Frank and Engelke 2001; Sallis, Bauman and Pratt 1998; Kitamura, Mokhtarian and Laidet 1997; Cervero and Gorham 1995; EDA Collaboration Inc n.d.; Jackson and Kochtitzky n.d.; Morris and Kaufman n.d.
Entropy	Timmermans 2004; Rajamani et al. 2003; Saelens et al. 2003; Cervero and Kockelman 1997
Street network	Sallis et al. 2004; Schlossberg and Brown 2004; Ewing, Pendall and Chen 2003.; Ewing et al.2003; Rajamani et al. 2003; Saelens et al. 2003; Saelens, Sallis and Frank 2003; Main 2003; Berrigan and Troiano 2002; Handy et al. 2002; Frank and Engelke 2001; Cervero and Kockelman 1997; Kitamura, Mokhtarian and Laidet 1997; McNally and Kulkarni 1997; Handy 1996; Cervero and Radisch 1996; Cervero and Gorham 1995; Friedman, Gordon and Peers 1994; Parsons Brinckerhoff Quade and Douglas Inc 1993; EDA Collaboration Inc n.d.; Jackson and Kochtitzky n.d.; Morris and Kaufman n.d.
Intersection density	Schlossberg and Brown 2004; Rajamani et al. 2003; Saelens, Sallis and Frank 2003; Handy et al. 2002; Frank and Engelke 2001; Cervero and Kockelman 1997; McNally and Kulkarni 1997; Handy 1996; Heart Foundation 1996; Handy 1993
Cul-de-sacs	Schlossberg and Brown 2004; Saelens, Sallis and Frank 2003; Handy et al. 2002; McNally and Kulkarni 1997; Heart Foundation 1996; JHK and Associates 1995
Retail	Saelens, Sallis and Frank 2003; Handy et al. 2002

Density is generally measured using either people or dwellings per gross area or as net residential area. Land use mix has used a range of mix per unit area, dissimilarity and entropy measures. The street network has created more measures, but is typically characterised using ratios of intersections to unit areas or road lengths, proportions of cul-de-sacs, three way or four way intersections to total intersections, network measures, average block lengths or street lengths. Retail access has attempted to measure distance to shopping, the ratio of retail area to parking and the orientation of parking. While this list is not exhaustive or all encompassing of the many measures reviewed above, it does present the essence of those measures that are most frequently included as part of the classification of walking supportive neighbourhoods. As part of the process of creating an objective measure of walkability, these factors are applied to this study; the methodology and results are presented in the next two chapters.

CHAPTER 3 METHODOLOGY

USING AUSTRALIAN DATA TO DERIVE A WALKABILITY INDEX

There are many environmental factors linked with walking behaviours that can be measured to classify spaces as either walk supportive or walk non-supportive. The factors linked with measuring walkability included; density, land use mix, street network and retail access (Grant 2004; Schlossberg and Brown 2004; Clifton, Livi and Harrell 2004: Handy et al. 2002; Handy and Clifton 2001; Saelens, Sallis and Frank 2003; Rajamani et al. 2003; Frank and Engelke 2001; Cervero and Kockelman 1997; Kitamura, Mokhtarian and Laidet 1997; Cervero and Radisch 1996; Handy 1996; Cervero and Gorham 1995; McNally and Kulkarni 1997; Ewing, Haliyur and Page 1996; Friedman, Gordon and Peers 1994; Bradshaw 1993; Handy 1993; and Parsons Brinckerhoff Quade and Douglas Inc. 1993). Density and land use mix have been grouped under the proximity heading and street network and retail access under the connectivity heading to simplify the relationships, these heading are applied in this research. In a number of studies there was a growing recognition that these variable were important for measuring walkability and that GIS was a useful tool for collecting, storing and analysing these data (Schlossberg and Brown 2004; Kirtland et al. 2003; Main 2003; Saelens, Sallis and Frank 2003; Handy et al. 2002; Rajamani et al. 2003; Frank and Engelke 2001; Giles-Corti and Donovon 2001; Pauleit and Duhme 2000; and McNally and Kulkarni 1997). GIS provides a methodology to

convert the potential walkability dimensions of proximity and connectivity described earlier into an objectively derived spatial index.

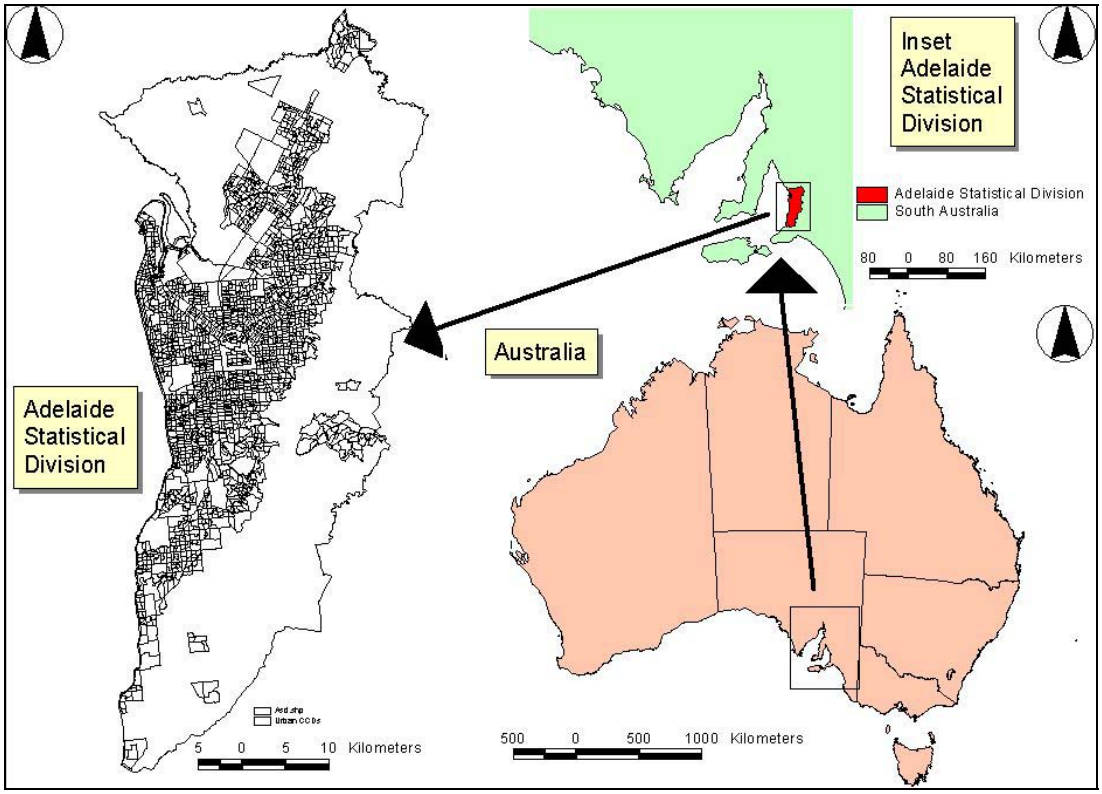
The spatial index of walkability is calculated using a range of physical characteristics identified as key variables in the transport, Smart Growth, sustainable cities and health literature (Saelens, Sallis and Frank 2003; Frank and Engelke 2001) for classifying an area into a supportive or non-supportive walk environment. In order to facilitate comparisons between research findings in Australia and the USA, this index uses measures developed in the USA modified to suit data that are readily available for Australian cities. The walkability index was created for use in the Physical Activity in Localities and Community Environments (PLACE) study, located in the Adelaide Metropolitan Area (Adelaide Statistical Division), South Australia.

3.1 Study Area

The spatial extent of the study is the Adelaide Statistical Division (ASD). The study area for this research was chosen to take advantage of the quality and availability of spatial data in South Australia. Adelaide is the capital city of South Australia and houses an estimated resident population of 1073788 people as at June 30 2001 (ABS 2003b). The ASD is approximately 1827 square kilometres and spans 85 kilometres north-south and 25 kilometres east-west (Figure 3.1).

The development of the ASD is similar to many cities in Australia and the USA, with older inner city development in the pre 1900s built upon a grid street pattern and mixed land use. Development over the next 100 years has been mainly lateral, involving a low density spread to the fringe areas. The urban form reflects the changing planning paradigms of this period, with an increasing separation of land use, a more curvilinear street pattern and increasing use of the cul-de-sacs.

Figure 3.1: Adelaide Study Area



Source: ABS, ASGC 2001.

The town planners are now looking to the earlier pattern of urban form for design inspiration and are curbing fringe urban growth for inner redevelopment in an attempt to cut infrastructure expenditure (Handy and Clifton 2001; Cervero and Kockelman 1997; Cervero and Radisch 1996;

Ewing, Haliyur and Page 1996; Handy 1996; Cervero and Gorham 1995; Handy 1993; Parsons Brinckerhoff Quade and Douglas Inc. 1993). In parallel with this change, health researchers are looking at how the environment is influencing physical activity levels (Berrigan and Troiano 2002; Handy et al. 2002, Handy and Clifton 2001; Humpel, Owen and Leslie 2002; Handy 1996; Handy 1993; Morris and Kaufman n.d.; Jackson and Kochtitzky n.d.) and research suggests that the older pattern of urban form was more conducive to levels of walking activity. The importance of different development paradigms on urban form, such as pre world war two, traditional neighbourhoods, transit oriented developments, automobile dominated neighbourhoods were described in more detail earlier and forms part of the selection rationale for the choice of the ASD for this study as the different development paradigms provide areas, which are considered as either supportive or non-supportive of walking behaviours. The walkability index will measure the physical attributes and classify areas into low through to high walkability.

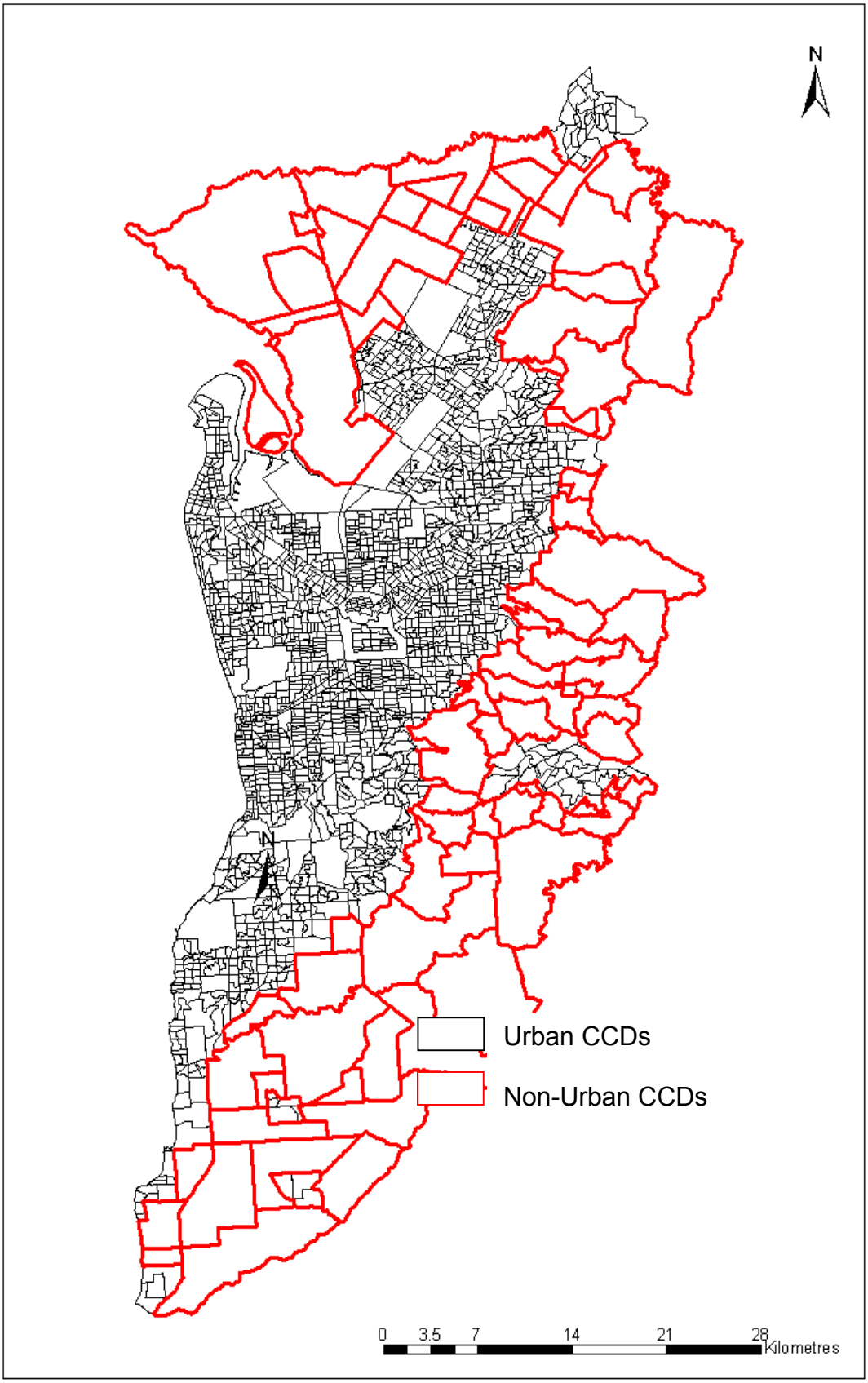
3.2 Spatial Units

Since there is a considerable amount of environmental variation within cities, any attempt to build a measure that classifies urban form should work with the most detailed spatial units available. The use of larger less detailed spatial units will encompass more variation in the identified factors used to construct the walkability index, dilute the index scores and seriously hamper the study objective. As this research is building a measure that is repeatable for Australian Cities, and population characteristics are part of the research

design, it follows that it is appropriate to use the smallest spatial unit for which population census data are made available. Unit record level data are not provided by the ABS and spatial aggregation is used by the ABS to preserve individual privacy. Consequently, the smallest spatial data unit available in Australia is the Australian Bureau of Statistics Census Collection District (CCD). The CCD is designed to provide a complete coverage of Australia without omission or overlap (ABS 2001). At the 2001 Census there was an average of around 225 dwellings in each CCD, but in rural areas the number of dwellings per CCD decline as population densities decrease. The areal size also increases as the population density decreases. In 2001, there were 37,209 CCDs across Australia, covering the entire landmass without overlap or omission. Even though the CCD is a basic unit, CCDs differ considerably in both size and population, especially between urban and regional areas.

In the Adelaide Statistical Division, there were 2150 CCDs at the 30 June 2001. To remove the influence of size and population variation in CCDs, the Adelaide Statistical Division CCD layer was filtered to include only urban CCDs to remove the influence that larger, sparsely populated CCDs would have upon the classification and analysis of walkability (Figure 3.2). This was based upon the ABS definition of urban CCDs, which have a population density of greater than 200 persons per square kilometre and are adjacent or proximal to other urban CCDs (ABS 2001). The walk index will use the CCDs as at June 30 2001, and therefore the other data used in this index are based upon this reference date.

Figure 3.2: Urban and Non-Urban CCDs, Adelaide Study Area



Source: ABS ASGC 2001.

3.3 Spatial Datasets

Six spatial data sets were used to create the ASD walkability index based upon the identified concepts of proximity and connectivity. The ABS and Planning SA provided these data sets which are described below, followed by a more detailed section on the processing of each element in the walk index.

The main data sets for this research are:

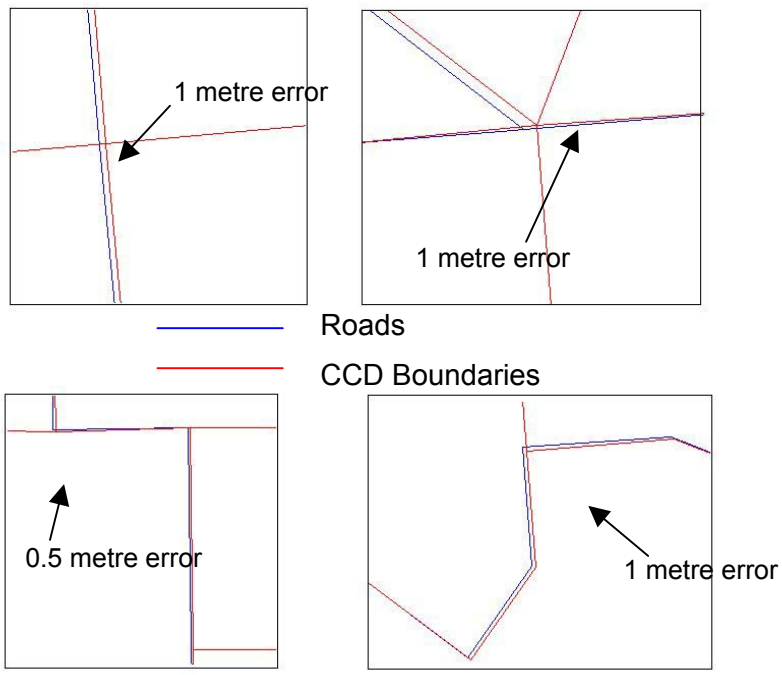
- Spatial Building Block
  - ABS 2001 Urban Census Collection District;
- Proximity
  - Digital Cadastral Data Base (DCDB);
  - Land Ownership and Tenure System (LOTS);
  - Land use;
  - Zoning;
  - Adelaide Retail Database; and
- Connectivity
  - Road centre line data.

3.3.1 Spatial Building Blocks

The ABS CCD form the building blocks for the walk index, and as stated above are confined to only those CCDs identified as urban at the 2001 census. Of the 2150 CCDs in the ASD, 2078 are classified as urban (Figure

3.2). It must be stressed, that a number of CCDs were included in this data set with very few dwellings and these are also filtered from the final set as these are potentially misleading, for example the Adelaide Parklands and the Adelaide Airport. The final number of CCDs is 2053. One problem when working with the ABS CCD is the lower level of spatial accuracy when compared with the other data sets and even though the spatial accuracy of the CCD was improved from previous censuses, it was still up to several metres different to the road centre line data (Figure 3.3). This is significant because the ABS incorporate the road centre line, as one of the key design parameters when creating the CCD unit and therefore the two data sets should be spatially coincident. However, this was not the case and the processing of the data was modified to overcome the error (see Section 3.5).

Figure 3.3: Road Centre Line and CCD Boundary Errors, ASD.



Source: ABS ASGC 2001; Road Centrelines, Planning SA.

3.3.2 Proximity Data

The key data here are the DCDB and LOTS as these data provide a detailed parcel based record of all land ownership in the ASD with attributes pertaining to land area, land use, dwelling age and site and capital value among many others. The DCDB covers all of South Australia and provides unit record level data for land use and ownership which enables a very detailed spatial scale for compiling the dwelling density and land use mix data for this project. In addition, Planning SA uses these data sets to derive a dwelling count for all residential land use and a primary land use classification for each parcel. This is significant because the DCDB and LOTS in their own right do not readily provide these outcomes. Historically, these two data sets were established for different purposes and were not designed to work together (Barnes, 1989). As a result, the data do not match on a one-to-one basis (i.e., one parcel of land equals one LOTS record). The actual situation with these two data sets is a relationship, which can be one-to-one, one-to-many, many-to-many and many-to-one. These situations reflect typical ownership outcomes such as two land parcels with one owner, one land parcel with two (or more) owners (a block of flats) and ownerships which due to size and location can have more than one land use as is common with commercial or industrial uses.

Examples of these outcomes are provided in more detail below. The importance of the processing done by Planning SA on these data serves two purposes. First and most importantly, the data have been validated by Planning SA and therefore can be used in the walk measure with a high level

of confidence. Second, as this processing has already been completed it reduces the time required to develop the walk index. These data are used to derive dwelling numbers, residential land area and land use for each CCD in the ASD.

Land use is derived from the Planning SA principal land use data set, based upon the primary land use, usually based upon parcel size. However, the LOTS data is designed as a vehicle to administer land tax and the land use classification is built by the valuation profession and does not match a land use planner's view of land use. The most problematic difference is the use of "vacant" as a land use; there is not an equivalent category in land use planning. In a land tax environment, a vacant land parcel will not result in a significant land tax and therefore it is relevant to maintain this class in the classification.

Land use planners use zoning as a means of controlling the way land is used and the underlying land zone is important as this controls what can occur on the land and in the case of vacant, land will be identified to be used as residential or industrial etc. Therefore, both land use and zoning are used to derive a measure of land use mix, based on the distribution of land uses grouped into five broad classes (residential, commercial, industrial, recreation and other) for each CCD.

The final proximity measure identified in the literature and included in this walkability index is a retail opportunity, which measures the difference

between site area and retail area. Planning SA has been collecting retail activity as a spatial data base since 1993 and this data set is the basis for this measure. The coverage of the Retail Data Base is land that is used for retail (DCDB-LOTS derived) or any land zoned for retail (Planning SA zoning data), where a cluster of three or more shops occurs or where one shop is larger than 250 square metres. A survey team visits each identified centre to record the retail activity and measure the gross retail floor space. This data set was last updated in 1998 and does not match the 2001 CCD data but as this level of data does not exist elsewhere and could not be derived from any other source it was the only option available to derive the retail measure.

3.3.3 Connectivity Data

The South Australian Department of Transport road centre line data was used to derive the street connectivity measure for each CCD. Street length is part of the data set, but intersections are not included and therefore were derived using the ESRI topology model (ESRI 1990). The processing of intersections is described later. The main issue with the road data as stated above was the problems associated with working with data of different spatial accuracy.

3.4 Walk Index Measures

The six data sets described above were used to derive five measures that were combined to create an index of walkability. These measures and the

processing required to create these measure are presented in the next section.

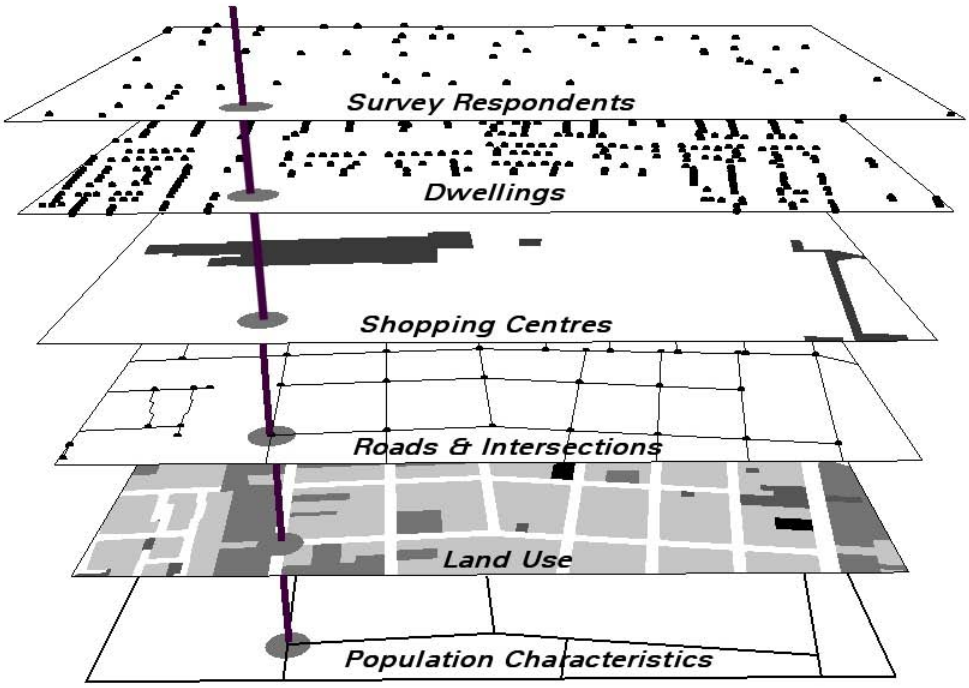
3.4.1 Spatial Building Blocks

The CCD is the spatial building block for the walk index and therefore each of the walk measures are extracted for each urban CCD. The CCD is an area based spatial unit usually termed a polygon theme and defined as a many-sided, closed figure, defined by a series of arcs comprising its border (ESRI 1999). The CCD polygon unit is then used to select all of the spatial features of the data themes listed in Section 3.3. As this research uses GIS as the tool for creating the walk index and space is the essential element, it is important to understand how the spatial selection process works.

There are two key elements, first the use of the polygon's centre point (centroid) and second, the different methods of space on space selections. With the exception of the road centre line data, all the data used for the walk measures are polygon themes, representing the actual spatial boundary upon the earth's surface of the different spatial themes. The centroid of a polygon (it's centre of mass) is calculated by defining a minimum bounding rectangle. This is a rectangle, which would completely contain the polygon and then uses geometric rules to calculate the centre of the rectangle. The centroid is a system derived feature and does not require any additional steps by the user, however it is still important to understand what it is and how it can be used.

Spatial selection is unique to GIS and provides a means for using one spatial element to select another spatial element. In a traditional data selection environment, different data tables can be used for selecting if both tables contain a matching unique identifying field. In GIS, different data sets can be selected because they share the same location, therefore a spatial element in one theme (the CCD) can be used to select the features of another theme (dwellings for example) (Figure 3.4).

Figure 3.4: Spatial Arrangement Using GIS.



Selection rules in GIS can use several concepts, the spatial selection methods include (ESRI 1999):

- Are Completely Within selects features in the walk index themes if they fall completely within one or more of the CCD features;
- Completely Contain selects features in the walk index themes that completely contain one or more of the CCD features;
- Have their Center In selects features in the walk index themes if their center falls inside the CCD features;
- Contain the Center Of selects features in the walk index themes that contain the center of one or more of the CCD features;
- Intersect selects features in the walk index themes that intersect the features in the CCD features. Intersection implies that at least one point is common to both the CCD and the walk index themes or one of them is completely within the other. If the CCD and walk index themes are the same, Intersect will select adjacent features; and
- Are Within Distance Of selects features in the walk index themes that are within a specified distance of the CCD features.

Two of these selection methods are used in the processing for the walk index measures, these are:

- Have Their Centre In; and
- Within Distance Of.

These methods are used to create the data sets, the first selects features based upon having their centre in the CCD theme and the second method selects the walk index measures if they are within ten metres of each CCD boundary. The second selection method is based upon a fuzzy boundary

concept that recognises that road intersections, for example, at or near the boundary the CCD boundary are just as likely be part of the adjacent CCDs as the selection CCD. These measures and the processing required to create these measure are presented in the next section.

3.4.2 Dwelling Density

The dwelling density measure includes both a gross dwelling density and a net residential density. In the first case, the number of dwellings is divided by the total area of each CCD.

EQ 1 Dwelling Density = D_i/A_i

Where D = dwelling count for each CCD

A = area for each CCD

To calculate net residential density, the dwelling count is divided by residential land area in each CCD.

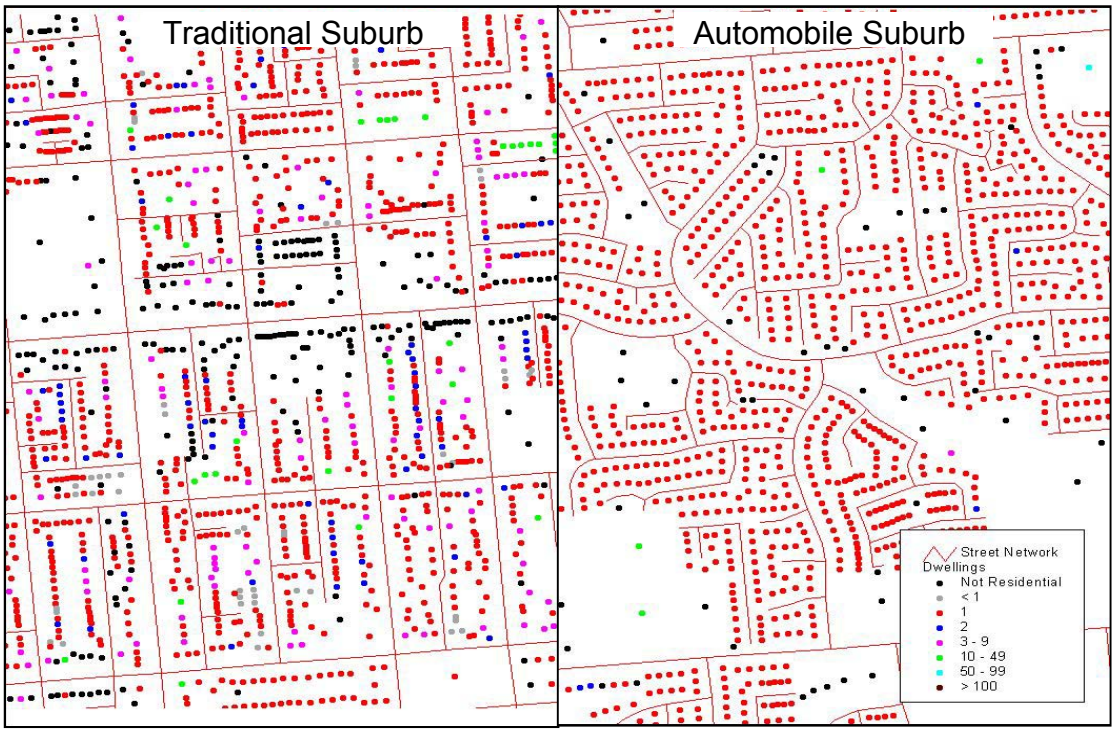
EQ 2 Net Dwelling Density = Di/RAi

Where D = dwelling count for each CCD

RA = residential area for each CCD

The dwelling count for each CCD is taken from the Planning SA dwelling count data. Each year, Planning SA obtains an extract of the DCDB and a linked LOTS valuation file as at the 30th June. Once these files have been validated and the table links verified, Planning SA run a routine, which calculates the number of dwellings for each parcel in the DCDB. Due to the complexity of relationships between DCDB and LOTS, the dwelling count per parcel can be less than one, one and more than one. In the first case, less than one will occur when the property owner(s) have more than one parcel but only one dwelling. In a case such as this, with two parcels for example, and one dwelling, the dwelling count for each parcel will be 0.5. In the one-parcel to one-dwelling situation the dwelling count will be 1. In the third instance, more than one dwelling is recorded at the parcel level (such as occurs in a block of flats) and the resulting count will be the sum of dwellings on the parcel. The result is a point spatial theme with an associated dwelling count value for each parcel. The dwelling count is constructed to ensure that when summing the dwelling count to various spatial units such as the CCD the result will not double count the dwellings (Figure 3.5).

Figure 3.5: Dwelling Count, Traditional and Automobile Suburbs, Adelaide.



Source: DCDB-LOTS.

The dwelling count in Figure 3.5 demonstrates the variation in dwelling density in the two suburb types, as the traditional suburb has more multi-dwellings and non-residential land uses, whereas the automobile suburb is dominated by single dwellings with very few non-residential land uses.

To provide a CCD level dwelling count, an avenue program was written to process the dwelling data. The Avenue program is included in Appendix 1. The logic of the routine is as follows.

For each CCD in the selected theme, select all features of the target theme (dwelling theme in this case) where the centroid is within the selected CCD. Add to the selected set all dwellings where the centroid is within ten metres of the selected CCD. Write to a new file, the CCD code (the ABS unique

identifier for the CCD, every CCD in Australia has a unique 7 digit code), the CCD area, the dwelling count and the dwelling parcel area. Repeat this for all CCDs in the urban CCD theme. Even though the routine works only on the urban CCDs, the dwelling data theme includes dwellings for all of the ASD, in this way the CCDs on the fringe of the urban set select those records immediately adjacent the urban CCDs but not actually part of the urban CCD area (see Appendix 1 for detailed code).

Once the new file is written, the file is imported to an access database for final processing. Processing involves calculating both the net and gross dwelling density for all urban CCDs. The results of the database calculations were exported as a table with dwelling count, area and density measures by CCD code (the unique identifier for each CCD). This table is joined to the CCD polygon theme to create a new CCD with dwelling density theme.

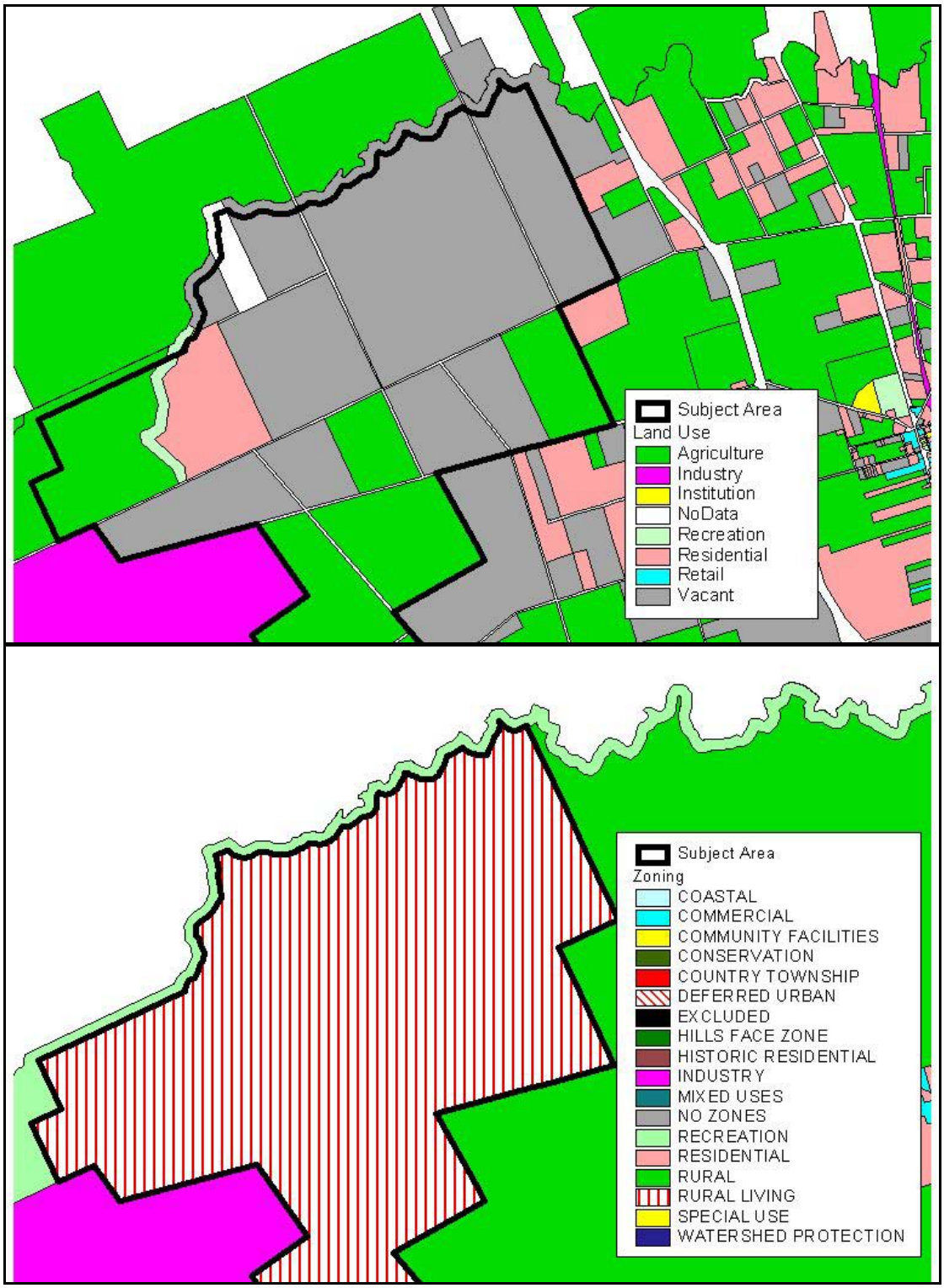
To compare the results of the five walk index measures, a means of standardisation was required. The method applied was to classify the new density measures into deciles, which are then recoded from 1 to 10, with the 1st decile value CCDs recoded to 1, the 2nd decile CCDs recoded to 2 and so on to the 10th decile that is recoded to 10. The dwelling density measure is now ready to be included in the walkability index.

3.4.3 Land Use Mix

The land use measure is the most complex to create and calculate, and uses two data sets, land-use and zoning. As stated earlier, the primary land use data set is created by Planning SA and is based upon the Valuer-General's valuation database for South Australia. Land use is based upon a valuer's view of the actual activity from a land tax viewpoint. Zoning is the local government means of controlling the use of land. Both data sets provide a means of establishing the land use or intended land use of land parcels in the ASD.

In the land use classification it is valid to have vacant land and these areas can be large areas that can encompass many land use zones. When calculating the land use measure, the large vacant areas could skew the measure and therefore, the underlying zoning was applied to reclassify the vacant areas (Figure 3.6).

Figure 3.6: Land Use and Zoning, Adelaide



Source: Land Use and Zoning, Planning SA.

As is evident from Figure 3.6, the subject area is largely vacant land use, but rural living (predominantly) zoning. To overcome the vacant land problem, the underlying land use zone is substituted and becomes the basis for determining land use. A spatial union of the land use theme with the land use zone theme achieves this. For those parcels with a vacant land use, the land use zone is used in place of the vacant class. Once the vacant land is replaced with a land use zone, the land uses are reclassified into the following five classes, residential, commercial, industrial, recreation and other (for a list of all the land uses and the classification see Appendix 2).

The Avenue routine detailed above is repeated for the land use measures and selects the output data set. The output file includes the selected CCD code, land use and land area. This files is imported to the access database for processing.

Land use, unlike the other walk index data, is not a single measure but an indication of the heterogeneity (or diversity) of land use mix in each CCD. Measurements of diversity are often applied in demographic analysis and include the entropy index and the interaction index. The entropy index uses the following formula, where k is the category of land use and N is the number of land use categories and P is the percent of each land use in the CCD:

EQ 3 $$\frac{\sum_k \left(p_k \ln p_k\right)}{\ln N}$$

The entropy equation results in a score of 0 to1, with 0 representing homogeneity (all land uses are of a single type), and 1 representing heterogeneity (the developed area is evenly distributed among all land use categories).

The interaction index, also known as the Simpson index in biology (Plane and Rogerson, 1994), use the formula, where k is the category of land use and N is the number of land use categories:

EQ 4 $$S = 1 - \sum_{K=1}^{n} (Pk / P)2$$

Once the diversity values are calculated for each CCD the resulting table is joined to the CCD theme and classified into deciles as detailed above.

3.4.4 Retail Opportunity

Net retail area poses the most difficulty in an Australian context, as there is no standard retail data set available for all capital cities. The Planning SA Retail Data Base provides a suitable data set for the ASD study area, although the data are not the same year as the other data. The Retail Data Base is a collection of all retail activity in centres with three or more shops or a single shop 250 square metres or larger. Field survey teams visit all centres and measure the gross retail area[2], the parcel area, retail activity and a range of

[2] Total gross floor area of the retail premise.

other data. It is the gross retail area and the parcel area that are used in this measure as a simple ratio.

EQ 5 $NRA = GRA / P$

Where GRA = gross retail area

P = total retail parcel area

The Avenue routine is used to create the data extract, which includes the CCD code, centre code (a unique centre code identifier), centre area and gross retail floor space. The output table is imported to the access database and processed. The resultant net retail area is joined to the CCD theme, classified into deciles and recoded 1 (1st decile) to 10 (10th decile).

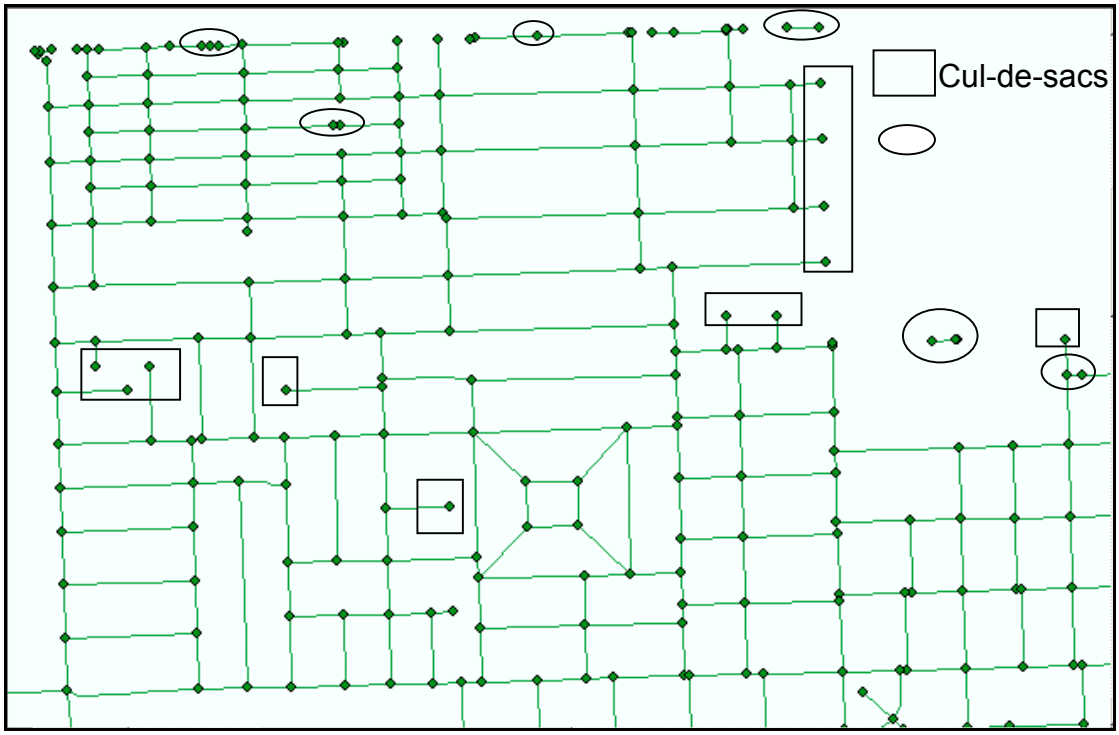
3.4.5 Road Length and Intersection Density

While the road centre line data set provides the road length data, intersections are not included and therefore a new spatial layer was created using the Environmental Systems Research Institute (ESRI 1990) model of topology. Topology was the model created by ESRI to model the spatial relationship of features within and between features in ESRI's ArcInfo GIS software. The model for within theme spatial relationships is termed topology and is built from points (termed nodes), arcs (or lines) and the way these features combine to form point, line or polygon spatial data. The topological model for a line network will create a node at any point in a line theme where a line is intersected (or crossed) by another line. Therefore, to create the intersection theme, the nodepoint process was run on the road centre line theme to create

a new point based theme with a point wherever one line intersected another line. This process resulted in 52347 nodes or intersections in the ASD. However, not all the nodes are true intersections, some nodes will be created at the end of a line and others where a line changes direction (Figure 3.7). These nodes or pseudo-nodes were culled from the final dataset using the psuedonode routine (unsplit) provided by ESRI.

After processing for the psuedonodes, the intersection theme was reduced by 5200 nodes (intersections). As is evident from Figure 3.8, there are still nodes, which occur at the end of roads, essentially the cul-de-sacs. The process of creating the nodes or intersections does not identify the number of links or directions of travel associated with each intersection so further processing was required to identify the number of arcs at each intersection.

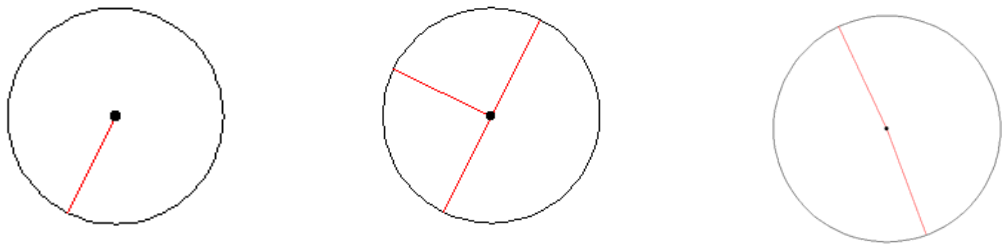
Figure 3.7: Nodes and Pseudonodes, Adelaide Street Network.



Source: Road Centrelines, Planning SA.

The logic for intersection arcs was to buffer each intersection with a 0.5 metre circle (buffer) around every intersection (node) and clip the road theme with the 0.5 metre buffer polygon. The outcome is a buffer polygon with the arcs (roads) that are part of each intersection (Figure 3.8).

Figure 3.8: Node Buffers for Allocating Directions of Travel.



Source: Road Centrelines, Planning SA.

This procedure allows the identification of the number of connections at each intersection. By counting the arcs by each buffer (or node intersection), those with only one arc can be identified, end of arc nodes. Also, by using the road name, those nodes that are not true intersections but change of road directions can be identified, as the road name is duplicated. Once identified the nodes are deleted from the final intersection layer. Once the pseudo-nodes are identified and removed, the final intersection point layer is created.

The number of arcs is counted for each intersection and the number of potential directions of travel added to each intersection, including the cul-de-sacs. The selection of the intersections and roads is then processed using the Avenue routine for the CCD theme. The output file includes the CD code, road lengths, road_id, intersection code, and direction count per intersection. The output table is imported to the access database and the road length and intersection density measures calculated. Density is calculated as the number of intersections by the area of the CCD. Road length per CCD is also calculated. A number of variants are created for testing, including the number of cul-de-sacs, intersections weighted by the number of directions of travel and road length divided by intersection count. The resulting table is joined to the CCD theme and classified into deciles and recoded as described in the previous section to provide a standard measure across the walk index variables.

Another set of connectivity measures are sourced from transport geography, transport planning, civil engineering and transport economics (Chou 1997) network analysis. There are several connectivity measures used in transport network analysis, including the γ index, connectivity, max routes, minimum routes and the gamma index (Chou 1997; Plane and Rogerson 1994). These are presented below.

The γ is the ratio of actual links to the maximum number of links possible in the network and is expressed as:

EQ 6 $$\gamma = \frac{l}{3(n - 2)}$$

where l = the number of links in a network

n = the number of nodes

Values range from 0 or a simple network with few links to 1 or a connected network with more links (Chou 1997).

The maximum number of routes:

EQ 7 $M = (n \times n - n)/2$

Where n= intersections

Connectivity measure:

EQ 8 $= r / M$

Where r = routes

M = maximum number of routes (EQ 7)

Minimum connectivity:

EQ 9 $m = 2 / n$

Where n = nodes

Gamma index, or the amount of connection within a network:

EQ 10 Equation Gamma index = (r/(3(n-2)))*100

Eta index, or the coverage of a network. Typically, a high Eta value indicates very little coverage and a low Eta value the greater the network coverage.

EQ 11 $Eta = r / L$

Where L = the total mileage of the network

r = the number of routes (EQ 7)

The variables required for the network measures were collected as part of the CCD streets and intersections data described above. Those that were additional, routes and links were collected using the same avenue routine and the fields written to the file were CD code, arc_id, arc length and street name. Routes are counted by dissolving on street name by CCD, in this way all links are combined to form a single route. The output table is imported to the access database and the network measures calculated.

Table 3.1 summarises and illustrates the types of measures used to create the walkability index.

Table 3.1: Walkability Variables.

Proximity	
Density	Dwellings by gross CCD area Dwellings by net residential area
Land Use Mix	Entropy
	Simpson Index
Connectivity	
Network	Intersections density by gross CCD area Intersections density > 3 directions by gross CCD area Total directions of travel per CCD Intersections density, cul-de-sacs by gross CCD area Route density by gross CCD area Maximum number of routes Connectivity measure Gamma index Eta index
Access	
Retail	Gross retail space by total parcel area

3.5 Creating the Walkability Index

The walkability index is calculated using the above data sets. The 1-10 score for each measure (dwelling density, intersection density, land use and net retail area) is summed for each CCD resulting in a possible score of 4 to 40. The resulting walkability index is further classified into quartiles with the 1st quartile used to identify low walkability CCDs and the 4th quartile identifying high walkability CCDs. The final walkability index is mapped using GIS to visually identify areas in Adelaide that are conducive or not to walking activities and presented in the next section.

3.6 Survey

The Walkability index detailed in this thesis was created for the PLACE research as a means of identifying areas to target for a questionnaire to test whether the physical environment was influencing physical activity. The walk index was the first task, those CCDs in the 1st and 4th quartile were further classified into high and low socio-economic status (SES). The importance of the census CD as the spatial building block is the range of census characteristics available to identify the high and low SES CCDs. The main census variables used to stratify SES were:

- Individual weekly income
- Household weekly income: and
- Labour force status.

Property valuations from the DCDB-LOTS data were also used to adjust this SES categorisation since some districts can be income poor but asset rich and some CCD were excluded on this latter basis. A further filter was added to the CCD walk index in an aim to identify comparable distributions of population by age group as the survey included adults, aged between 20 and 65, who resided in private dwellings such as houses, flats or units. Residents of group-living establishments like hotels, nursing homes, hostels and military barracks were excluded. Once the walk index and SES filters had been applied to the 1st and 4th quartile CCDs, 32 communities were identified representing the different combinations of high and low Walkability and SES, there were:

- High walk - high SES;
- High walk - low SES;
- Low walk – high SES; and
- Low walk – low SES.

A total of 156 CCDs were selected from the 2078 urban CCDs and an address list created using the LOTS data. Simple random sampling was used to select households from the address list for each community. The survey aimed to recruit approximately 2400 residents aged between 20 and 65 from the 32 communities, with a target of 75 for each community (75 X 32 = 2,400).

The survey was designed to use a mail out methodology with questionnaires mailed to eligible participants with a six-month interval between the first and

second questionnaire. The recruitment phase of the survey was carried out over the period July 2003 to June 2004. In total, 2652 eligible participants returned the Survey 1 questionnaire. Although five individual communities were slightly short of the target, all four quadrants achieved their target of 600 participants. The overall response rate was 11.5%, ranging from 10.5% in both of the low SES quadrants to 12.8% in the high walkable, high SES quadrant. The results from the survey will be used in the next phase of the PLACE research to further test the index of Walkability in terms of how respondents perceive their communities level of Walkability and against reported levels of physical activity.