Evidence review

Increasing density in Australia:
maximising the health benefits and minimising harm

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Executive summary

The debate about density in Australia exists in a context of increasing pressures on population growth and fuel prices; growing recognition of the need to increase public transport, conserve the natural environment and reduce carbon emissions; and the need for preservation of arable agricultural land to retain Australia's food security. Confronted by the potential for rapid population growth in the next four decades, state and federal governments are recognising the need to rethink the way populations are housed and mobilised.

The rationale for shifting from low-density cities

From a public health perspective, it has long been acknowledged that the living conditions in cities and the health outcomes of their inhabitants are interrelated. The mass movement of people to cities in the 19th century spurred the first Public Health Act in the United Kingdom (UK). More recently, evidence shows that compact cities have the potential to promote physical activity by encouraging more walking, cycling and public transport use, and to decrease sedentary behaviour. Conversely, suburban sprawl is associated with less walking, more sedentary behaviour and increased vehicle miles travelled. This, in turn, contributes to the burgeoning obesity prevalence, particularly for drivers. Walkability and the development of more accessible communities are also vital ingredients in sustainability because they decrease the reliance on motor vehicles.

Urban and transport planners have attempted to categorise the urban design features required to encourage more walking, cycling and public transport use into the five 'D's: density, diversity, design, distance to transit and destination accessibility.[1,2] At the top of the list is density. Without a minimum threshold of population density, public transport and local shops and services are not viable, nor are there sufficient populations to create vibrant local communities.

From a health and sustainability perspective, the need to increase population densities seems inevitable. However, as a shift occurs from single residential development to higher density development, it is timely to consider how to maximise the benefits of increased population density while minimising any harm.

Purpose of this report

The National Heart Foundation of Australia commissioned the University of Western Australia's Centre for the Built Environment and Health to conduct a literature review into the impact of density on health. The review addressed:

- the intended and unintended consequences of increased density
- the meaning of 'good' density from a health and active living perspective; and
- the types of amenity associated with positive health and physical activity outcomes in areas of high residential density.

What is density?

Density is a complex concept. It is defined in numerous ways globally and differently by various disciplines.[3] In simple terms, density is the number of units (e.g. people, dwellings, employees, trees) per unit of land area.

What is the impact of density on health?

The review considered the impact of density on a range of health outcomes and across the life course, including physical activity, cardiovascular and cancer mortality, road traffic mortality, respiratory health, and mental health.

The impact of density on physical activity

A strong body of evidence confirms the association between higher residential density (and the associated mixed land uses) and increased transport walking across all age groups.[4-27] The association is particularly evident in adult populations. Moreover, living closer to shops and services is a consistent predictor of walking, both for transport and recreational purposes, for all age groups.[2,4-9,11,19,20,28-38] One limitation of the evidence examining residential density and walking is that most studies are cross-sectional, so causality cannot be determined. However, despite limited causal evidence, several major international health and transport agencies agree there is sufficient evidence to warrant actions aimed at improving the built environment to promote physical activity, particularly active transport.[39-41]

The impact of density on mortality

All-cause mortality: There was little clear evidence that increasing population or dwelling density *per se* was associated with increased all-cause mortality, although there was some evidence of a positive association between density and mortality in some sub-groups (i.e. older adults) that cannot be ignored.[42]

Although the evidence is limited, access to green space in high-density cities may be protective of the development of risk factors in older age, either because it is restorative or provides opportunities for recreational walks.[43]

The relationship between crowding and mortality was more consistent, regardless of whether crowding was measured by persons per room or the number of housing units per structure.[44,45] Notably however, this was not the case for population density.[44,46,47]

Cardiovascular mortality: Increased density appears to be protective for cardiovascular disease (CVD) through its impact on CVD risk factors (i.e. physical activity [principally through transport walking],[39] decreased sedentary behaviour,[48,49] obesity levels,[50,51] and lower blood pressure[52-54]). However, the evidence in terms of the incidence of CVD and CVD mortality is inconsistent as it is difficult to separate the impact of density from issues related to socioeconomic status (SES).[54,55] Another confounding issue is the location of higher density housing. A meta-analysis found CVD was consistently associated with exposure to

environmental stressors such as air pollution and traffic.[56] Thus, higher density housing located on roads with heavy traffic, may increase the risk of CVD.

Cancer mortality: A small number of studies have found positive relationships between total cancer mortality and colon cancer, and population density, for both males and females.[57,58] A positive relationship has also been identified between breast cancer in women and population density. However, in these studies there has been inadequate adjustment for known confounders, such as SES. Despite the limitations of evidence based on ecological studies, it is plausible that urban living could contribute to the aetiology of cancer by increasing exposure to environmental agents, such as air pollution, and negatively influencing lifestyle risk factors for cancer, such as fruit, vegetable and red meat intake, physical activity and smoking. For example, although walking is beneficial for cardiovascular health, there is evidence that for specific cancers (e.g. colon cancer),[59] a higher volume and intensity of physical activity is required. Thus, in highly urbanised environments, there is a need for sufficient access to recreational facilities or cycling infrastructure to encourage participation in more vigorous physical activities or cycling. There is also a need for sources of affordable, fresh and healthy food and to minimise exposure to harmful pollutants.

Road traffic mortality: Studies consistently show an inverse relationship between the level of density and road traffic mortality.[55,60-62] However, few of the reviewed studies focused specifically on intra-urban difference. In sprawling metropolitan areas, more time is spent in vehicles and more vehicle miles are travelled than in denser cities. In denser cities, trip distances are shorter and there is a greater reliance on walking and public transport. This fact is highlighted by a study of cities in the United States (US) that found lower automobile fatality rates (excluding pedestrians) in denser cities compared with sprawling cities.[63] It is plausible that in higher density neighbourhoods trips are shorter and traffic travels at slower speeds. However, in higher density environments with local shops and services, there are likely to be more pedestrians and cyclists circulating (including children and adolescents), which could potentially increase the risk of injury. A number of neighbourhood features appear to increase the risk of pedestrian injuries, particularly for children,[63] including:

- high traffic speeds and volumes

- high density of curb parking

- the number of streets crossed during routine travel

- the absence of a park or play area near home

- the presence of cross walks where there are no traffic lights present; and

- dwelling or population density.

It has been suggested that higher density areas, with heavy traffic volumes, high traffic speeds and insufficient safe play areas or nearby parks, may increase the risk of pedestrian fatalities in children.

What can be done to mitigate the effects of density on premature mortality?

The main impact of density on all-cause mortality appears to be related to crowding rather than population density *per se*. To meet the needs of families, for example, future higher density housing developments may need to have a minimum percentage of housing large enough to accommodate families. Family accommodation needs to be co-located, to provide social support and a sense of community for adult and child residents.[64]

The location of higher density housing, and the amenity provided within and near this housing, may also help mitigate the effects of density on residents. While further research that redresses methodological weaknesses in the evidence-base is warranted, there is merit in ensuring that higher density neighbourhoods have access to recreational facilities and cycling infrastructure that encourage more vigorous forms of physical activity. Residents should also have good access to fresh fruit and vegetables.

While there is evidence that traffic fatalities are negatively associated with density, higher density areas appear to be associated with increased risk of pedestrian fatalities and injuries, particularly in children. As cities intensify, environmental modifications are required to reduce the risk of pedestrian injuries. Locating higher density housing away from traffic, and ensuring access to play areas and parks nearby, appears to be important. Efforts to calm traffic are also necessary. This can be done by:

- separating pedestrians from vehicles

- reducing vehicle speeds via narrower traffic lanes, curved or zigzag roadways

- raising intersections

- building speed bumps; and

- the creation of a 'woonerf' (i.e. low traffic speed streets for living).[63]

Given the importance of this issue, further investigation into how to reduce the risk of pedestrian injuries in high-density areas is warranted.

The impact of density on respiratory health

There is consistent evidence that proximity to busy roads, high traffic density and increased exposure to pollution are linked to a range of respiratory conditions.[65-74] These can range from severe conditions (i.e. a higher incidence of death) to minor irritations (i.e. a respiratory tract irritation). Moreover, these respiratory health impacts affect all age groups.

Nevertheless, the strength of the evidence varies, and the exact relationship between traffic pollution and proximity to main roads, and respiratory health, is unclear. Some

methodological issues persist in these studies, including the misclassification of exposure and self-selection (i.e. people most affected by air pollution may move away). In both instances, these limitations dilute the relationship between traffic pollution and respiratory illness, suggesting that the impact on respiratory health may be even greater.

The impact of higher density housing on respiratory health relates to its design and location. When considering the building and location of higher density housing in relation to respiratory health, a number of factors should be considered, such as:

- locating residential developments away from major roads or roads that carry high traffic volumes[68-70]

- allowing for local prevailing winds and topographic characteristics to avoid building higher density housing downwind of busy roads that carry high traffic volumes[72]

- locating residential developments in areas where there is sufficient and regular public transport,[75] and infrastructure that supports other forms of active transport (e.g. walking and cycling)

- locating higher density housing in leafy areas,[66] but ensuring low-allergen trees are planted near higher density housing; and

- designing buildings and apartments to maximise natural airflow[76] and ensuring that balconies and air-conditioner draw points do not overlook busy roads.

The impact of density on mental health

Studying the impact of the built environment on mental health is a complex and relatively new field. However, even discounting the sociodemographic characteristics of residents, living in higher density housing appears to have a range of potential direct and indirect influences on mental health. Importantly, some of these impacts appear to be influenced by the location, design, and construction of high density housing.[77-79] Individually and collectively these factors appear to directly influence mental health by exposing residents to environmental stressors, or indirectly influence mental health by impacting activities of daily living and social interactions between residents. Moreover, the incidence of social incivilities (including crime) in the building itself and surrounding areas, can affect residents' fear of crime. This can affect their sense of control, and result in social and physical withdrawal.

Crowding, noise, indoor air quality and light appear to directly influence mental health. The location, construction and design of higher density housing directly affects each of these environmental stressors. While acute exposure to relatively minor environmental stressors can be transiently stressful, continual exposure to ongoing noise, pollutants or crowding can result in chronic stress, which has important implications for mental health.

Noise appears to affect mental health by causing annoyance, which in turn causes stress. The impact of noise on the mental health of residents of higher density housing is likely to be partly related to the location of the building (e.g. whether or not it is on a busy road), and partly to its construction and insulation, which can affect the amount of noise transfer between the outdoor environment and also between neighbours.[77]

Poor-quality housing appears to be associated with greater psychological distress.[78] Consistent evidence from both cross-sectional and longitudinal studies shows that housing quality is associated with psychological health; and that living in higher quality housing located in higher quality neighbourhoods is beneficial to mental health.[77]

The quality of higher density housing is also affected by its **governance and maintenance**. This can indirectly impact on the mental health of residents by creating either a functional or dysfunctional living environment that either enhances or reduces residents' sense of control and safety.[80] Attention therefore needs to be paid to the governance of buildings to ensure that social control and maintenance are maximised. As the quality of the environment deteriorates, incivilities such as vandalism, crime and disorder tend to escalate.[81]

The built environment can also indirectly impact mental health through its influence on a range of **psychosocial processes** known to be associated with mental health outcomes.[78,79] The evidence suggests that residents of high-rise housing have more mental health problems than people living in low-rise or single-detached houses.[77] A major flaw in the evidence reviewed was that many studies failed to adequately control for confounding variables. Nevertheless, the evidence suggests that the impact of higher density housing on residents' mental health may relate to:

• who else lives in the housing, and their socioeconomic status

• the floor on which they live, which may affect the quality of the living environment; and

• levels of social interactions and social support.

The evidence on the impact of **floor level** is indicative rather than conclusive, but does suggest that floor level in high-rise housing appears to be associated with mental health outcomes.[77,78] People living on higher floors, particularly stay-at-home women with children, appear to be at greater risk of poor mental health. Contributing factors included anxiety about accidents and falls, particularly for parents of young children and the elderly, and a lack of social networks.[81]

It is plausible that two mechanisms are at play in higher density housing that may impact mental health. The first relates to **enforced social interactions**, which people find stress-enhancing because they are unable to avoid others. The second relates to **insufficient social interactions**, which are required to develop and maintain social networks. Rather, it appears to be important to provide opportunities for 'selective interactions'.

Despite the limitations of the evidence base, there appears to be sufficient evidence to warrant caution that high-rise housing (i.e. over four storeys) may increase the risk of mental health problems for people living on higher level floors. However, the impact is likely to depend on who lives in the building, as well as its design and facilities.

The **location of higher density housing** is a key factor that influences mental health. The location affects the extent to which residents are exposed to environmental stressors, and the building design reduces or enhances the impacts of a sub-optimal location (e.g. exposure to noise or air pollution). The location of higher density housing also affects access to neighbourhood resources, which indirectly impacts on residents' quality of life. The presence of local facilities and services, combined with the neighbourhood's overall attractiveness, can affect residents' satisfaction with their home and neighbourhood, which is closely aligned with mental health. Neighbourhood satisfaction appears to be related to the length of residence, amount of social interaction, satisfaction with traffic, and the neighbourhood's appearance and aesthetic appeal.[82] The physical characteristics of neighbourhoods appear to be strongly associated with neighbourhood satisfaction, including features that encourage pedestrian activity and create opportunities for interactions between neighbours, as well as decrease motor vehicle dependency. Moreover, as traffic volumes increase neighbourhood satisfaction is said to decrease. [83]

To meet the **security needs of residents**, both the housing and the neighbourhood need to be safe, and the importance of real and perceived safety needs to be considered. In summary, there are a number of pathways through which crime, and fear about crime and safety, can affect mental health. First, it can increase anxiety and psychological distress.[77,78] Second, it can cause people to constrain their behaviour and reduce participation in social and physical activities that help to promote mental health.[84] Finally, fear of crime can reduce feelings of personal control, and the resultant feelings of helplessness are risk factors for poor mental health.[78]

Higher density housing with higher population densities, particularly located near shops and services, is likely to increase the incidence of local crime and disorder – simply because there are more people circulating in the area. However, the introduction of crime prevention through environmental design (CPTED) features within the building itself (e.g. territoriality and natural surveillance),[85] as well as the local neighbourhood, is likely to decrease the incidence of crime and disorder.[86] Decreasing the incidence of crime, and increasing feelings of safety is important from a mental health perspective. Thus, designing buildings and neighbourhoods to create safer environments is important from a safety perspective, and also from a mental health perspective.

Access to natural or 'green' environments including vegetated areas such as parks, open spaces, and playgrounds has been found to be associated with a range of health benefits in cross-sectional studies, including mental health outcomes and factors protective of mental health.[63,87,88] Nevertheless, a limited number of studies have specifically considered the impact of green space in higher density areas. The perceived importance of public open space (POS) to residents of high-density housing is evident in studies examining the 'willingness to pay' for this privilege. For example, in a Scottish study, sale prices for flats on a park's edge were higher than an equivalent flat 800 m away from a park; these findings were not observed for other housing types.[89] The researchers concluded that POS is more important to people living in higher density housing compared with others because it substitutes for the private space available to residents of low-density housing. In a separate study, neighbourhood attractiveness (including the amount of green space) was shown to be the most important correlate of housing satisfaction in apartment dwellers, and much more so than for residents of other types of housing.[90] This is important because housing and neighbourhood satisfaction can influence mental health. Moreover, cross-sectional studies show that exposure to green space or nature is associated with a wide range of benefits including reducing attention fatigue and stress, enhancing restoration, and promoting positive mood and emotional states associated with pleasant arousal and relaxation.[87,91-94]

There are a number of reasons why green space may be beneficial to mental health. Adults who have access to green environments such as parks tend to walk more, particularly for recreation, which has both physical and mental health benefits.[49,95-98] However, the benefits to mental health associated with access to POS may also accrue from the restorative aspects of nature exposure.[98] In addition, access to POS may also affect mental health by influencing social processes that are protective of mental health. For example, evidence suggests that access to POS is associated with the development of social ties and sense of community,[99,100] both of which reduce the risk of premature mortality.[101-103]

In summary, although the evidence base in relation to the presence of POS and increased density is limited, there is considerable evidence that exposure to nature is beneficial to mental and physical health, and both the presence and quality of POS appears to be important. There are a number of mechanisms through which access to POS influences health: access to high-quality open space is associated with increased levels of walking and positive mental health outcomes. The potential mechanisms through which access to POS influences mental health include reducing mental fatigue and stress, enhancing restoration and promoting positive mood and emotional states associated with pleasant arousal and relaxation. However, it is also plausible that access to POS influences social processes (e.g. the development of social networks). There is evidence that POS is valued by residents of higher density housing, as indicated by increased property prices near POS. POS is more important to people living in higher density housing compared with others because it

substitutes for the private space available to residents of low-density housing. Neighbourhood attractiveness (including the amount of green space) has been shown to be an important correlate of housing satisfaction in apartment dwellers, and much more so than for residents of other types of housing. Housing and neighbourhood satisfaction is an important factor influencing mental health.

It is clear that POS is particularly important to people living in higher density housing who do not have access to private open space. Although this report is inconclusive as to the exact amount of POS required to meet the needs of multiple users across the life course, it appears that a hierarchy of POS – within and outside higher density complexes – is necessary.

The impact of density on special populations

The needs of **children** in relation to higher density housing deserve special attention. Density (and, more broadly, living conditions) may affect child development, mental health and physical health, restricting their physical activity, independent mobility and active play. The evidence indicates that high-rise living may be associated with behavioural problems,[104,105] and that independent activity and active play may be restricted in girls living in high-rise buildings, resulting in increased levels of overweight and obesity.[51,106] Independent mobility and, more generally, physical activity, is associated with the proximity and range of destinations, and neighbourhood attributes such as safety, walkability and the presence of traffic.[107,108] POS is particularly important, as this is often where children engage in active play. A hierarchy of play spaces may be required to cater for increasing autonomy with age, as well as providing access to a variety of formal and informal areas.[109] Moreover, for younger children, the mental health of parents (particularly mothers) may be affected if they are unable to allow their children to play in well-surveilled outdoor areas.

Locating higher density housing in which children reside, along or near roads carrying heavy traffic, may result in parents restricting their children's mobility, and also increasing the risk of child-pedestrian accidents. Moreover, children exposed to traffic pollution are at greater risk of respiratory problems including asthma. A small amount of evidence highlights other health impacts on children living in higher density housing. This includes short-sightedness due to a restricted length of vision[110], and diminished auditory discrimination and reading ability[111] due to increased exposure to noise. Co-locating families with young children may be useful to create a sense of community among families and children.[64] However, attention to design is required to minimise any potential source of conflict between residents (e.g. noise). Finally, meaningfully involving young people in the planning and designing of residences and communities may produce better outcomes for the children and youth who live in those neighbourhoods.[112]

For **older adults**, mobility, perceived and actual safety, and opportunities for socialisation are key factors to consider when planning housing.[113] The provision of facilities and services (including POS) that encourage physical and social activities will help to promote good health, and prevent or delay the onset of chronic disease. Residential and neighbourhood satisfaction is protective of mental health. Generally, high-rise living is associated with lower levels of satisfaction and a poorer sense of community in older adults.[114] It is therefore recommended that the densification of housing intended for older adults be achieved through low- to mid-rise developments.

Feelings of safety and perception of crime are of particular importance and relevance to older adults. Incorporating CPTED features that aim to increase safety and reduce fear appear to be critical.[115] Thus, in older adults, the location and design of higher density housing may be more important than density *per se.*

Discussion and conclusions

The purpose of this report was to undertake a narrative review of the literature addressing the following questions:

- What are the intended and unintended consequences of increased density?

- What constitutes 'good' levels of density from a health and active living perspective?

- What type of amenity is associated with positive health and physical activity outcomes, in higher residential density areas?

What are the intended and unintended consequences of increased density?

Increasing housing density, if carefully planned, has the potential to produce numerous benefits to the environment and the health of the community by:

- increasing the use of active modes of transport and public transport

- reducing vehicle miles travelled

- improving air quality

- reducing traffic congestion

- providing more affordable housing closer to amenities; and

- reducing the footprint of cities by reducing the amount of space required for each person.

However, despite good intentions, without careful consideration it is easy to get this wrong.

The evidence suggests that the success or otherwise of the implementation of policies to increase population density will depend on three main factors:

- the **building** (i.e. its location, construction, design, management and maintenance)

- the **social, socioeconomic and cultural make-up** of residents and the local neighbourhood; and

- the **quality and amenity of the neighbourhood environment** in which higher density housing is located.

Moreover, to optimise outcomes, it appears necessary to address all three factors: i.e., building factors, social and cultural factors, and neighbourhood factors, concurrently.

What constitutes 'good' levels of density from a health and active living perspective?

What constitutes 'good' levels of density depends on a range of factors. There appears to be more potential harm associated with living in high-rise housing; however, this may depend upon who lives there, how well it is designed and built, and where it is located. For example, high-rise inner-city housing, occupied by employed adults with no children, may work very well. Moreover, high-rise housing in high socioeconomic areas with good neighbourhood amenity, built-in security, shared facilities (e.g. recreational space), opportunities for selective interactions, and structures addressing building and social governance, may also work well for people who can afford to live there.

However, to optimise outcomes across the spectrum for current and/or future residents, there appears to be a strong preference and desirability for families, for example, to live on the lower floors of medium-density housing of no higher than three to five storeys. Moreover, this accommodation should be large enough to avoid issues of over-crowding, and allow families to be co-located to create a sense of community. Achieving higher densities through lower rise development would appear to be optimal not only for families, but also older adults.

What type of amenity is associated with positive health and physical activity outcomes in higher residential density areas?

The evidence suggests that it is optimal for higher density housing to be located away from roads with heavy traffic, but within easy access of public transport, shops, services and a hierarchy of POS. This includes on-site open space that can be surveilled by parents as their children play. Moreover, desirable building design features include:

- ensuring adequate noise insulation and breeze-ways that optimise ventilation

- designing balconies so that they do not overlook roads with heavy traffic

- using CPTED features that enhance territoriality and promote natural surveillance

- providing opportunities for selective (but not enforced) interactions between residents (including children); and

- co-locating families on the same levels.

These design features will provide for the daily transport and recreational needs of residents, and also assist in creating a sense of community and protecting the health of residents.

Abbreviations

μm	Micrometre (1/1,000,000 m)
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
BC	Black carbon
CABE	Commission for Architecture and the Built Environment
CPTED	Crime prevention through environmental design
CVD	Cardiovascular disease
FEV1	Forced expiratory volume in one second
FVC	Forced vital capacity
Ha	Hectare
km	Kilometres
km^2	Kilometres squared
m	Metres
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxides
NSW	New South Wales
NYC	New York City
$PM_{2.5}$	Particulate matter with a diameter less than 2.5 μm
POS	Public open space
SES	Socioeconomic status
UK	United Kingdom
US	United States

Glossary

Active play	Children's play that incorporates physical activity, such as running, skipping or jumping
Active transport	Physical activity undertaken as a means of transport. May include walking, cycling, or other non-motorised vehicles. Also includes use of public transport where walking or cycling is required at the beginning or the end of the journey
Age-segregated	Segregation of housing based on age. Most frequently involves segregation of the elderly from younger people and families by location of these people in a separate housing structure, or in the case of high rise, on a separate floor
Burden of disease	The 'weight' of disease borne by a community which is a reflection of morbidity, mortality, disability and reduced quality of life
Congregate housing	Housing, often for the elderly or disabled persons, which incorporates the provision of some services and/or shared facilities
Corridors	Land use corridors are passages of space that may be created either formally or informally, which are dedicated for a particular use (such as transit, employment, housing, or wildlife)
Ecological study	A scientific study in which the unit of analysis is the population, rather than individuals
Green space	Land dedicated for public use, which may be parks, gardens, bush land, rivers or lakes, that provides an opportunity for sport and/or recreation, as well as being valued for aesthetic enhancement of an area
High density	Over 60 dwellings per hectare and generally five storeys or more high
High rise	Five or more storeys
Housing development/estate	A group of residential buildings planned and built together
Independent mobility	The ability of children to traverse their neighbourhood independent of adult supervision

Infill	Redevelopment of vacant or under-utilised land that is located between existing structures and is centrally located. Redevelopment is often for residential, commercial or retail use
Longitudinal study	A scientific study that follows a group of participants over time and in which the exposure and outcome measures can be temporally sequenced
Low density	< 25 dwellings per hectare and single residential housing
Low rise	Two storeys or less
Medium density	Generally between 25 and 60 dwellings per hectare and not usually more than three or four storeys in height
Meta-analysis	Integration of numerous independent studies measuring similar exposures and outcomes in order to increase the statistical power or weight of evidence
Mixed density	Co-location of multi-dwelling housing (such as flats) alongside townhouses and single-dwelling structures, catering for a range of preferences and housing budgets
Mixed use	Incorporation of residential and retail structures in the same geographic location
Multi-dwelling housing	The incorporation of several housing units into one building
Prevalence	The total number (or rate) of disease or illness in a defined population at a particular point in time
Private open space	Open space that is usually privately owned and is not usually accessible by members of the public
Public/social housing	Housing provided to low-income persons and families by the government or not-for-profit organisations with the specific intention of providing affordable housing for groups vulnerable to housing insecurity
Public open space (POS)	Areas dedicated for public use which may be green space (see definition above) or built infrastructure (such as town square, piazza)
Retrofitting	Redevelopment or updating of existing urban areas or structures that aims to improve living conditions, increase population density and/or improve sustainability

Selective interaction	Interaction with neighbours or other members of a community that takes place on one's own terms
Stratified analyses	Statistical analysis of groups based on demographic variables (such as age, marital status, education, dwelling type) that allows for inter-group comparison
Territoriality	A sense of guardianship or ownership over a place or space
Transit oriented development (TOD)	A compact mixed use residential and commercial development positioned with good access to public transport (such as a centrally located train station or bus stop)
Transitional zone	A zone of property between 'private' and 'public' space (such as a landing or entrance that a number of residents share but to which the public do not have access)
Urban fringe	The outermost perimeter of an urban area, where urban and rural or semi-rural land uses meet
Urban sprawl	The organic and often unplanned growth of a city from a high-density centre, to increasingly low-density fringes that encroach into rural areas
Urbanisation	The degree to which an area is developed by urban amenities including residential, retail, commercial and transportation
Walkability	The extent to which a neighbourhood encourages and supports walking for transport and recreation
Woonerf	The Dutch name for a 'living street', in which the needs of car drivers are secondary to the needs of users of the street as a whole. It is a 'shared space' designed to be used by pedestrians, playing children, bicyclists, and low-speed motor vehicles. It is intended to be a public place for people instead of a single-purpose conduit for automobiles

1.   The rationale for shifting from low density cities

"The ... city should be a collection of communities where every member has a right to belong. It should be a place where every man (sic) feels safe on his streets and in the house of his friends. It should be a place where each individual's dignity and self-respect is strengthened by the respect and affection of his neighbours. It should be a place where each of us can find the satisfaction and warmth which comes from being a member of the community of man. This is what man sought at the dawn of civilisation. It is what we seek today."

–Lyndon B Johnson

Rethinking the ways cities are built to promote healthy and sustainable living has become a multi-sector pursuit, fuelled by global concerns about rising levels of obesity and physical inactivity, climate change, population growth and declining oil supplies.[116] Low-density, car-dependent cities typical of Australia and North America are increasingly recognised as having a detrimental impact on human health and the environment. These cities encourage unhealthy behaviours (e.g. physical inactivity and sedentary behaviour) and increase vehicle miles travelled, traffic congestion and air pollution.

Although debates about population growth are hotly contested, Australian Bureau of Statistics (ABS) estimates suggest that Australia's population could grow to 36 million or more by 2056,[117,118] driven by natural fertility, increased life expectancy, and migration.[119] Left unplanned, population growth has the potential to undermine 'community liveability and wellbeing' by limiting access to adequate infrastructure, services and employment opportunities, and adversely affecting housing supply and affordability.[119]

Confronted by the potential for rapid population growth, state and federal governments are recognising the need to rethink the way populations are housed and mobilised. Central to this consideration is the need to shift away from motor vehicle dependent low-density suburban sprawl to more compact mixed use communities accessible by active transport.

A number of (sometimes conflicting) trends provide the backdrop to the shift to more compact living;[118] including that older people are living longer and increased numbers of people are living alone. Despite these trends, the majority of new dwellings in Perth (80%) and Brisbane (62%), and a large proportion of dwellings in Melbourne (44%) and Sydney (33%), are single detached houses.[118, p.77]

Thus, at least in some states, there appears to be a disconnect between population trends and housing demand and/or provision. For example, despite a decline in the average number of persons per household from 3.1 to 2.6 in the decade from 1994, during this same period the number of new homes with four or more bedrooms increased from 17% to 28%.[118]

Australian houses are now the largest globally; therefore, the amount of space required per person for housing is greater than in other countries.[118]

A key focus for discussions about a shift to more compact, accessible communities is the need for increased population density. Without a minimum threshold of population density, public transport and local shops and services are not viable, nor are there sufficient populations to create vibrant local communities.

While pressure to increase density mounts, specific targets remain relatively modest. A number of state governments recommend 'at least 15 dwellings per gross urban zoned hectare' for greenfield developments,[120-122] or as a minimum along transport corridors.[120] Higher density targets (up to 35 dwellings per hectare) are being proposed around activity centres and transit-oriented developments.[120,122,123]

By international standards, these targets are, at best, modest. Nevertheless, they reflect a clear trend, with some jurisdictions setting targets that will inevitably increase densities across Australian cities. These include:

- targets for inner-city proximity (i.e. the total number of dwellings within a 7.5 km radius of the city centre)[124]

- increasing ratios of infill development to urban fringe development[122,125] (as high as 70:30 by 2030[120]); and

- increasing the focus on new development within transit-oriented developments.[120]

Other proposals aim to increase proximity to employment and services, including:

- polycentric city structures that redistribute jobs and activities, enabling people to work closer to where they live

- the development of employment corridors along high-capacity public transport corridors[121,122]

- amendments to local government planning schemes to facilitate mixed land use to increase demand for public transport within 800 m of high-frequency transit corridors[122]; and

- an aim to locate 80% of all new housing within walking distance of mixed use neighbourhood centres.[126]

2.   Purpose of this report

From a health and sustainability perspective, the need to increase population densities seems inevitable. However, as we shift from single residential development to higher density development, it is timely to consider how to maximise the benefits of increased population and minimise any harm. The world is littered with historical and contemporary examples of poorly planned density, which – despite good intent – has unintentionally harmed human and community health. Thus, the aim of this report was to undertake a narrative review of the literature and address the following questions:

- What are the intended and unintended consequences of increased density?

- What constitutes 'good' levels of density from a health and active living perspective?

- What type of amenity is associated with positive health and physical activity outcomes, in higher residential density areas

The Heart Foundation requested that this review consider:

- the health and social impacts in populations across the life span associated with increased density

- optimal levels of density from a physical activity and health perspective, and under what conditions this occurs

- the type of amenity and features of good design associated with positive health outcomes in higher residential density areas

- an exploration of 'intelligent density', with consideration being given to activity centre dispersal, POS, and levels of density that support walking for transport; and

- conclusions (when supported by the strength of the evidence)

This report presents the literature review. The literature review included studies from peer-reviewed journals and the grey literature sources from a range of databases, and from references included in articles reviewed. The databases searched included ISI web of knowledge, Medline, PsychInFO, science direct, super search, and PubMed.

The literature search was limited to the English language and humans, but not restricted by year or country. The following search terms were used:

- 'housing density'; 'housing density and health'; 'housing density and obesity'; 'housing density and mental health'; 'housing density and physical activity'

- 'residential density'; 'residential density and health'; 'residential density and obesity'; 'residential density and mental health'; 'residential density and depression'; 'residential density and physical activity'

- ['population density' or 'urbanisation' or 'housing density' or 'high rise']; and ['cardiovascular disease' or 'asthma' or 'respiratory illness' or 'respiratory disease' or 'mortality' or 'neoplasms' or 'mental health' or 'health (limit to humans)' or 'children' or 'older adults' or 'elderly' or 'injury']

- 'high rise and health'

- 'housing and health'

- 'crowding and health'; 'residential crowding and health'

- 'compact housing and health'

- 'medium density and health'; 'medium density housing and health'

- 'high density and health'; 'high density housing and health'

- 'open space and density'; 'parks and density'; 'public open space and density'; 'public open space or open space or parks and residential density'; 'public open space or open space or parks and high rise'; 'public open space or open space or parks and high rise living'; 'high rise development and public open space'

- 'transit-oriented development and health'

- 'activity centre dispersal and health'

- 'inclusive city'

- 'lifetime city'

- 'inclusive mobility'

- 'independent mobility and density'

- 'children and density'; 'children and residential density'; 'children and housing density'; 'child health and density'; 'children and health and density'

- 'older people and density'

- 'housing for the elderly'

- 'high rise living and the elderly'

- 'family and density'

- 'high rise living and children'

- 'built environment and health'.

The initial search from the databases returned a substantial number of articles (> 100,000). Further refinements were made by subject areas and categories. The remaining articles were then screened for relevance to the scope of work – judging from the title, abstract and source of articles. A total of 179 articles were selected.

3. What is density and how is it measured?

Density is a complex concept. It is defined in numerous ways globally, and differently by different disciplines.[3] Put simply, density is the number of units (e.g. people, dwellings, employees, trees) per unit of land area. It is expressed as a ratio where, for example, the numerator is the population or number of dwellings and the denominator is an area unit (e.g. hectare, square mile or square kilometre). When measuring density, an added complexity is whether the denominator includes net area (i.e. only land occupied by the dwellings in addition to the streets and pathways to access those homes) or gross area (i.e. the land included in net residential area in addition to all the local utilities and services). Some standard definitions of density are listed below.

Population density: the number of people divided by the size of a given area.[3]

Residential or dwelling density: the number of residences or dwelling divided by the size of a given area.

Employment density: the number of employees within a designated geographic area, divided by the size of the area.[127]

Net residential density (or parcel density): the number of dwellings or residents divided by the site or parcel area.[128] The area typically includes land occupied by the dwellings in addition to the streets and pathways required to access them.[129]

Gross residential density number: includes the area of land included in the net residential density (that is, the land occupied by the dwellings in addition to local and collector roads) plus local parks and open space, drainage reserves, community facilities, primary schools, local retail centres and services.[129,130]

Floor area ratio: the ratio between the floor space in a building and the size of the parcel on which it is situated.[39] This measure relates to the building itself.

Living density: relates to any given dwelling and is the number of persons per room. In calculating living density, some authors include communal rooms such as the kitchen and bathroom, and some do not.[3]

Mixed density: refers to a combination of housing types, forms and sizes, a composition of stand-alone single dwellings and multi-family units.[131]

High density: over 60 dwellings per hectare and generally five storeys or more high (e.g. apartment buildings).[132]

Medium density: generally between 25 and 60 dwellings per hectare and not usually more than three or four storeys in height. Examples include town houses and terrace housing.[132]

Calculating density can be challenging because the population density of an area may change, while the dwelling density remains the same. This reflects an earlier point that the number of people living in the same household has declined over time in Australia.[118]

It should be noted that, in the research reviewed, researchers often conceptualise 'density' somewhat differently to practitioners and policy-makers. In the studies reviewed, density was conceptualised to reflect the:

- number of dwellings per acre, hectare, or kilometres squared (km^2)

- percentage of building land coverage

- units per building

- floor level

- perception of overcrowding

- comparison of housing types

- floor area per person

- percentage of buildings in the community classed as 'high rise'

- number of houses visible from an individual's front door.

Thus, in this review, all identified definitions of density were used. However, the diversity of ways of conceptualising density may mean that some relevant literature was not identified and may have been omitted.

4.   The impact of density on physical activity

Concerns about low-density car-dependent cities from a sustainability, environmental and traffic management perspective complement those raised in the public health literature. Various calls for action in public health[40,41,133-136] have been driven by a growing and consistent body of evidence showing that the design of cities and neighbourhoods affects the physical activity patterns of residents. Physical inactivity is a major modifiable risk factor for cardiovascular and other major chronic diseases,[137] and is the fourth leading contributor to the global burden of disease.[138] Yet despite the well-known benefits of living an active lifestyle, about 60% of the world's adult population is insufficiently active,[139] and physical inactivity causes about 1.9 million deaths annually.[140] In Australia, the problem is also significant. Over 13,000 deaths each year are attributable to inactivity,[141] and approximately 50% of Australian adults are insufficiently active to benefit their health.[142] Physical inactivity and sedentary behaviour are independent risk factors for obesity,[143] and obesity statistics are alarming. Globally, around 20 million children and 1.3 billion adults are either overweight or obese.[142] In Australia, two-thirds of men, half of women[144] and one-fifth of children are overweight or obese.[144]

Building habitual active transport into daily routines has been identified as a means to increase physical activity.[40,133,134] Yet active transport, particularly in children, has rapidly declined in most developed countries over the past three decades.[145-150]

Public health authorities globally now highlight the importance of encouraging active modes of transport as an alternative to driving.[40,41,131,133-135,151] Increasingly, it is acknowledged that the built environment is an important contributing factor to alarming downward trends in physical activity. The evidence suggests that, in developed countries, 'obesogenic' environments[152-154] have been created that discourage physical activity and encourage unhealthy food consumption.[155]

Specifically, low-density car-dependent cities discourage active living – in particular walking, cycling and public transport use – and encourage driving for activities of daily living. Studies repeatedly show that urban sprawl, as characterised by the low densities, curvilinear street networks and separated land uses of most US and Australian cities, decreases local walking and increases vehicle miles travelled.[39] In turn, this increases sedentary behaviour.[48] This is in contrast to the compact, higher density, well-connected neighbourhoods that increase walking, cycling and public transport use.

In Australia, this low-density housing phenomena replicates the US model for urban growth in the post–World War II period, which involved separating land uses, investing in roads and building to low densities.[156] This contrasts with earlier traditional housing developments, in which urban areas were relatively concentrated, public transport was the principal mode of

transportation, and car ownership was rare.[157] In fact, Davison reports that before World War II, only one in four Melbournian households owned a vehicle.[158] Notably at this time, streets also tended to be multi-functional and included play spaces for children, places to socialise, as well as routes for walking, bicycling, public transport and cars.[158]

The suburbanisation of populations into lower-density communities separated from retail, services and employment has increased distances between destinations. In turn, this has increased the dependency on cars and the reliance on private vehicles for most trips.[39] On average, walking speeds are about 4.8 km/hour and cycling speeds are about 12.9 km/hour. Thus, access to nearby transport-related destinations is a key factor that facilitates the actual and perceived feasibility of utilitarian walking and cycling.[39]

Public health researchers often combine the environmental components that help predict transport walking (i.e. residential density, street connectivity, access to shops and services) into 'walkability' indices, which reflect the capacity of the physical environment to promote utilitarian walking.[159-161] The evidence confirms associations between these measures of neighbourhood walkability and transport walking across all age groups: children,[4] adolescents,[162,163] adults[52,161,164-166] and older adults,[167] as well as children's physical activity.[168]

As noted, the presence of nearby shops and services is dependent on higher residential densities, as local businesses require sufficient residential densities to ensure they are viable. There is a strong body of evidence confirming the association between these interdependent variables (i.e. higher residential density and mixed use planning) and transport walking across all age groups.[4-13,15-27,169] Similarly, the close proximity of shops and services is a consistent predictor of walking for transport and recreational purposes for all age groups.[2,4-9,11,19,20,28-38] However, it should be noted that the environmental correlates of recreational walking are often more ambiguous than for transport walking.[170] They also tend to be associated with other neighbourhood factors, such as the presence of nearby, high-quality, well-maintained POS and aesthetic presentation.[95,171,172]

A limitation of the studies examining residential density and walking is that most are cross-sectional, so causality cannot be determined. The implication is that people may move (or 'self-select') to neighbourhoods that support their existing walking behaviours, rather than the neighbourhood design changing to their behaviour patterns. Longitudinal studies are needed to explore issues of self-selection and causality. However, there are inherent difficulties in designing and implementing randomised controlled trials to examine how changes to the neighbourhood environment affect physical activity. Consequently, a number of large cohort studies have explored the impact of community design on health by focusing on study participants who have moved during follow-up.[173-178] These studies reveal inconsistent findings, possibly due to a range of methodological problems including small

samples of 'movers' and the application of measures that lack specificity or were intended for another purpose. Natural experiments designed to examine the impact of residential relocation on health are rare,[179] and this has been identified as an important area for future research.[180]

Despite limited causal evidence, there is a strong body of cross-sectional evidence confirming the association between residential density (and the associated access to shops and services) and transport walking. Moreover, several major agencies agree that there is sufficient evidence to warrant actions aimed at improving the built environment to promote physical activity, particularly active transport.[39-41]

4.1   What is required to increase active travel?

Urban and transport planners have attempted to categorise land use features required to encourage more walking, cycling and public transport use into the five 'D's.[181] At the top of the list is density, followed by diversity, design,[1] distance to transit and destination accessibility.[181] In the transportation literature, land use diversity and population, employment and retail density are consistently positively associated with walking and cycling for transport.[39] Nevertheless, as Handy thoughtfully observes, it is not density *per se* that increases walking and cycling for transport and transit use; rather, density makes these local destinations (that encourage active modes) viable.[39] Distance to the nearest destination is consistently shown to be negatively associated with active mode choice.[39] McCormack and colleagues found that for each utilitarian destination present, transport-walking increased by around six minutes per week.[182]

Notably, three of the five Ds relate to increasing access to destinations (i.e. diverse land uses and employment opportunities, transit and ease of access to destinations). However, as illustrated in Figure 4.1, population and employment density underpin the impact of these three land use features on active modes. Without density, it is not possible to have mixed-land uses, and nearby and accessible destinations and transit. In Australia, the average suburban density is about 13 persons per hectare,[183] which is significantly lower than that required to increase access to public transport and support local shops and services. Newman and Kenworthy estimate that urban intensity (i.e. both people and employment) of at least 35 persons per hectare is the minimum required to provide high-quality public transport.[184]
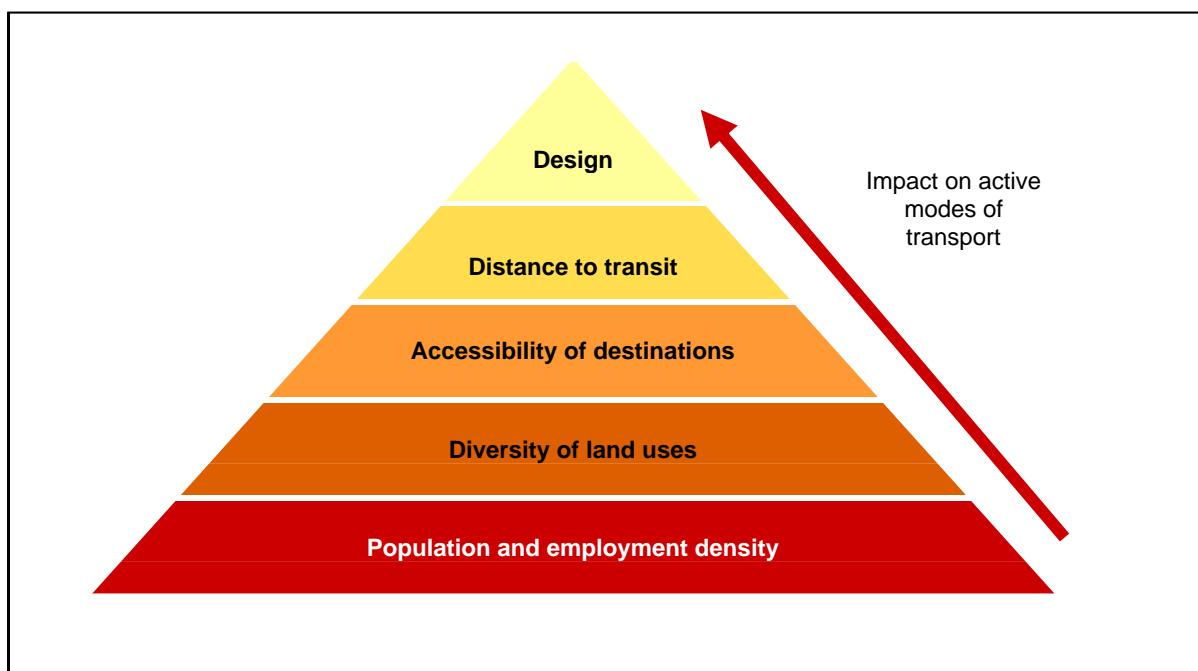
Figure 4.1 The impact of the five Ds of land use features on active modes of transport

4.2 Summary of the impacts of density on physical activity

Physical inactivity is a major modifiable risk factor for cardiovascular and other major chronic diseases,[137] and the fourth leading contributor to the global burden of disease.[138] Moreover, physical inactivity contributes to many other health outcomes examined in this review, highlighting the importance of increasing physical activity levels.

Building habitual active transport into daily routines has been identified as a means to increase physical activity; however, active transport has declined in most developed countries over the past three decades.[145-150] In part, this decline is related to the post–World War II style of urban development, characterised by low residential densities and the separation of land uses that have proliferated in Australia and the US.

Specifically, low-density car-dependent cities discourage walking, cycling and public transport use, and encourage driving for activities of daily living. Studies repeatedly show that urban sprawl, as characterised by low densities, curvilinear street networks and separated land uses, decreases local walking, and increases vehicle miles travelled.[39] In turn, this increases sedentary behaviour.[48] This contrasts to the compact, higher density, well-connected neighbourhoods that increase walking, cycling and public transport use. Several major agencies agree that there is sufficient evidence to warrant action aimed at changing the built environment to promote physical activity, particularly active transport.[39-41]

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5. The impact of density on mortality

A number of studies have examined the association between population density and mortality. However, in general, these studies have tended to be ecological or have insufficient adjustment for important confounders such as SES. For example, higher density housing could be a surrogate for area-level SES, with people living in high-density housing having lower socioeconomic backgrounds, poorer education, diminished access to quality community infrastructure, and other known determinants of ill health. Thus, any relationships observed between density and increased mortality may simply reflect the relationship between these social determinants of health and mortality rather than living in higher density housing *per se.*

In fully adjusted studies, there is little clear evidence that increasing population or dwelling density *per se* is associated with increased all-cause mortality. In fact, van Hooijdonk et al. identified protective effects of urban living after controlling for neighbourhood SES.[55] This was particularly true for women, children and adults (aged 10–39 years), the elderly (aged 80 years and over), single adults, and people of non-Western origin. Similarly, Factor and Waldron's study of Chicago communities, which was matched for SES, found no significant association between density and mortality.[46]

Nevertheless, evidence suggests a positive association between density and mortality in some sub-groups which cannot be ignored; for example, in older adults living in the mega-city of Tokyo.[42] However, in a more recent longitudinal study of older adults living in Tokyo (i.e. with a density of 13,050 inhabitants/km^2), Takano and colleagues found that the five-year survival rate was higher in participants who reported access to walkable green space.[43] This suggests that access to green space in high-density cities may be protective, either because it is restorative or provides opportunities for recreational walks. Access to green space in this study was only measured by self-report. However, the findings make a plausible connection between the location of higher density housing and access to local amenities. This issue is addressed later in this report, in *Section 7.7 The location of higher density housing and the quality of the local neighbourhood.*

The relationship between crowding and mortality appears to be more consistent. After adjustment for known confounders such as SES, level of education, living arrangement density and housing tenure, a number of studies have found living density (i.e. crowding) is positively associated with mortality.[45,47] These results were consistent regardless of whether crowding was measured by persons per room or the number of housing units per structure.[44,45] Notably, this was not the case for population density.[44,46,47]

5.1 Density and cardiovascular disease mortality

Increased density appears to be protective for CVD through its impact on CVD risk factors. Increased density is associated with participation in physical activity (principally through transport walking),[39] and decreased sedentary behaviour[48,49] and obesity levels.[50,51] Moreover, US[52,53] and French[54] evidence suggests that living in compact cities is associated with lower blood pressure. However, in terms of the incidence of CVD and CVD mortality, the evidence is inconsistent. A Dutch study found that living in more densely populated urban areas was protective of CVD.[55] As with other ecological studies, it is difficult to separate the impact of density from issues related to SES. As noted by Chaix, Rosvall and Merlo,[54] 'the clustering of deprived individuals in an area may create detrimental conditions'. In many countries those most disadvantaged live in higher density areas.

Another confounding issue is the location of higher density housing. A meta-analysis found CVD was consistently associated with exposure to environmental stressors such as air pollution.[56] Living near traffic is associated with a range of adverse CVD outcomes including self-reported coronary events[185] and cardiopulmonary mortality.[186] Exposure to outdoor air pollution accounts for about 2% of the global cardiopulmonary disease burden.[187-189]

5.2 Density and cancer mortality

A number of studies have investigated the relationship between cancer-specific mortality and density. Ecological studies undertaken in the US[57] and Taiwan[58] found positive relationships between total cancer mortality and colon cancer, and population density, for both males and females. The studies also showed a positive relationship between breast cancer and population density in women. However, neither of these studies adjusted for known confounders such as SES. A Dutch ecological study examined all-site cancer mortality, and breast and lung cancer with adjustment for age, gender, marital status, region of origin, and neighbourhood SES.[55] After adjustment, all-site cancer mortality and lung cancer deaths increased with population density, but there was no significant association between breast cancer and population density in women.

Despite the limitations of evidence from ecological studies, urbanised living could contribute to the aetiology of cancer by increasing exposure to environmental agents (such as air pollution), and having a detrimental influence on lifestyle risk factors for cancer (such as fruit, vegetable and red meat intake, physical activity and smoking). For example, although walking is beneficial for cardiovascular health, there is evidence that for some cancers (e.g. colon cancer),[59] a higher volume and intensity of physical activity is required. Thus, in highly urbanised environments, there is a need to ensure sufficient access to recreational facilities or cycling infrastructure to encourage participation in vigorous physical activities or cycling. Similarly, there is a need for sources of affordable, fresh and healthy food (see Figure 5.1 for New York's Green Carts); and to minimise exposure to harmful pollutants. If not

appropriately managed, increasing urbanisation could increase exposure to environmental agents and negative lifestyle changes that could potentially increase the risk of cancer.

Figure 5.1 A 'Green Cart' mobile food cart that sells fresh produce in areas in New York City identified as having poor access to fresh fruit and vegetables

(Source: www.nyc.gov/html/doh/html/cdp/cdp_pan_green_carts.shtml)

5.3   Density and road traffic accident mortality

Studies examining the association between road traffic accident deaths and population density consistently show an inverse relationship.[55,60-62] Higher mortality of motor vehicle occupants (per 100,000 population) is associated with decreasing population density,[60] and death following road traffic injury is more likely with decreasing population density.[61] However, most studies compare rural and urban environments, and the inverse association between motor vehicle accident mortality and population density could be due to:

- rural conditions, such as higher speeds

- road conditions

- lack of seat belt use (not compulsory in all US states)[60]

- driver behaviour[62]

- poorer access to critical care in increasingly rural areas[61]; and/or

- more road kilometres travelled.

Importantly, none of these studies focus specifically on intra-urban differences. A Dutch study presented relative risks across density quintiles (from rural through to urban), and closer examination of the urban areas suggests an inverse relationship between density and mortality due to road traffic accidents.[55] In sprawling metropolitan areas, people spend more time in their vehicles and travel more kilometres, while in denser cities trip distances are shorter and there is a greater reliance on pedestrian and public transport trips. This is highlighted by a study of US cities that found lower automobile fatality rates (excluding pedestrians) in denser cities compared with sprawling cities.[63] It is plausible that in higher density neighbourhoods, trips are shorter and traffic travels at slower speeds. In higher density environments with local shops and services there are likely to be more pedestrians and cyclists circulating (including children and young people). It is possible that this could increase the risk of injury. Ewing and colleagues, for example, ranked nearly 450 metropolitan US counties using a sprawl index and found a strong positive relationship between sprawl and pedestrian and vehicle occupant fatalities.[52,53] Traffic fatalities were nearly 10 times higher in the most sprawling counties compared with the most compact. After a review of the evidence, Frumkin and colleagues concluded that a number of neighbourhood features increased the risk of pedestrian injuries, particularly in children.[63] These included:

- high traffic speeds and volumes

- high density of curb parking

- the number of streets crossed during routine travel

- the absence of a park or play area near home

- the presence of cross walks where there are no traffic lights present; and

- dwelling or population density.

Importantly, the authors concluded that, in higher density areas, heavy and high-speed traffic and insufficient safe play areas or nearby parks may increase the risk of pedestrian fatalities in children.

5.4   What can be done to mitigate the effects of density on premature mortality?

As noted above, the main impact of density on all-cause mortality appears to relate to crowding rather than population density *per se*. This may be an important issue to consider as the amount of higher density housing increases in Australia. For example, in a recent study of higher density housing built in inner Sydney, Australia, Randolph inferred that insufficient attention was given to support families living in this type of accommodation.[64] He noted that while families were under-represented in inner-city flats, many families were attracted by the amenity and affordability of inner-city apartments, which were too small to

comfortably accommodate them. He called for future higher density housing developments to have a minimum percentage of housing large enough to accommodate families. He also suggested family accommodation should be co-located, to help provide social support and a sense of community for family residents.

The amenities provided within and near higher density housing may also help mitigate the effects of density on residents. Although only limited evidence is available, a longitudinal study of older adults in Tokyo (one of the most densely populated cities globally),[43] suggested that providing an enriched environment can lessen the effects of high-density living. In this study, perceived access to walkable green space increased the five-year survival rate of participants.[43] Ecological evidence suggesting that mortality due to site-specific cancers may be increased in higher density areas is worthy of consideration. While the pathways are inconclusive, exposure to pollutants and a built and food environment that does not support more intensive physical activity or healthy diets are plausible explanations. Further research that redresses methodological weaknesses in the evidence base is warranted. However, there is merit in ensuring that higher density neighbourhoods have access to adequate recreational facilities and cycling infrastructure to encourage more vigorous forms of physical activity. There should also be good access to fresh fruit and vegetables.

Evidence suggests that traffic fatalities are negatively associated with density, and higher density areas are associated with increased risk of pedestrian fatalities and injuries, particularly in children. As cities intensify, environmental modifications are required to reduce the risk of pedestrian injuries. This includes separating pedestrians from vehicles, increasing the visibility of pedestrians to drivers, and reducing vehicle speeds. A variety of techniques can be used to slow traffic including:

- narrowing traffic lanes

- curved or zigzag roadways

- raised intersections

- speed bumps; and

- the creation of a 'woonerf' (i.e. street for living) that reduces motor vehicle speeds to walking speed.[63]

Ensuring that higher density housing is located away from traffic, with access to nearby play areas and parks, appears to be important. Further investigations into how to reduce the risk of pedestrian injuries in higher density areas is warranted.

5.5   Summary of the impacts of density on mortality

The evidence reveals an inconsistent relationship between density and mortality. Moreover, where there is insufficient adjustment for confounding variables, it is likely that 'density' is simply a surrogate for SES. In studies that have been fully adjusted for confounders there is little evidence that density is associated with mortality. Notably, some studies point to increased density being protective in some adult sub-groups. However, the relationship between all-cause mortality and crowding is more consistent, with increased levels of crowding being associated with higher mortality.

For CVD mortality, increased density appears to have a protective effect as it can promote mediating lifestyle factors, such as walking and cycling. However, some inconsistent evidence exists, as it is difficult to separate the impact of density from issues related to SES. To minimise CVD mortality, it is important that urban densification does not lead to an increase in environmental stressors, such as air pollution and high levels of traffic, as these factors are associated with increased CVD mortality.

The relationship between density and cancer mortality is also inconsistent. A few studies have identified positive associations between population density and total cancer mortality and colon cancer in males and females. Studies have also identified a positive association between population density and breast cancer in women. However, there has generally been inadequate adjustment for confounders such as SES in these studies. Again, exposure to environmental stressors and factors that detrimentally affect lifestyle choices (e.g. fruit, vegetable and red meat intake, smoking), rather than density *per se*, may contribute to the aetiology of some cancers. This highlights the need for careful consideration of the location and design of density.

Studies consistently reveal an inverse relationship between density and road traffic accident mortality; however, few studies examine intra-urban differences, focusing instead on urban-rural comparisons. Studies examining intra-urban variation indicate that compact cities are protective against pedestrian and vehicle occupant fatalities, whereas sprawling cities increase the risk of accidents. It is plausible that in higher density neighbourhoods trips are shorter and traffic travels at slower speeds. However, in higher density environments with local shops and services, there are likely to be more pedestrians and cyclists circulating (including children and young people), and this could increase the risk of injury. Although increased population density appears protective against road traffic accident mortality, it should occur in tandem with access to walking and cycling infrastructure, traffic moderators and services nearby. These measures are particularly important to decrease the risk of pedestrian fatalities in children.

6. The impact of density on respiratory health

A small number of studies have investigated the direct effects of density on respiratory health. These studies examined the association between allergens and population and household density,[65] and asthma prevalence and population density.[66,67] More commonly, the potential indirect effects of density on acute and chronic respiratory illnesses have been studied in relation to traffic density,[68-70] air pollution exposure,[71-73] and asthma-related hospitalisations and the degree of urbanisation.[74]

6.1 Asthma

There is growing awareness that urbanisation is associated with increased risk of asthma; however, the exact nature of the relationship is unclear.[190] A Swedish cross-sectional study of asthma and population density observed that for each increase of 100 residents per square kilometre, the prevalence of asthma increased by 2%.[67] However, there are various pathways through which asthma might be affected.

A potential pathway through which higher density housing increases asthma risk is through exposure to allergens. Allergens produced by dust mites, cockroaches and pets play a significant role in the causal pathway of asthma and its exacerbation.[191-194] Thus, higher density housing and crowding might increase the risk of asthma by increasing residents' exposure to allergens. A US study by Leaderer et al. found a significant positive association between population and household density and cockroach allergens, but a significant inverse association between population density and dust mite allergens.[65]

There are likely to be other indirect pathways that explain the relationship between higher density housing and asthma, such as its location. For example, a US study investigating adult asthma by degree of urbanisation in six Pennsylvanian counties showed a non-linear relationship between asthma-related hospitalisations and urbanisation.[74] In this study, asthma-related hospitalisations were highest in areas with both high and low urbanisation, while in areas of moderate urbanisation, hospitalisation due to asthma was lowest. This curvilinear relationship could suggest two different mechanisms are operating to increase asthma hospitalisations. In highly urbanised areas, exposure to high levels of traffic and air pollution might increase asthma risk, while in rural areas exposure to environmental agents may be implicated. Nevertheless, this study had a number of methodological problems which limits confidence in its findings, relating to: (1) the construction of its urbanisation measure; and (2) insufficient control for confounding variables. Despite these methodological flaws, the findings suggest that an indirect pathway through which higher density housing might be associated with asthma is via exposure to traffic. This is affected by the site location and the design of higher density buildings (e.g. balconies and/or windows facing high traffic roads).

Air quality related to local vegetation may also affect asthma in people living in higher density housing. A New York study investigating the relationship between asthma and street trees found that population density was positively associated with asthma prevalence in children aged four to five, but not hospital admissions due to acute asthmatic episodes.[66] However, street tree density was inversely associated with asthma prevalence (i.e. more trees per street segment appeared to be protective against asthma prevalence, although it was not associated with asthma-related hospital admissions). The authors and others[195] have highlighted the methodological weaknesses of this study, not least of which was whether the trees themselves reduced the risk of less severe asthma, or whether the presence of trees encouraged more physical activity, which is protective of asthma. Nevertheless, if these findings were replicated in longitudinal studies, it would suggest that planting low-allergen trees near higher density housing may be beneficial.

With the exception of studies focused specifically on building-related allergens, all other studies suggest that, from a respiratory health perspective, it is critical to consider the location of higher density housing. This point is particularly relevant when the impact of traffic exposure and respiratory health is considered.

6.2   Traffic density and proximity to traffic

The relationship between traffic exposure and poor respiratory health is well documented. Studies show that, compared with children with less exposure to traffic, children attending schools in areas with more traffic,[70] or living within 200m of a major road with heavy traffic (> 24,000 vehicles/day),[69] have:

- reduced pulmonary function (measured by forced vital capacity [FVC])

- more respiratory symptoms (e.g. recurrent wheezing and dyspnoea [shortness of breath])

- increased point prevalence of the common cold[70]; and

- more asthma-related hospital admissions.[69]

A German study of young people who self-reported the frequency of truck traffic and traffic noise showed that traffic density was positively associated with respiratory symptoms such as wheezing and allergic rhinitis.[68] Of course, the major factor contributing to the impact of traffic on respiratory health is exposure to air pollution. There is considerable evidence of the impact of air pollution on respiratory health.

6.3   Air pollution

In Australia, 1% of the burden of disease and injury is attributed to urban air pollution.[141] Urban air pollution varies by location, with particulate matter accumulating at traffic lights, where air flows are interrupted and vehicles idle. Urban air pollution therefore concentrates near major heavily trafficked and congested transport arteries.[196] Evidence shows that

people living on or near busy roads (i.e. within 300 m) are exposed to significantly higher levels of pollutants, including particulate matter, carbon monoxide and nitrogen oxide (NO).[197,198] Moreover, numerous meta-analyses report a relationship between air pollution exposure and a range of health impacts including:

- asthma onset in childhood[199]

- asthma exacerbation[199,200]

- non-asthmatic respiratory symptoms[199,201,202]

- impaired lung function[199,203,204]

- cardiovascular mortality and morbidity[56,199-201,203]

- all-cause mortality[200,203,204]

- hospital admissions[203]; and

- restricted physical activity.[203]

Moreover, associations are seen even at the relatively low pollution levels observed in Australia.[205,206]

A statement by the American Thoracic Society concluded that exposure to air pollution was associated with a number of conditions, ranging from severe illness to minor irritations, including:[207]

- increased mortality and incidence of cancer

- worsening of disease in people with existing cardiopulmonary illness

- increased incidence of asthmatic attacks, lower and upper respiratory tract infections that may or may not interfere with normal activity

- decreased lung function as assessed by forced expiratory volume in one second (FEV1) and/or FVC

- increased prevalence of wheezing and chest tightness and cough and/or phlegm requiring medical attention; and

- eye, nose and throat irritations that may interfere with normal activity if severe.

Notably, research highlights that exposure to air pollution impacts children's respiratory health. For example, a San Franciscan study of school children found that higher levels of air pollutants including black carbon (BC) and nitrogen oxides (NO_x) were found in schools within 300 m downwind of a major traffic source, compared with schools upwind or further away.[72] After adjustment for known confounders, the investigators found a positive association between particulate matter with a diameter of less than 2.5 μm ($PM_{2.5}$), NO_x, NO and BC and self-reported bronchitis in children in grades three to five, but not with physician-

confirmed asthma. In stratified analyses, the effects were stronger in girls but non-significant in boys. These findings support an earlier stratified study in the Netherlands which found that self-reported wheeze, breathlessness with wheeze, and the use of respiratory medication was significantly associated with living in neighbourhoods with higher estimated pollution for girls (aged 0–15 years), but not for boys.[73] Other respiratory illnesses, such as dyspnoea, asthma diagnosis, chronic cough, and allergy, were examined but were not significant. Furthermore, a German study[71] of young children also found that exposure to $PM_{2.5}$, $PM_{2.5}$ absorbance (a diesel exhaust marker) and nitrogen dioxide (NO_2) were significantly associated with both cough without infection and dry cough at night for children under 12 months. Exposure to $PM_{2.5}$ and NO_2 was associated with dry cough at night for children in the first two years of life. Contrary to the studies reported above, a stronger effect was observed for boys than girls (the findings for girls attenuated after gender stratification).

6.4 What can be done to mitigate the effects of exposure to environmental stressors and improve respiratory health and comfort?

Manipulating building and environmental factors has the potential to mitigate the effects of exposure to environmental stressors. Figure 6.1 illustrates how building and location factors can affect respiratory health.
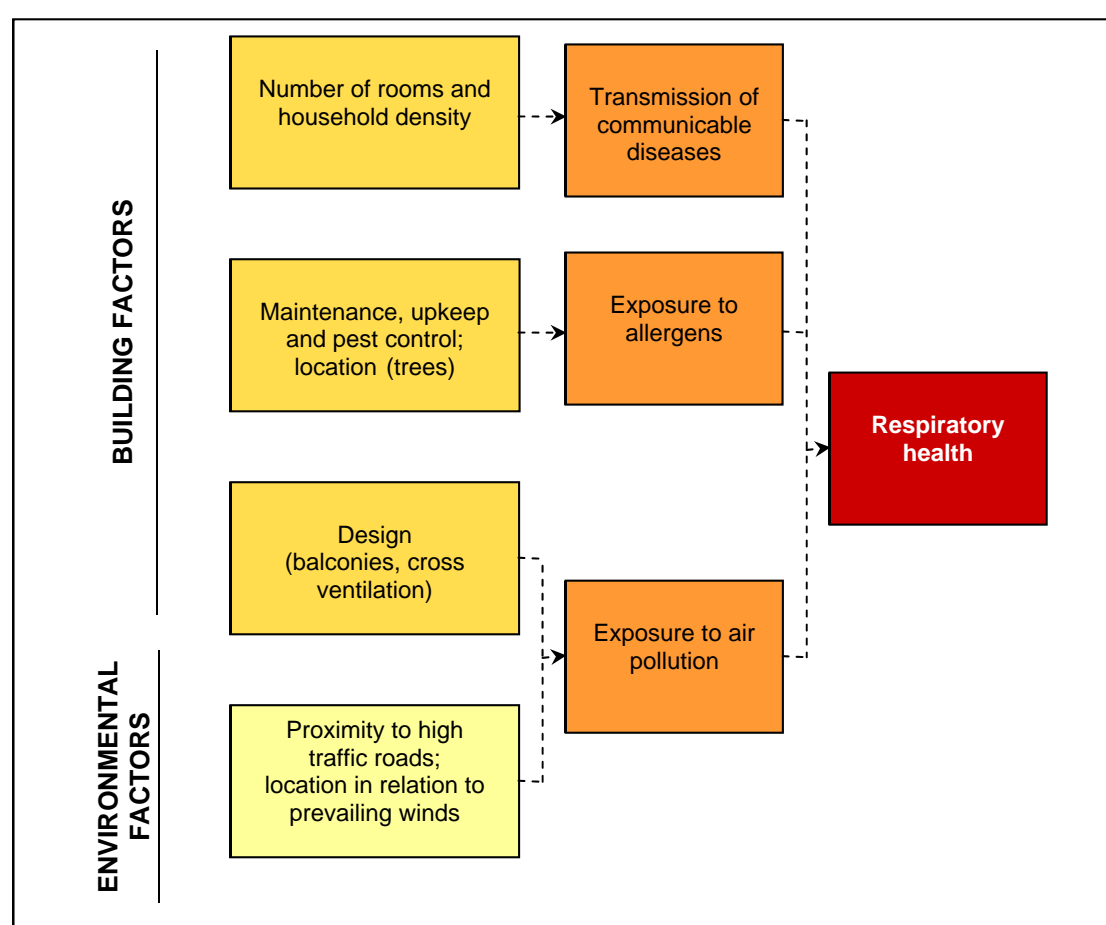
Figure 6.1 Building and environmental factors that impact respiratory health

Many strategies can lessen exposure to allergens and pollutants, with the aim of preventing exposure to environmental stressors, and to improve respiratory health and comfort. The strategies listed below outline factors to be considered when choosing the **location** and **design** of higher density housing, as well as policies that minimise exposure to environmental stressors, including:

- Locating residential centres, including higher density housing, away from roads with heavy traffic.[123]

- Diverting traffic away from cities and higher density housing, and encourage the use of active alternatives through the provision of public transport,[75] and pedestrian and cycle networks and infrastructure. Car and bike share schemes may also assist.

- Minimising the impact of traffic that travels through higher density areas by introducing schemes that:

    ▪ encourage the scrapping of old vehicles (e.g. www.abc.net.au/news/stories/2010/07/24/2963130.htm)

    ▪ restrict the use of high-emission vehicles in urban areas

    ▪ replace buses and taxis with 'clean fuel' alternatives; and

    ▪ tighten emissions standards for new vehicles.[75]

- Considering restricting scooters and vehicles with two-stroke engines near higher density housing. While these vehicles may be appealing because they are inexpensive to run, they are often noisy and pollute the environment.

- Avoiding building designs that position balconies, windows and draw points for air-conditioners towards heavily trafficked or congested roads and intersections where motor vehicles idle (see Figure 6.2).

Most people prefer natural ventilation over air-conditioning[76] provided it does not introduce noise or air pollution. Therefore, thoughtful design is required for cross-ventilation that heeds local wind, weather and topological features.[76] This could reduce reliance on air-conditioners, leading to a commensurate decrease in energy consumption.

Figure 6.2 Housing with balconies and windows overlooking roads carrying heavy traffic, in areas where there is traffic congestion and intersections where motor vehicles idle

(Source: Billie Giles-Corti)

6.5 Summary of the impacts of density on respiratory health

Consistent evidence suggests that proximity to busy roads, high traffic density and increased exposure to pollution are linked to a range of respiratory conditions. These conditions can range from severe illness (i.e. a higher incidence of death) to minor irritations (i.e. a respiratory tract irritation). Moreover, these respiratory health impacts affect all age groups.

Nevertheless, the strength of the evidence varies, and the exact nature of the relationship between traffic pollution and proximity to main roads and respiratory health is unclear. These studies have some methodological limitations, including the misclassification of exposure and self-selection (i.e. people most affected by air pollution may move away). In both instances, these limitations dilute the relationship between traffic pollution and respiratory illness.

Higher density housing has the potential to benefit respiratory health by providing the critical mass of people necessary to justify investment in frequent, accessible public transport, ensuring viable alternatives to private vehicles. Moreover, when higher residential density is near retail and other essential services, it can reduce reliance on vehicular transport and maximise active transport modes. However, the impact of higher density housing on respiratory health relates to its design and location. When considering the building and location of higher density housing in relation to respiratory health, a number of factors should be considered:

- locating residential developments away from major roads that carry high traffic volumes[68-70]

- considering local prevailing winds and topographic characteristics to avoid building higher density housing downwind of busy roads that carry high traffic volumes[72]

- locating residential developments in areas where there is sufficient and regular

public transport,[75] and infrastructure that supports other forms of active transport (e.g. walking and cycling)

- locating higher density housing in leafy areas,[66] but ensuring low-allergen trees are planted near higher density housing; and

- designing buildings and apartments to maximise natural airflow,[76] and ensuring that balconies and air-conditioner draw points do not overlook roads with heavy traffic.

7.   The impact of density on mental health

Studying the impact of the built environment on mental health is a complex and relatively new field.[77,78] Freeman warns that, 'it would be wrong … to make simplistic statements', for example, '… that high-rise housing causes depression', because there are multiple etiological and contributing factors.[81] Nevertheless, even discounting the sociodemographic characteristics of residents, living in higher density housing does appear to have a range of potential direct and indirect influences on mental health. Importantly, some of these impacts appear to be influenced by the location, design, and construction of higher density housing.[77-79] Individually and collectively, these factors appear to directly influence mental health by exposing residents to environmental stressors, or indirectly influence mental health by impacting activities of daily living and social interactions between residents. Moreover, the incidence of social incivilities (including crime) in the building itself and surrounding areas can affect residents' fear of crime. This, in turn, can affect their sense of control, and result in social and physical withdrawal. These complex factors are considered in this section, which draws heavily on several comprehensive reviews of mental health and the built environment[78,79] and housing,[77,78] as well as a range of specific papers published in this field of study.

7.1   Direct impacts of higher density housing on mental health

Crowding, noise, indoor air quality and light appear to directly influence mental health, as shown in Figure 7.1.[78] The location, construction and design of higher density housing directly affects each of these environmental stressors. According to Freeman, there appear to be two main mechanisms through which environmental stressors affect mental health: a physiological and a psychological coping response.[81] While acute exposure to relatively minor environmental stressors can be transiently stressful, continual exposure to ongoing noise, pollutants or crowding can result in chronic stress, which has important implications for mental health.[79]
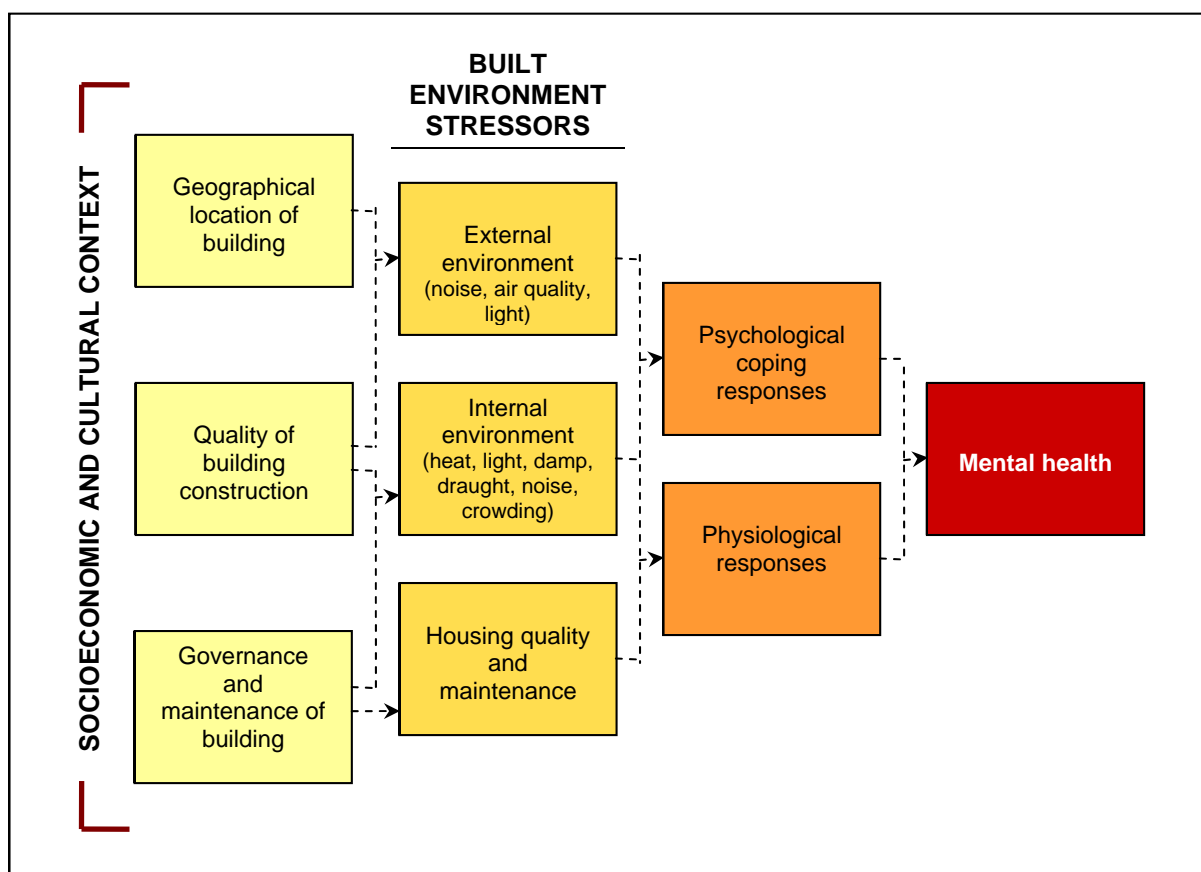
Figure 7.1 The direct effects of the built environment on mental health

(Modified from Halpern[79])

7.2 Noise

Noise can affect mental health by causing annoyance which, in turn, causes stress. However, the extent to which individuals become annoyed is affected by their level of sensitivity, and how they attribute or appraise the meaning of the sound. This varies between individuals.[79] Halpern suggests that the perceived information conveyed by a noise is the cause of the irritation, rather than the noise itself.[79] Thus, noise from neighbours can be perceived as more 'annoying and intrusive' than objectively louder impersonal non-human sounds (e.g. the sound of a train).

A review by Evans, Wells and Moch suggests that most studies on the impact of noise and mental health relate to airport noise.[77] Few studies have examined the impact of noise from neighbours or traffic. An English study of residents in low socioeconomic areas found that, after adjustment for a range of other built environment elements and sociodemographic factors, noise from neighbours was one of several factors that predicted poor mental health outcomes.[208] Similarly, a study of Austrian children exposed to traffic noise from roads and trains found a dose–response relationship between noise and psychological distress.[209] Traffic noise may also impact residents' physical health. A longitudinal study of older adults in mega-city Tokyo found that men (but not women) who reported no trouble with traffic noise lived longer than others.[43] Furthermore, living within 200 m of a busy road is a risk

factor for admission to hospital due to any cause,[69] and is associated with other health effects including psychological stress and vulnerability to disease and illness. Thus, the impact of noise on the mental health of residents of higher density housing is likely to be partly related to the building's location (e.g. whether or not it is on a road with heavy traffic), and partly to its construction and insulation, which affects the amount of noise transfer between the outdoor environment and also between neighbours.

7.3   Housing quality

Poor-quality housing appears to be associated with greater psychological distress.[78] In their comprehensive review on housing and mental health, Evans, Wells and Moch[77] reviewed 27 studies related to housing quality and mental health in adults. Studies with a wide range of housing quality measures (e.g. structural deficiencies, cockroach and rodent infestation, dampness and mould) and mental health outcomes (e.g. neurotic conditions, emotional and psychological distress, anxiety, depression, alienation and isolation) were included. Nearly half of the studies involved participants from social housing or lower socioeconomic backgrounds. Irrespective of how housing quality was conceptualised or measured, it was positively associated with psychological wellbeing. The authors noted that a major limitation of the evidence base to date is that housing quality is measured by self-report. However, the review included three studies that assessed housing quality using trained assessors,[210-214] and these findings were consistent with the self-report studies (i.e. that housing quality is associated with mental wellbeing). Another methodological issue that affects studies of this type is self-selection (i.e. that people with a mental health illness are more likely to live in sub-optimal housing rather than sub-optimal housing influencing their mental ill health). However, the review included six longitudinal studies of low-income study participants who were relocated to new or public housing. Although some of these studies had small samples,[215,216] in each case there was some improvement immediately following relocation to a higher quality environment, and even with longer-term follow-up.[79,211,217-219]

The question arises whether these types of studies would be relevant in Australia. The review by Evans and colleagues[77] included only one Australian study, which examined self-reported housing discomfort and psychological stress. However, its findings were consistent with studies undertaken elsewhere: perceived housing quality predicted psychological distress.

In summary, there appears to be consistent evidence from both cross-sectional and longitudinal studies that housing quality is associated with psychological health, and that living in higher quality housing located in higher quality neighbourhoods is beneficial to mental health.

7.4   Building governance and maintenance

The quality of higher density housing is affected by its governance and maintenance. Thus, building governance and maintenance in higher density developments can indirectly impact the mental health of residents by creating either a functional or dysfunctional living environment. This can either enhance or reduce residents' sense of control and safety. For example, living in deteriorating neighbourhoods has been shown to have both direct and indirect effects on stress and depressive symptoms.[80] Kruger suggests that exposing residents to potentially dangerous conditions has a direct impact.[80] Indirect effects relate to the stresses stemming from perceived insecurity and crime, high resident turnover and/or living in an area with declining property values. The impact of fear of crime on mental health is considered in *Section 7.8: Insecurity: crime and fear of crime*. This section considers building governance, in terms of its impact on maintenance and residents' control of stressors such as noise.

The importance of governance and building maintenance is highlighted by Freeman[81] who describes how substandard maintenance of higher density housing impacts on residents, particularly people of low SES. Freeman notes a tendency to underestimate the maintenance costs associated with living in high-density accommodation (e.g. for elevator maintenance). He suggests there needs to be sufficient funds to indefinitely maintain the building, including all the mechanical features required to keep high-rise housing functional, the cleaning of communal areas and the policing of crime.[81] With inadequate maintenance, essential services soon break down, and tenants are generally powerless to repair these themselves. Freeman (1993) refers to a 'cycle of environmental deterioration' which is shown in Figure 7.2. As the quality of the environment deteriorates, incivilities such as vandalism, crime and disorder tend to escalate. Families with sufficient resources move out, and those with fewer social assets move in, continuing the cycle of deprivation.
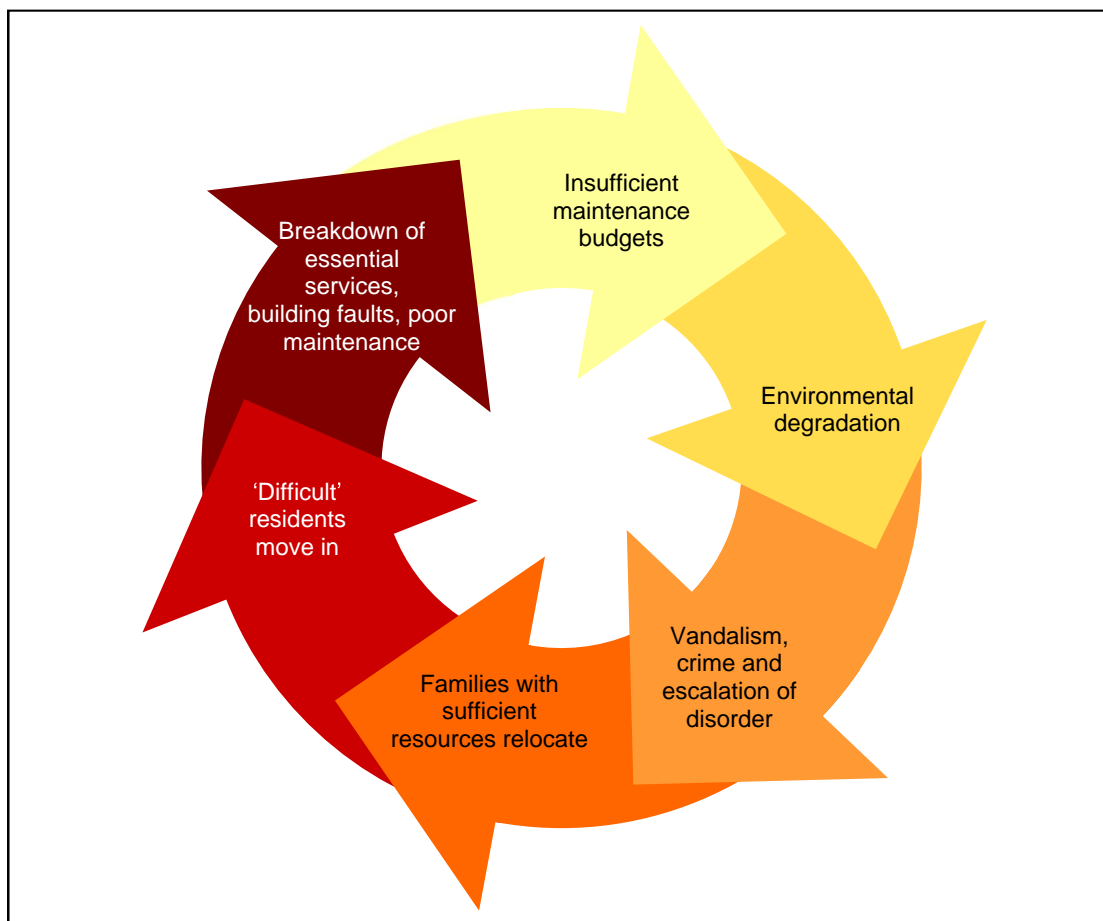
Figure 7.2 The cycle of environmental deterioration[81]

7.5 Indirect impacts of higher density housing on mental health through psychosocial processes

The built environment can indirectly impact mental health through its influence on a range of psychosocial processes known to be associated with mental health outcomes (see Figure 7.3).[78,79] Built and social environment factors that appear to influence mental health outcomes through a range of social processes include:

- the floor level of the residence

- environmental factors that stimulate crime or fear of crime (e.g. lack of natural surveillance, vandalism); and

- the presence or absence of local recreational facilities (i.e. 'escape' facilities).

These factors have the potential to be restorative or to encourage social participation, which enhances social support and a sense of community, and are protective of mental health. Moreover, safe buildings and neighbourhood environments that are free of crime and disorder increase individuals' sense of personal control, which is also associated with mental health.

In their review of housing and mental health, Evans, Wells and Moch[77] considered 18 studies comparing the type of housing on a range of mental health outcomes. Generally,

they found that residents of high-rise housing had more mental health problems than those living in low-rise or single-detached houses. Nevertheless, a major flaw in the evidence reviewed was that many studies failed to adequately control for confounding variables. For example, SES is associated with both poor-quality housing and mental health, and sub-standard housing typically located in low-income neighbourhoods. Five of the studies reviewed, however, compared residents living in high- and low-rise apartments. The studies showed that people living in high-rise housing were more likely to:

- feel alienated[220]

- have less social support[221,222]

- be less socially involved[221,222]

- have less sense of control[222]; and

- encounter more people.[223]

However, a study of apartment **owners** (rather than renters) found no difference in the social support of residents of high- and low-rise buildings, although high-rise residents encountered more people and more strangers.[223] Thus, the impact of higher density housing on mental health may relate to:

- the other people who live in the housing and their socioeconomic status

- the floor on which people live, which may affect the quality of the living environment; and

- the level of social interactions and social support.
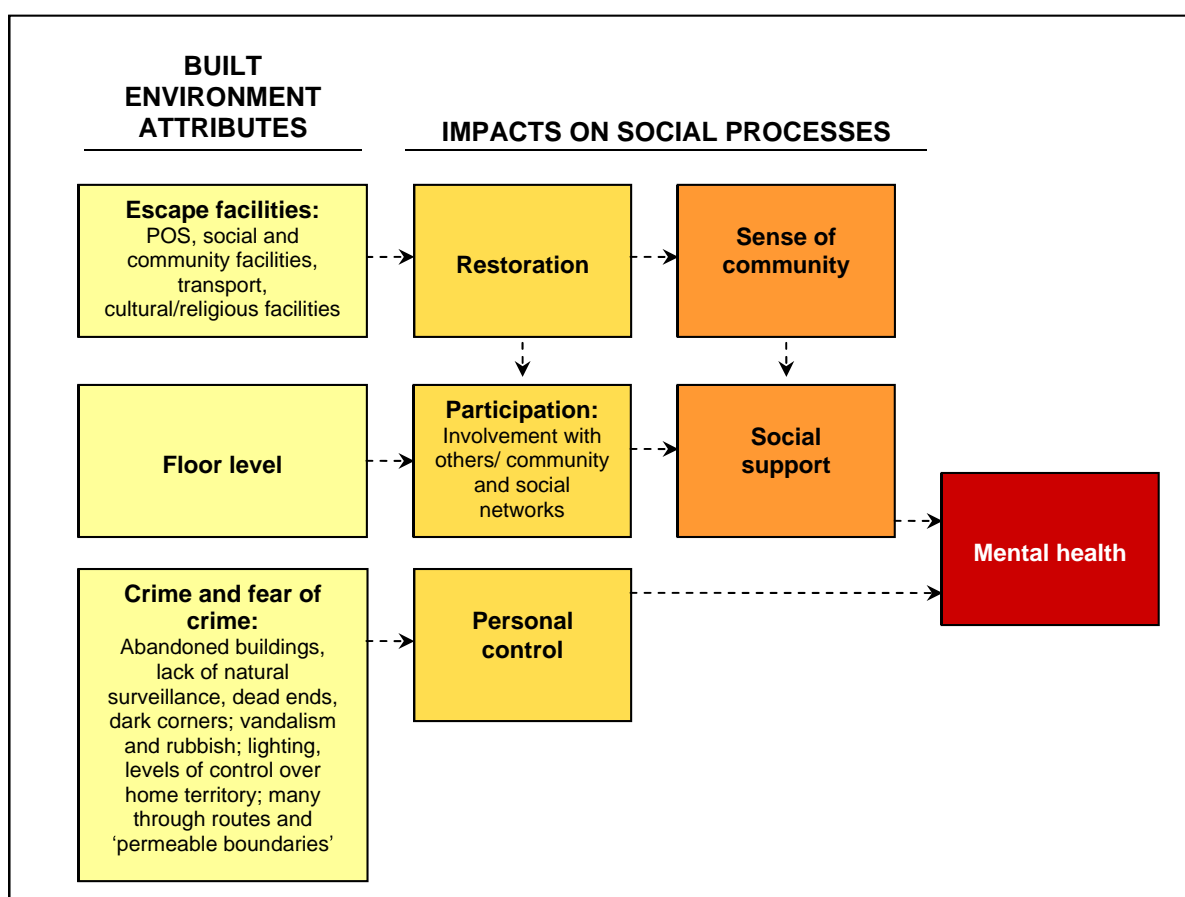
Figure 7.3 The indirect effects of the built environment on mental health

(Modified from Halpern[79])

7.6   Floor level

The floor level on which people live appears to have an impact on their ability to interact with others. Thus, floor level in high-rise housing appears to be associated with mental health outcomes, and people living on higher floors, particularly stay-at-home women with children, are more at risk. In their review of housing and mental health, Evans, Wells and Moch[77] reported that six of the eight studies reviewed found adverse mental health outcomes associated with living on higher floors. Contributing factors included anxiety about accidents and falls, particularly for parents of young children and the elderly, and a lack of social networks. For example, stay-at-home mothers with young children appeared to be most vulnerable when living in high-rise housing. The authors hypothesised a number of plausible explanations for the findings including social isolation, a lack of play spaces for children, and an inability to allow children to play outside. A Canadian study of residents of public housing developments found a strong positive interaction between gender and floor level. The study also showed greater psychological strain in women, but difficulties associated with child supervision, confinement and social isolation only partly explained this relationship.[224] Thus, other factors appeared to be at play. For example, it is possible that living on the upper floors of buildings reduces residents' connection with the neighbourhood and other residents. A Dutch study found that what differentiated residents of high (more than or equal to four

storeys) and low-rise (fewer than four storeys) housing was their sense of community, which appeared to be related to levels of social support rather than frequency of interactions (which did not differ significantly).

Given that the development of social networks and the availability of social support are protective of mental health, it is plausible that two mechanisms are at play in higher density housing that may impact mental health, as shown in Figure 7.4. One mechanism relates to **enforced interactions**, which people find stress-enhancing because they are unable to avoid others, while the other relates to **insufficient interactions**, which are required to develop and maintain social networks. It appears that providing opportunities for 'selective interactions' is important.
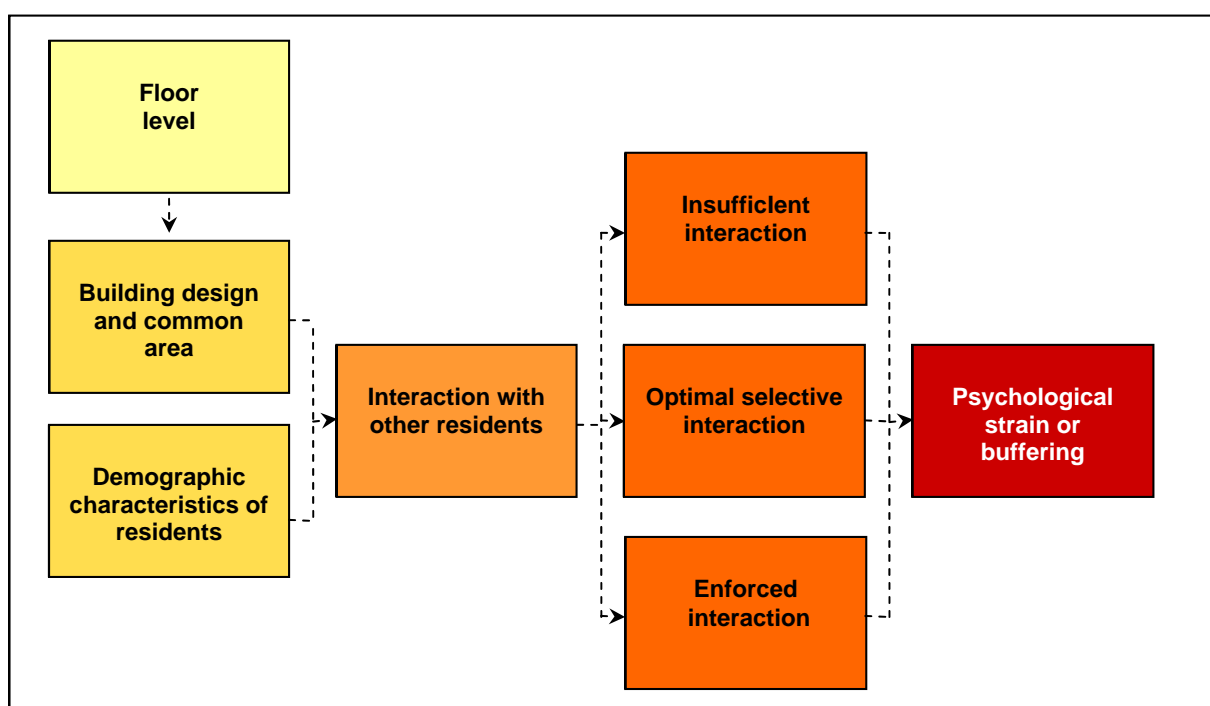
Figure 7.4 Hypothesised mechanism through which floor level influences mental health outcomes in residents

Overall, the evidence on the impact of floor level is indicative rather than conclusive, and suggests that certain adult sub-groups are more at risk, including mothers who don't work outside the home and lower socioeconomic groups.[77,78] However, the inconclusive nature of the research is mainly due to methodological issues that affect density studies generally, including those examining the role of floor level.[77,78] For example, due to the cross-sectional nature of the evidence base, self-selection cannot be ruled out (i.e. people with poorer mental health may tend to live on higher floors). Other methodological issues identified by Evans and colleagues related to length of exposure; for instance, residents on specific floors may have longer tenure than others.

Despite these limitations there appears to be sufficient evidence to warrant caution that high-rise housing (i.e. over four storeys) may increase the risk of mental health problems for people living on the higher floors; however, the impact is likely to depend on who lives in the building, as well as its design and facilities. Importantly, as noted by Freeman, people from low socioeconomic groups with 'below average social assets' may struggle in high-rise housing.[81] Unlike people from high socioeconomic groups, they do not have the 'safety valves of holidays, outdoor sports or car travel' nor do they necessarily live in neighbourhoods with local 'escape facilities' such as attractive POS, which is restorative.[81]

In the 1970s, after conducting a comprehensive study of high-rise housing and disadvantage, Newman concluded that higher density housing for lower socioeconomic families should be restricted to walk-up buildings of no more than three storeys.[225] Importantly, to protect the mental health of these residents, higher density housing should be designed to provide opportunities for 'selective' rather than 'enforced' interactions with other residents. Figure 7.5 shows an example of a community garden in a public housing development that provides opportunities for 'selective' positive interactions between residents. Other examples include men's sheds and play areas for children (see Figure 7.6 for a roof-top play area for children). In this regard, Newman's study was also instructive in that he concluded that building entries and vertical and horizontal circulation corridors should be designed so that as few families as possible share a common lobby.[225] This approach to design increases the sense of control for residents and reduces disorder, both of which are related to mental health impacts.

Figure 7.5 Western Region Health Centre older persons higher rise program, Floyd Lodge community garden

(Source: Western Region Health Centre)

Figure 7.6 Secure roof-top play area for children in New York City

(Source: Billie Giles-Corti)

7.7 The location of higher density housing and quality of the local neighbourhood

As previously indicated, the location of higher density, together with building design, is a key factor influencing mental health. The location affects the extent to which residents are exposed to environmental stressors, and the building design reduces or enhances the impacts of a sub-optimal location (e.g. exposure to noise or air pollution).

However, the location of higher density housing also affects access to neighbourhood resources, which indirectly impacts on residents' quality of life. Lee and Ewing proposed that five Ds were required to encourage active modes of transport: density, destinations, distance to transit, destination accessibility and design.[173,181] With some modification, this framework may equally apply to the broader needs of residents of higher density housing, in terms of determining the level of amenity, safety and quality of local neighbourhoods. Figure 7.7 summarises the key attributes necessary to promote healthy density, from safe, quality accommodation with access to employment at its base, through to attractive aesthetics at its peak.
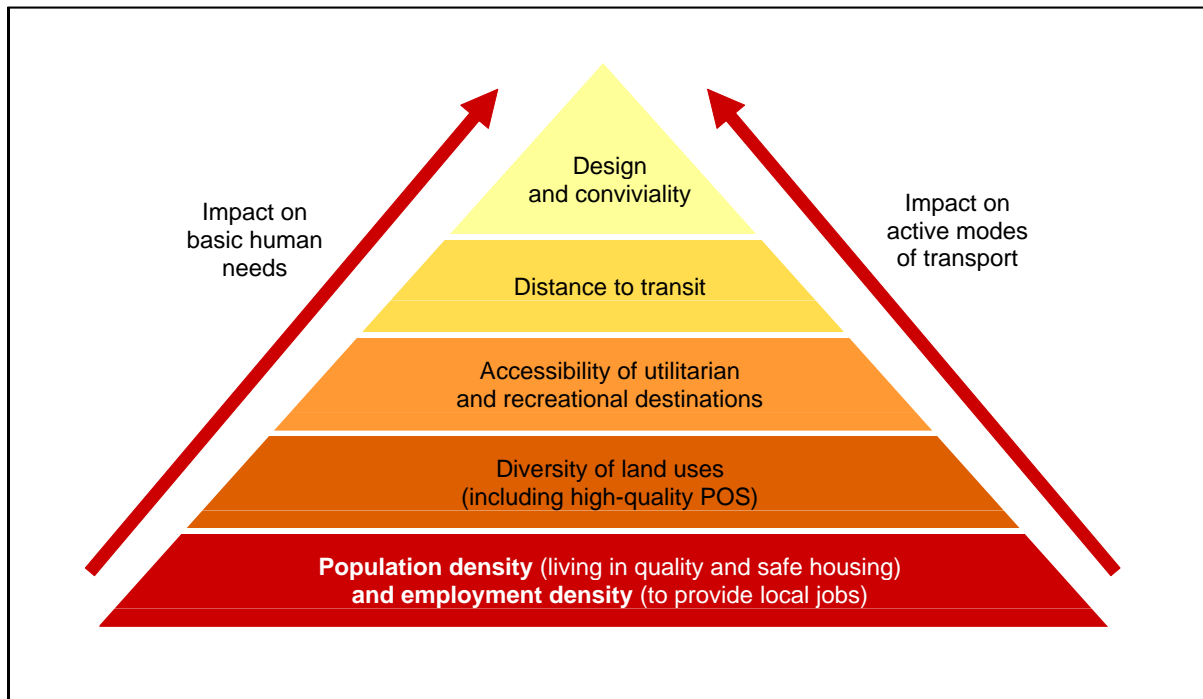
Figure 7.7 Hierarchy of factors required to meet the needs of residents living in higher density neighbourhoods

The presence of local facilities and services, combined with the neighbourhood's overall attractiveness, can affect residents' satisfaction with their home and neighbourhood. Neighbourhood satisfaction has been widely studied in the housing literature and is closely aligned with mental health. A high level of neighbourhood satisfaction is said to increase residents' sense of community, and vice versa.[82] A sense of community has the potential to enhance mental health by increasing social ties. For example, being more satisfied with one's neighbourhood reduces the urge to relocate, which in turn increases quality of life,[82] partly by increasing social ties.

The physical characteristics of neighbourhoods appear to be strongly associated with neighbourhood satisfaction. These characteristics include features that encourage pedestrian activity and create opportunities for interactions between neighbours, as well as decrease motor vehicle dependency. Indeed, the importance of reducing exposure to traffic to enhance communities was highlighted in a landmark study by Appleyard. This study demonstrated that residents living on streets with lower traffic had more social interactions and stronger social ties with neighbours than residents living on roads with a higher traffic volume.[83] Moreover, as traffic volumes increase neighbourhood satisfaction is said to decrease.[82]

Although not explored extensively in this review, these findings appear to be borne out in research examining satisfaction with living in higher density housing. A small cross-sectional study found that, for residents of apartments, satisfaction with their home was associated with:

- the perceived attractiveness of their neighbourhood (e.g. the amount of open space and greenery, quietness, nearness to neighbours and friendliness of people)

- the perceived friendliness of the neighbourhood; and

- satisfaction with recreational facilities.[90]

Of particular relevance to this review was the finding that these perceptions were more important predictors of neighbourhood satisfaction for apartment dwellers than residents of other types of housing. A related study found that increased views of forests and landscaping were negatively associated with concerns about local density.[226]

In summary, neighbourhood satisfaction is associated with mental health. It appears to be related to the length of residence, amount of social interaction, satisfaction with traffic, and the neighbourhood's appearance and aesthetic appeal.[82] Nevertheless, to meet the security needs of residents, both the housing and the neighbourhood need to be safe. The importance of actual and perceived safety is considered in *Section 7.8: Insecurity: crime and fear of crime*.

7.8 Insecurity: crime and fear of crime

A number of studies have found that perceptions of crime and feelings of insecurity are associated with poorer mental health,[84,227] particularly for people in deprived areas.[208,228] There are several pathways through which fear of crime or concerns for safety could affect mental health. It can:

- increase anxiety and psychological distress[77,78]

- cause people to constrain their behaviour and reduce participation in social and physical activities that can help promote mental health[84]; and

- reduce feelings of personal control, and the resultant feelings of helplessness are risk factors for poor mental health.[78]

The burden of fears about personal safety is not shouldered equally; rather, it is predominantly borne by those who are physically or ecologically vulnerable to crime.[229,230] For example, women and the elderly feel physically vulnerable to crime, whereas ethnic minorities or lower socioeconomic groups tend to have 'fewer financial resources to protect themselves or their homes against crime' and often live in areas of concentrated deprivation.[230] Fears about crime are also aggravated by either being a direct victim of crime, or hearing about a crime second-hand from a friend or family member.[230]

Evidence suggests that the built environment can influence the incidence of crime and feelings of safety. Globally, there are countless examples of poorly designed higher density housing, particularly the large-scale high-rise housing developments designed for low socioeconomic groups that were demolished after years of crime, disorder and dysfunction.[231,232] Expressions of physical disorder (e.g. litter, graffiti and vandalism) aggravate feelings of insecurity, and this association persists, regardless of whether an environment constitutes 'high density'.[233] For example, even in suburban settings 'mundane' forms of disorder, such as garden upkeep and house presentation, can intensify feelings of insecurity.[234-237] However, urban environments tend to generate more physical disorder, due to the greater volume of people circulating and the presence of non-residential land uses that attract people.[238] Moreover, disorder tends to cluster in lower socioeconomic environments,[239,240] meaning these negative visual cues are often amplified in higher density, low-income neighbourhoods.

Aside from the presentation of neighbourhoods, the physical design and layout of buildings can also influence crime and perceived safety (see Figure 7.8). In a seminal 1970s study, Oscar Newman empirically assessed how the design of higher density housing for low-income residents was associated with crime, disorder and vandalism.[225] By comparing two housing projects with similar populations and social characteristics, but different designs, he illustrated that 'defensible space' characteristics reduced the incidence of crime. The building without defensible space had 50% more crime incidents compared with the high-rise development that had many (but not all) defensible space attributes.

'Defensible space' refers to a range of mechanisms 'that combine to bring an environment under the control of its residents'.[225] It includes real and symbolic barriers, defined areas of influence and opportunities for surveillance. Newman[225] proposed four factors that influenced the creation of defensible space in higher density housing:

1) forming 'territorial influence' zones which re-enforce residents' sense of ownership over a space (e.g. limit the number of people who enter the building entrance and the number of apartments per hallway)

2) designing buildings to enhance natural surveillance by providing opportunities for residents to informally monitor the public areas of their living environment

3) using design to 'neutralise the symbolic stigma' of a housing development (i.e. to reduce any images of isolation and vulnerability of residents); and

4) locating higher density housing in 'safe zones' rather than within or adjacent to areas with 'unsafe' activities.

Figure 7.8 Higher density housing built in New Zealand in the 1990s
(Source: Karen Witten, Massey University[241])

In practical terms, Newman suggested that to create defensible space, attention needs to be given to:

- site design, to reduce anonymity and to create territorially restricted areas for particular buildings

- viewing the buildings and the grounds as an 'organically' interrelated whole, and relating building entrances to territorially defined grounds

- subdividing the city streets to better define blocks and areas (see Figure 7.10, for after school play spaces for children living in high-rise developments in New York City)

- the use of real and symbolic barriers to create 'perceptible zones of transition from public to private spaces', providing cues that one is passing from public to private space, where one's 'presence requires justification'.

Real barriers between the level of the public street and private apartments might include walks and fences, and locked gates and doors. Symbolic barriers could include a short run of steps, tree or shrub plantings or changes to the textural surfaces of walking paths. Furthermore, zones of influence can be created within the building itself. In general, the lower the number of apartments per hallway, units per building and buildings per project, the

better, in terms of creating defensible space that encourages territoriality in residents. For example, when fewer apartments share a corridor, residents tend to develop 'territorial concern' for the space adjacent to their apartment. Newman found that corridors with fewer apartments (i.e. between two and five) had almost half the incidence of crime.[225, p.69]

CPTED considers the ideas of defensible space.[242] The key CPTED principles combine to increase opportunities for natural surveillance and use design and maintenance to distinguish private from public space, signifying a sense of ownership over the space.[85] Research in a suburban setting confirms an association between these CPTED themes (i.e. surveillance, demonstrations of territoriality) and lower odds of physical disorder in adjacent streets.[243] Similarly, CPTED house design characteristics have been associated with less property crime,[86] and house and street maintenance, which results in greater feelings of safety.[234-236]

Neighbourhoods with higher residential densities tend to have more shops and facilities to service the local population, and these destinations have been associated with crime. Environmental criminologists assert that safe neighbourhoods are characterised by greater land-use homogeneity, with less mixed use development, more single-family housing, and restricted vehicular and pedestrian access.[244,245] The basic premise is that street layouts that facilitate vehicular and pedestrian traffic circulation, and the land uses that attract this traffic, are associated with more crime. For instance, property crime tends to occur near destinations that attract both locals and visitors (e.g. shopping centres, transport nodes).[246-249] In contrast, personal crimes typically occur in the home or in the vicinity of drinking venues.[250,251] Many published studies emphasise an association between destinations (e.g. grocery or convenience stores, vacant lots, hotels and motels, alcohol sales, public high schools) and crime.[245,252-256] But there is also evidence to the contrary, suggesting that some land uses, which provide venues for positive social interaction (e.g. recreation centres), can help minimise crime.[250] This highlights some complexity in the relationship between density, land use and crime. In general, many criminal offences are a function of the volume of people circulating in an area. For example, a large volume of pedestrian traffic can conceal relatively minor crimes (e.g. pickpockets, drug sales), but protects against more serious offences.[257]

In summary, there are a number of pathways through which crime, and fear about crime and safety, can affect mental health. First, it can increase anxiety and psychological distress. Second, it can cause people to constrain their behaviour and reduce participation in the social and physical activities that can help promote mental health. Finally, fear of crime can reduce feelings of personal control, and the resultant feelings of helplessness which are risk factors for poor mental health. Higher density housing with higher population densities, particularly located near shops and services, is likely to increase the incidence of crime and disorder – simply because there are more people circulating in the area. However, the

introduction of CPTED features within buildings (e.g. territoriality and natural surveillance), as well as the local neighbourhood, is likely to decrease the incidence of crime and disorder. Decreasing the incidence of crime, and increasing feelings of safety, is important from a mental health perspective. People who are fearful are more likely to:

- feel anxious and experience psychological distress

- constrain their behaviour and reduce participation in social and physical activities that are protective of mental health; and

- have reduced feelings of personal control and feelings of helplessness.

Thus, designing buildings and neighbourhoods to create safer environments is important from a safety perspective, and also from a mental health perspective.

7.9   Access to green space

Cross-sectional studies show that access to natural or 'green' environments including vegetated areas, such as parks, open spaces, and playgrounds, is associated with a range of health benefits, as well as mental health outcomes and factors protective of mental health.[63,87,88] A small number of studies have specifically considered the impact of green space in higher density areas.

As noted earlier, a longitudinal study in Japan found that older people who lived near walkable green spaces had higher survival rates compared with others.[43] Other studies found that the amount of green space in a neighbourhood is associated with better perceived general health,[258] and higher perceived general health status.[259] An English cross-sectional study found that, after adjustment, the presence of green space and community facilities (along with space within the home and feelings of safety) protected mental health in residents of deprived areas, independent of the level of perceived crowding.[208]

The perceived importance of POS to residents of higher density housing is evident in studies examining 'willingness to pay' for this privilege. A Scottish study of real estate prices of housing near POS[89] highlights how much green space is valued by apartment dwellers with the ability to pay. This study found that sale prices within 800 m of city parks were increased for higher density housing compared with lower density housing. For example, sale prices for flats on a park's edge were almost 18% higher than an equivalent flat 800 m away from the park. These findings were not observed for other housing types. The researchers concluded that POS is more important to people living in higher density housing compared with others because it substitutes for the private space available to residents of low-density housing. Moreover, Gruber and colleagues found that neighbourhood attractiveness (including the amount of green space) was the most important correlate of housing satisfaction in apartment dwellers, and much more so than for residents of other types of housing.[90] Housing and neighbourhood satisfaction is an important factor influencing mental health.

While access to POS provides population health benefits, similarly **private open space** also confers health, social and environmental benefits. Private yards and gardens provide sites for child rearing, social and recreational activities, and space for home food production. They offer visual amenity, ensure access to natural light and ventilation, provide shade, and help with cooling and water drainage.[260] Australians have a strong connection to their private gardens and backyards; however, functional private space has dwindled in many new suburbs in favour of maximising internal house space (i.e. as characterised by the 'McMansion').[261] Increasing densities would further contribute to the reduction in private open space, and it is vital that the POS (including communal building gardens) provided is of a sufficient size and quality to offset the reduction or loss of the private garden (see *Section 7.11: How much POS?*).

7.10 What are the mechanisms through which green space might impact health outcomes?

As noted above, cross-sectional studies[88,262] show that exposure to green space or nature appears to be associated with a wide range of mental health benefits including:

- reducing mental fatigue[92] and stress[92,93]

- enhancing restoration[92-94]; and

- promoting positive mood and emotional states associated with pleasant arousal and relaxation.[87]

In his comprehensive review of the impact of the built environment on mental health, Evans concluded that: 'Laboratory, field, and intervention studies converge on nature reducing stress and diminishing fatigue'.[78, p.547]

A number of explanations for the benefits of green space to mental health are plausible (see Figure 7.9). Adults who have access to green environments such as parks tend to walk more,[49,95-97] particularly for recreation.[98] This has both physical and mental health benefits. Nevertheless, Sugiyama and colleagues found that increased recreational walking, and also perceived social coherence, only partly explained the relationship between perceived greenness and mental health.[48,49,263] They concluded that benefits to mental health associated with access to POS may also accrue from the restorative aspects of nature exposure.

Access to POS may also influence mental health[48,49,263] by influencing social processes that are protective of mental health. For example, evidence suggests that access to POS is associated with the development of social ties and sense of community,[99,100] both of which reduce the risk of premature mortality.[101-103]
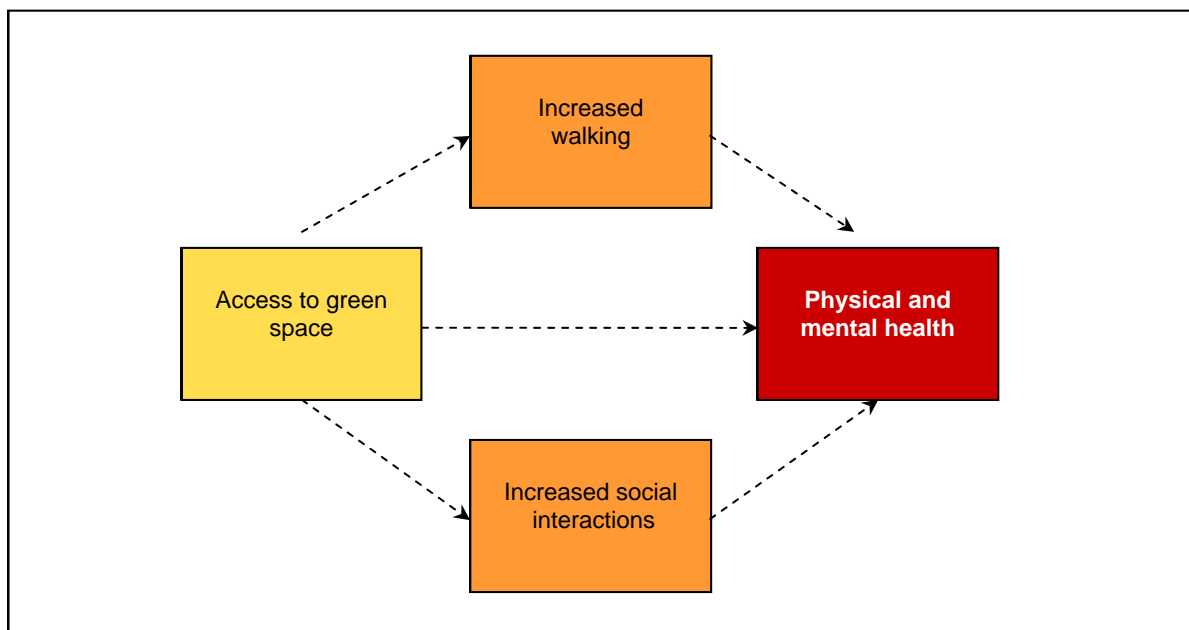
Figure 7.9 The main pathways through which access to green space may impact physical and mental health

The importance of access to green space relates not only to its presence, but also its quality. In another study of residents in Australian suburbs, Sugiyama and colleagues[98] found that access to a large attractive POS, even if further from home, was associated with achieving sufficient recreational walking for good health. Similarly, Francis found that access to high-quality POS (irrespective of its size or close proximity to home) enhanced positive mental health, even if it was not used by residents.[264] This is consistent with the belief that even looking at green space is restorative, and protective of mental health.[87,265]

Thus, both the presence and quality of POS appears to be important. In this regard, findings from a study by Mitchell and colleagues are instructive.[266] They found that, in low-income suburban areas, higher rates of poor health were associated with higher levels of green space, findings contrary to those in higher income areas. They noted that for suburban residents with access to private green space, POS may be less important generally than in more urban areas. Nevertheless, they concluded that large quantities of poor-quality green space may be detrimental to mental health.

It is possible that these findings reflect the fact that people with poorer mental health live in low-income areas and the findings simply highlight issues of self-selection. However, other explanations are plausible. For example, Foster and colleagues found that in suburban urban fringe neighbourhoods, access to local parks with litter, graffiti and vandalism decreased the likelihood of achieving recommended levels of walking.[267] The opposite was true for access to parks with attractive amenities. As observed above, disorder appears to directly affect mental health by elevating residents' fears for personal safety and decreasing feelings of control. It may also have an indirect impact, as residents limit activities such as physical activity and interactions with neighbours. Another potential mediating pathway may

be through identity.[77,78] The presence of poor quality and poorly maintained POS may affect people symbolically, by stigmatising the area in which they live, which may be internalised by local residents.[77,78]

In summary, although the evidence base in relation to the presence of POS and increased density is limited, there is considerable evidence that exposure to nature itself is beneficial to mental and physical health. Both the presence and quality of POS appears to be important. Access to POS influences health in many ways. Access to high-quality open space is associated with increased levels of walking and positive mental health outcomes. The potential ways that access to POS influences mental health include:

- reducing mental fatigue[91,92] and stress

- enhancing restoration; and

- promoting positive mood and emotional states associated with pleasant arousal and relaxation.

However, it is also plausible that access to POS influences social processes (e.g. the development of social networks).

POS is valued by residents of higher density housing, as evidenced by property prices close to POS. POS is more important to people living in higher density housing compared with others because it substitutes for the private space available to residents of low-density housing. Neighbourhood attractiveness (including the amount of green space) has been shown to be an important correlate of housing satisfaction in apartment dwellers, and much more so than for residents of other types of housing. Housing and neighbourhood satisfaction is an important factor influencing mental health.

Figure 7.10 POS used by adults and children within New York City's high-rise Stuyvesant Estate

(Source: Billie Giles-Corti)

7.11 How much public open space?

The amount of POS required to meet the needs of communities is contentious. Of particular importance is whether the provision of POS should be based on standards or 'community needs'. While standard approaches to public health provision (i.e. how much space per 1,000 persons) has been criticised, Veal notes that standards 'refuse to lie down'.[268] This is likely because, while a 'needs-based' approach to the provision of POS may overcome some of the limitations of a 'standards approach', it lacks some of the merits of standards. Presumably, it also overcomes the problem that the definition of 'needs' may depend on who is defining needs, and for whom.

Veal outlines the various approaches to defining standards, including:

- fixed standards

- area-percentage standards; and

- catchment area–based standards, facility standards and local standards.[268]

The standard frequently used in New South Wales (NSW) is 2.83 hectares per 1,000 persons.[268] In Western Australia, 10% of gross dividable land in each new development is allocated to POS. Veal[268] attempted to trace the history of these standards, which appeared to be linked to British pre–World War II standards, although some of the origins were not clear.

The current Western Australian standards were based on an interpretation of standards clearly laid out in the Western Australian Metropolitan Planning Scheme developed by Stephenson and Hepburn in 1955.[269] Stephenson and Hepburn based their standards on those outlined in 'The Density of Residential Areas', a UK report published in 1952 by the Minister of Housing and Local Government.[269, p.92] They specified the amount of POS per 1,000 people required in localities (i.e. population = 10,000) and districts (comprising two to six localities, i.e. population ~ 60,000). The requirements were further stratified by the type of district; that is, whether districts were located centrally (i.e. inner city), in redevelopment areas due for consolidation and intensification, in new developments, the semi-rural hills area or elsewhere. Inner city areas were not included in the recommendation because the report authors argued that it would not be possible to provide open space for adult playing fields in these areas. The authors recommended up to 8.3 acres per 1,000 persons of POS (i.e. 3.35 hectares) be provided (excluding playing fields in schools), made up as follows:

Localities

- Minor open spaces in housing estates: 0.5 acres

- Children's play grounds: 0.8 acres

- Adult playing fields: 1.5 acres

- Parks and gardens: 0.5 acres

Districts

- Adult playing fields: 4.5 acres

- Parks and gardens: 0.5 acres

Thus, excluding school playing fields (but including 0.5 acres for local greens), Stephenson and Hepburn recommended allocating 8.8 acres per 1,000 persons or 3.56 hectares per 1,000 persons.

In the UK standard, an additional 0.5 acres per 1,000 persons was allocated for the provision of local greens. Stephenson and Hepburn argued that this additional space was not necessary in low-density Australia because most people had backyards. Although, with intensified land use and less private space, as is likely in the future in Australia, one might expect that this additional space might be required. Similarly, while the guideline for sports playing fields proposed by Stephenson and Hepburn[269] was applicable in 1955, it may need revising for the 21st century. Their adult playing field standard was based on a national survey of various sporting associations conducted by the National Fitness Council.[269, p.94] It was based on the 'number of grounds stated to be required to field the maximum number of teams that present membership support'. However, the survey assumed 'the exclusive use of each ground for the particular sport concerned, and (did) not allow for the sharing of facilities'. Based on the findings of the survey, the authors estimated that 4.0 acres per 1,000

persons was required as a minimum standard, but suggested this be raised to '4.5 acres per 1,000 persons, which would allow for an increase in the popularity of sport and for possible increased demand for private recreation grounds'. There was no provision in 1955 for the sharing of sporting facilities with schools. Given pressures on land and financial resources, there may be scope to adjust local public space requirements for playing fields by sharing resources between codes and with schools, as is already the case in some countries.[108,270] However, ensuring there is sufficient large-scale district playing space for sport remains critical.

Importantly, many of these original standards were based on the number of people the POS was intended to serve. Table 7.1 shows the amount of space required for districts with varying levels of density, using Stevenson and Hepburn's 3.56 hectare per 1,000 persons standard. At 12 houses per hectare (which was the level of density in Perth, Western Australia at the time), the amount of green space required in a housing development serving 60,000 people would be around 10% of the gross area. This is the 'standard' adopted in Western Australia since the 1950s.[271] However, this area-percentage standard ignores Stephenson and Hepburn's intent (i.e. that as density increases, the amount of green space required would also increase as a substitute for less private space). At a density of 35 dwellings per hectare (which Newman and Kenworthy[184] argue is the minimum level of density required to deliver higher quality public transport), the amount of POS required jumps to 32% of the district. However, as density increases, there may need to be some reconsideration of an upper threshold. For example, as Veal observes, the provision of POS becomes unviable if the allocation of the NSW population ratio standard of 2.83 hectares per 1,000 population is strictly adhered to (i.e. 59% of space would be required for 80 dwellings per hectare and 118% for 160 dwellings per hectare).[268]

Table 7.1 Standards for the average amount of POS required in housing developments with different levels of density

A	B	C	D	E	F
Number of dwellings per hectare	Average number of residents per hectare	How many hectares per 60,000 persons e.g. a district?	How many acres per 60,000 persons e.g. a district?	How many acres of POS required for 60,000 people e.g. district?	Percentage green space required for housing development for 60,000 people at different levels of density
	i.e. Column A × 2.6	i.e. 60,000 / Column B	i.e. Column C x 2.47	i.e. Amount of POS x 60	i.e. Column E / Column F
1	3				
12	31	1923	4750	498[*]	10
35	91	659	1629	528[†]	32
50	130	462	1140	528	46
60	156	385	950	528	56
80	208	288	713	282[‡]	40
160	416	144	356	282[‡]	79

[*]8.3 acres per 1,000 persons, excluding green space in schools (i.e. 1.9 acres per 1,000 persons).

[†]8.8 acres per 1,000 persons, excluding green space in schools (i.e. 1.9 acres per 1,000 persons) but adding 0.5 acres per 1,000 persons for the local 'green' omitted from the Stephenson and Hepburn report on the basis that people have their own backyards.

[‡]Excludes 4.7 acres per 1,000 persons for local and district open space for adult playing fields on the basis that, at this level of density, it is more likely to be inner city and this level of provision would not be feasible.

POS provides physical, mental, social and environmental benefits for communities. As a result, more people are likely to rely on POS for recreational needs and restorative benefits as density increases and private open space declines. Therefore, it is plausible that more land will need to be allocated to POS in higher density areas than for suburban areas. Due to the complexities involved, the importance of meeting the needs of multiple users across the life course, and the need to maintain biodiversity, it is important that POS provision is evaluated in the face of increasing density.

Although this report does not specify the exact amount of space that should be allocated, it highlights the need to re-evaluate the amount of land being allocated to POS, as Australian cities consider intensifying land use and increasing densities. Further discussion with the various stakeholder groups is required to develop standards for the quantity and quality of POS that meets the needs of competing demands and user groups. These discussions

should consider the different housing types, the health needs of residents and, in an environment with scarce water and resources, opportunities for shared use with schools and between different sports codes. Importantly, in higher density environments there should be sufficient POS to meet the needs of users across the life course and to optimise the benefits for individuals and local communities. It may be appropriate to return to the use of a standards approach, up to a threshold which takes into account the proximity to, and number of, potential users.

In this regard, it may be helpful to examine trends internationally. For example, in high density New York City, the sustainability strategy PlaNYC 2030 (www.nyc.gov/html/planyc2030/) seeks to increase the amount of POS provided to meet the needs of its growing population and ensure that 'all New Yorkers from every neighbourhood live within a 10-minute walk to a park'. Moreover, the city's Million Trees NYC initiative (www.milliontreesnyc.org), seeks to plant and care for one million new trees across the city's five boroughs over a five-year period. The aim is to implement a 'cost-effective way of easing problems associated with population growth'. In justifying this program, the plan notes that trees:

- help clean the air and reduce the pollutants that trigger asthma attacks and other respiratory diseases

- cool the streets, sidewalks and homes on hot summer days

- increase property values and encourage neighbourhood revitalisation; and

- make the city more comfortable and beautiful to live, work and visit.

In summary, it is clear that POS is particularly important to people living in higher density housing who do not have access to private open space. Although this report does not specify the exact amount of POS required to meet the needs of multiple users across the life course, it appears that a hierarchy of POS will be necessary. Figure 7.11 shows images of the variety of POS available in New York City, which is currently reclaiming docklands and disused rail lines (e.g. see the High Line project www.thehighline.org/galleries/images) to increase the amount of POS available throughout the city.

Figure 7.11 Various types of POS available for different users in New York City

(Source: Billie Giles-Corti)

7.12 Summary of the impacts of density on mental health

The relationship between density and mental health is complex. Consistent with other health outcomes discussed in this review, it is often the location, design, construction and quality of housing which influence mental health, rather than density *per se*. The ways in which housing density effects mental health may be direct, as is the case with environmental stressors (e.g. such as crowding, noise, indoor air quality and light), or indirect (i.e. other factors that impact activities of daily living and social interactions between residents).

High-quality housing located in high-quality neighbourhoods is most beneficial for mental health. Noise appears to affect mental health by causing annoyance, which in turn causes stress. However, the amount of noise residents experience relates to the location (e.g. on a busy road) and quality of housing (e.g. construction and insulation). Consistent evidence suggests that housing quality in itself is also associated with psychological health. Housing quality is affected by building governance and maintenance, which contribute to residents' sense of control and perceived safety. For example, if the quality of the built environment deteriorates, incivilities such as vandalism, crime and disorder tend to escalate, which impacts on residents' feelings of safety.

The built environment can indirectly impact mental health through its influence on a range of **psychosocial processes** known to be associated with mental health outcomes. Evidence suggests that residents of high-rise housing have more mental health problems than those in low-rise or single-detached houses. However, a major flaw in the evidence is that many studies fail to adequately control for confounding variables such as SES and prior mental health problems. Nevertheless, the evidence suggests that the impact of higher density housing on mental health may relate to:

- the social environment (i.e. who else lives in the housing and their SES)

- the floor on which residents live; and

- levels of social interactions and social support.

The evidence on the impact of living at floor level is indicative rather than conclusive, but does suggest that living on higher floors can impact on mental health, particularly for stay-at-home women with children. Contributing factors include anxiety about accidents and falls, and a lack of social networks. It appears important that building designs provide opportunities for 'selective interactions', where residents are able to control the frequency and intensity of their interactions with neighbours.

As discussed earlier, the location of high-density housing affects the extent to which residents are exposed to environmental stressors, and the building design can reduce or enhance the impacts of a sub-optimal location (e.g. exposure to noise or air pollution). The location of higher density housing also affects access to neighbourhood resources, which

indirectly impacts on residents' quality of life. The presence of local facilities and services, combined with the neighbourhood's overall attractiveness, can affect residents' satisfaction with their home and neighbourhood, which is closely aligned with mental health. Neighbourhood satisfaction is also associated with length of residence, amount of social interaction, satisfaction with traffic, and the neighbourhood's appearance and aesthetic appeal.

Factors associated with housing quality and location can also affect crime and fear of crime, which in turn impact on mental health. Heightened fear of crime, whether justified of not, can exacerbate psychological distress and anxiety, and induce social and physical withdrawal. This can reduce the level of social support, an important factor in buffering stress and protecting mental health. Again, these issues are complex and inter-related, as higher density housing with higher population levels can increase the incidence of crime and disorder, simply because there are more people circulating in the area. CPTED features (e.g. surveillance and territoriality) within the building itself and local neighbourhood could help reduce crime and fear of crime.

Although few studies explore density and POS *per se*, there is considerable evidence that exposure to nature is beneficial to mental and physical health. The presence and quality of POS is important. Access to high-quality open space is associated with increased levels of walking and positive mental health outcomes. The potential ways in which POS influences mental health include reducing attention fatigue and stress, enhancing restoration and promoting positive mood and emotional states associated with pleasant arousal and relaxation. It is also plausible that access to POS influences social processes (e.g. the development of social networks). Moreover, neighbourhood attractiveness, including the amount of green space, is an important correlate of housing satisfaction in apartment dwellers and, in turn, housing and neighbourhood satisfaction influence mental health.

8.   The impact of density on special populations

8.1   Children and young people

As noted in *Section 7: The impact of density on mental health*, the psychological wellbeing of women with young children – particularly from low-income families – appears to be directly affected by living in high-rise housing and this was exacerbated by living on upper levels.[77] While a growing number of reports call for the creation of child-friendly cities,[272] there may be a mismatch between rhetoric and practice. For example, Randolph[64] suggests that there is an insufficient diversity of housing stock required to support the needs of families moving into higher density housing in inner-city developments in metropolitan Sydney. These observations are supported by Whitzman and Mizachi in Melbourne.[109] Thus, this section considers the specific needs of children and families.

Living in higher density housing has been associated with behavioural and other health impacts in children and young people, as outlined below.

Behavioural problems: A British study found that 93% of children living in centrally located high-rise flats had behavioural problems; this percentage was higher than for children living in owner-occupied estates, council-owned estates and redeveloped central areas including three-storey houses and low-rise maisonettes.[104] Similarly, an Austrian study showed the impact of household crowding on disturbances in classroom behaviour was higher for children living in multiple-dwelling units (mostly four storeys, but up to 10) than those living in single-family houses and row houses.[105]

Overweight and obesity: Few studies have examined the impact of living in higher density housing on weight status in children. A Cypriot study of children aged nine to 13 years[106] examined the relationship between weight status, urbanisation (high-, medium- and low-density levels) and housing type. The study found that, compared with girls living in highly urbanised areas, girls living in areas of medium urbanisation were four times as likely to be overweight or obese, after controlling for confounding factors. There was no significant association for girls in low urbanisation areas. Housing type was also related to overweight/obesity status. Compared with girls living in a house with a yard, girls living in apartments were 2.6 times more likely to be overweight or obese, but there was no difference between girls living in a house with or without a yard. There was no relationship between weight status and urbanisation or housing type in boys. However, living in an apartment appeared to protect against being overweight or obese in adult women.[106] The latter finding is consistent with previous research associating sprawl with weight status.[51] These findings warrant follow-up in other urban environments and highlight the complexities of studying these relationships. However, the results for girls could reflect differences in

parenting styles for boys and girls, and the unwillingness of parents to give girls permission to be independently mobile.

Independent mobility: As evidenced by the Cypriot study above, living in compact mixed use environments may encourage a more active lifestyle in adults. However, this environment may restrict active play and independent mobility, particularly in girls, who are known to have less independent mobility than boys.[28,112,273,274] Nevertheless, if given the option, children would like to visit local destinations including open space, playgrounds, libraries, and commercial centres.[275] When 12-year-old children were asked to describe their understanding of child-friendly cities, children residing in the inner city referred to improving what they saw as basic services, such as sports halls, shops, entertainment, libraries, computers, books, cinemas, and restaurants. Urban qualities and the environment were also important to these young people, including parks, grassed areas, swimming pools, the outdoors and nature. Finally, safety and security were emphasised, primarily danger from traffic and violence.[275] In this regard, a number of studies have found that children are more likely to be independently mobile (including walking to school) in more walkable neighbourhoods.[4,276] This is also true if they live in close proximity (i.e. 800 m to 1 km) to school[109,277] or a park (i.e. < 300 m).[109] Studies have examined the interaction between the connectivity of street networks, proximity to destinations and traffic exposure. One study found that children attending schools in areas with highly connected street networks and high traffic exposure were less likely to walk to school than children attending schools in areas with highly connected street networks and low traffic exposure.[278] This relates to real and perceived concerns about traffic safety and the risk of pedestrian injury.[108]

Risk of pedestrian injury: Concerns about traffic safety is a major factor influencing children's participation in active transport and independent mobility.[108] A review by Frumkin and colleagues found that, apart from housing or population density, other neighbourhood features associated with the risk of childhood-pedestrian injury included the presence of high traffic volume and speeds, high density of curb parking, and the number of streets crossed during routine travel.[63] Importantly, in terms of the design and location of higher density housing, the risk of pedestrian injuries also increased for children who did not have a park or play area near the home. This is particularly relevant for children living in higher density housing, who do not have private open space in which to play. These findings highlight the need to carefully consider the location of higher density housing and how easy it is to get it wrong. This is illustrated by Figure 8.1, which shows recently built high-density housing in Canberra, Australia, compared with high-density housing in the Stuyvesant Estate in New York City.

Inner city, Canberra

Stuyvesant Estate, New York

Figure 8.1 The location and design of higher density housing in relation to traffic and the relationship to children's physical activity and independent mobility

(Source: Billie Giles-Corti)

Physical activity: A range of factors impact on children's and adolescents' activity levels[21,279] including their age, their level of independent mobility, social norms and parental factors. Higher urban density and neighbourhoods with mixed use planning appear to be associated with increased physical activity in older children and adolescents, which is likely to reflect their greater autonomy. Parents allow their children greater independent mobility and freedom to explore their local environment as they get older.[280] Hence, the walkability of the local neighbourhood can either hinder or facilitate levels of independent mobility and physical activity in older children. Importantly, the presence of nearby destinations,[107] including access to local parks and sports centres, encourages more active travel and physical activity in children and adolescents.[108] Having nearby and accessible sport centres and parks has been shown to significantly increase weekly moderate to vigorous physical activity in adolescents.[108] Thus, unsafe neighbourhoods will constrain the outdoor physical activities of children and young people,[281] particularly girls and young women.[236] From a child's perspective, relevant aspects of safety include:

- traffic safety

- personal safety (i.e. stranger danger, attacks and bullying)

- safety from crime or violence; and

- visual indicators of safety such as incivilities.[108]

Importantly, there may be thresholds for density that impact on children's physical activity, and this warrants further research. For example, a European study found that densities no higher than six storeys were associated with higher levels of physical activity in children.[282]

Active play: Play is the 'work' of children, and is important for child development and both physical and mental health.[283] As children in higher density housing do not have access to private open space, the design of POS or semi-POS is particularly important. This not only impacts the children, but also the parents. As noted in *Section 7: The impact of density on mental health*, the mental health of mothers is affected by the provision of play spaces for their children. As parents are the gatekeepers of their children's behaviour,[21] their satisfaction with available play spaces is important. Becker assessed parent satisfaction with play areas in high- and low-density urban and suburban areas in New York City.[273] In general, he found that parents were dissatisfied with the play areas provided, and this was strongest among parents living in high-rise housing. He concluded that:

> *"Parents' satisfaction with the development as a place to raise children was a combination of the desirability of playmates for children, safety in the neighbourhood and on the development, the types of facilities, and adequate play space in the dwelling unit." [273, p. 570]*

Becker recommended that space and facilities for children 'be conceptualised as multifunctional and be designed to accommodate as many compatible uses as possible' (p. 564). His observations were echoed by Elsley's study of Scottish 10- to 14-year-old children.[112] Elsley found that young people wanted both formal and informal play spaces, with the informal or 'wild' places becoming increasingly popular as they became more independent and capable. Notably, the children disliked places that were vandalised, unsightly, or unsafe, highlighting the need for well-surveilled areas to reduce the likelihood of anti-social behaviour.[284]

A number of studies have considered the recreational needs of children living in high-rise housing, with remarkably similar findings, despite cultural differences. Whitzman and Mizarchi's Australian study of children aged 8–12 years living in high-rise buildings in Melbourne found that the proximity and amenity of local recreational facilities was important and emphasised the need for other children and the ability to have fun.[109] These investigators concluded that a hierarchy of play spaces near high-rise housing is needed to facilitate children becoming increasingly independent and adventurous as they age.[109] These findings were supported by a South Korean qualitative study of children aged 7–12 years living in a high-rise neighbourhood.[285] The investigators found that while younger children (aged 7–9 years) preferred playgrounds and developed parks and green space, older children preferred playfields, and city or community facilities. This further emphasises that higher density housing needs to be located close to a range of community facilities.

Child density: In his review of high-density housing in Sydney, Randolph recommended that, in addition to increasing the amount of family-sized accommodation in inner-city high-density housing, more attention be given to co-locating families to provide opportunities for interaction.[64] For example, Elsley's qualitative study of young people found that playing near home was viewed negatively if there were few or no other young people in the street.[112] Nevertheless, co-locating children does require some consideration. For example, Ineichen found that neighbourly conflict in different areas with various housing types was due to the presence of children.[104] However, this may have been due to the neighbourhood's layout or a lack of supervision, rather than the number of children. For example, Newman concluded that children in lower socioeconomic families living in high-density housing were often unsupervised, which may have contributed to their anti-social behaviour.[225] Moreover, in terms of building design, he recommended that children from families of lower SES *not* be housed in buildings greater than three storeys. This recommendation is in part supported by Becker, who found that residents with children under five years living in low-rise (rather than high-rise) accommodation had higher levels of satisfaction.[273] This is important, given that housing and neighbourhood satisfaction appears to be associated with mental health outcomes.

Involving young people in decision-making: There is growing recognition of the need to involve children and young people in the planning of communities. Young people, when asked, have clear view of what they do, and do not, like.[109,275] Policy-makers and practitioners need to be aware of and reflect the views and lived experience of children and young people, and it is essential that this occurs through meaningful engagement.[112]

Other impacts: A range of extraneous health impacts have been associated with children living in higher density housing. For example, an Australian study of short-sightedness found that, after adjustment for age, gender, near work, outdoor activity and parental myopia, myopia in children became more common as housing type became progressively more restrictive from separate houses, to terrace houses, to apartments.[110] Another small study explored auditory discrimination and reading ability in children in grades two to five living in a multi-storey apartment erected on bridges spanning the Interstate 95 in New York City (see Figure 8.2). This study found that, after adjustment for parental education, children who lived on higher floors were exposed to lower levels of noise. In turn, floor level was positively correlated with both auditory discrimination and reading ability for children living in the residence for four or more years.[111] The authors hypothesised that noise exposure over a long period of time inhibits a child's ability to attend to acoustic cues and this subsequently results in decreased reading ability. These findings echo those of an Austrian study, which found a dose–response relationship between noise and psychological distress in children exposed to traffic noise from roads and trains.[209] Moreover, these findings are relevant to the

location of higher density housing, and the impact of traffic pollution on the respiratory health of children, as outlined in *Section 6: The impact of density on respiratory health*.

Figure 8.2 High-rise housing built over freeways[111]

(Source: http://graphics7.nytimes.com/images/2004/06/18/nyregion/18BUILD.jpg,
http://wirednewyork.com/forum/showthread.php?t=3682)

In summary, the needs of children, as a particularly vulnerable section of the community, deserve special attention in relation to higher density housing. Density, and living conditions more broadly, may affect child development, and their mental and physical health. This can restrict their physical activity, independent mobility and active play. The evidence indicates that high-rise living may be associated with behavioural problems, and that independent activity and active play may be restricted in girls living in high-rise buildings, resulting in increased levels of overweight and obesity. Independent mobility, and physical activity more generally, is associated with the proximity and range of destinations, and neighbourhood attributes such as safety, walkability and the presence of traffic. POS is of particular importance, as this is often where children engage in active play. A hierarchy of play spaces may be required to cater for increasing autonomy with age, as well as a variety of formal and informal areas. Moreover, for younger children, the mental health of parents, particularly mothers, may be affected if they are unable to allow their children to play in well-surveilled outdoor areas.

Locating higher density housing in which children reside along or near roads carrying heavy traffic may result in parents restricting their children's mobility, and also increase the risk of child-pedestrian accidents. Moreover, children exposed to traffic pollution are at greater risk of respiratory problems including asthma. A small amount of evidence suggests other potential health impacts on children living in higher density housing. These include short-sightedness due to restricted length of vision, and diminished auditory discrimination and reading ability due to exposure to noise. Co-locating families with young children may be useful to create a sense of community among families and children. However, attention to design is required to minimise any potential source of conflict between residents (e.g. noise). Finally, meaningful involvement of children in the planning and designing of residences and communities may contribute to producing better outcomes for the children and young people who live in those areas.

8.2   Older adults

The need to create age-friendly cities as the population ages is now recognised.[286] Adults aged over 65 years are the most rapidly growing age group and this group will continue to grow as baby boomers turn 65 over the coming years. By 2050, the number of people over 65 in Australia is expected to more than double, with people aged 85 years and over more than quadrupling.[287] Devising prevention strategies that assist older adults to be socially and physically active as they age is critical given the size of this population segment and the fact that older adults generate the highest levels of medical expenditure.[288] For example, in terms of physical activity, it has been estimated that a cost-saving impact on the health budget could be achieved within one year if older adults increased their level of activity.[288]

Providing safe, affordable and well-connected housing that helps keep older adults socially and physically active as they age is critical. Older adults – particularly women – are more fearful and more vulnerable to crime, thus the design and location of housing is important to avoid people constraining their behaviour. As noted by Piro and colleagues:

"… reduced mobility of some elderly may make them 'prisoners of space'… Thus the impact of neighbourhood conditions … may be greater for the elderly than any other group."[113]

Thus, the built environment can lower or increase the disability threshold, by facilitating or discouraging active living.[187-189,289] Therefore, for older adults, designing and locating higher density housing with the aim to facilitate active lifestyles, social interaction, and creating a safe living environment with amenities for daily living would appear essential.

Few studies appear to have specifically studied the impact of living in higher density housing *per se.* The following section reviews the available evidence.

Mortality and chronic diseases: As noted earlier, a longitudinal Japanese study found that, after adjustment, the five-year survival of older adults living in the high population density city of Tokyo was higher in people with access to walkable green space.[43] However, a national study of Americans over 55 years found that, in adjusted and unadjusted models, there was no association between six chronic disease conditions. Living in high crime and more (racially) segregated neighbourhoods was associated with cancer in both men and women. In additional analyses, the researchers reported that both crime and segregation measures predicted cancer onset, in both African American and Caucasian participants. Although exposure to an environmental toxin could not be ruled out, the researchers hypothesised that a non-specific biological mechanism may be involved, such as a stress response that interrupts the body's ability to fight the development of cancer. In this study, older women living in economically disadvantaged neighbourhoods were more likely than others to have heart problems.[290] It has been hypothesised that the mechanisms through which the built environment might affect CVD could be walking, levels of obesity and exposure to air pollution.[291] Contrary to these hypotheses, in their study Freedman and colleagues did not find an association between CVD and other outcomes, with connectivity, air pollution and density.[290] However, this may have related to measurement error of environmental variables. For example, in this study 'density' was captured by the number of food stores, restaurants and housing units per square mile, as well as by tract-level population density. It is plausible that the imprecision of the scale that measured these variables may have contributed to the results.[292]

Obesity and overweight: Few studies have examined the impact of the built environment on obesity in older adults. A study of American adults aged 55 years and over found an association between density and obesity and overweight in women, but not men.[293] However, the measure of density in this study included food stores, restaurants, and housing and population density measured at different scales. Nevertheless, the findings suggest that the risk of obesity is reduced in women who live in higher density, mixed use neighbourhoods. Berke and colleagues found associations between objectively measured neighbourhood walkability and walking in both men and women.[167] However, although associations between neighbourhood walkability and obesity were as anticipated, the results were not statistically significant.

Physical activity: Many studies have specifically examined the impact of living in higher density environments and physical activity in older adults. Li and colleagues found that increased employment and housing density (as well as access to green and open space) were associated with self-reported neighbourhood walking.[27] King and colleagues found that the presence of more destinations increased physical activity in older women.[294]

Satisfaction and sense of community: Satisfaction with one's neighbourhood, housing and sense of community are associated with mental health outcomes. A study of US public housing residents found that satisfaction was high in both high-rise and walk-up apartments in rows of four to six.[295] All residents claimed to prefer living in low- or mid-rise housing (rather than high-rise). The source of satisfaction for low-rise residents was related to the physical space in which they lived and proximity to nature; high-rise residents' satisfaction came from the richness of their social lives. However, Zaff and colleagues found that residents of garden apartments had a greater sense of community than residents of high-rise dwellings.[296] They concluded that for older adults, garden apartments were the most appropriate form of housing. These conclusions were supported by a study of wellbeing in older adults living in higher density social housing.[114] This study found that greater building height, but not size, was associated with lower housing satisfaction.

Real and perceived safety: Older adults are more vulnerable to crime, and women in particular are more fearful. A number of studies have examined the impact of housing type on various aspects of real and perceived crime and safety. Burby found that people's perception of crime and fear of crime was lowest in high-rise congregate housing, compared with high-rise non-congregate housing or age-integrated residences.[115] Congregate housing includes shared facilities such as a dining room or recreational facilities. These findings are in contrast to a study of public housing estate residents[297] which found that, after adjustment, building height was negatively associated with fear of crime, but that perceived crime was positively associated with segregation status. Devlin found that high-rise residents also feared elevator malfunction and fire.[295] A key factor influencing real and perceived safety is the governance of buildings and, in particular, building management and maintenance. For example, it has been suggested that building management can be important in developing housing for older adults by reducing fears, the delivery of appropriate services and maintaining morale.[115] Moreover, managing the social environment appears to be important. The presence of a 'social leader' can assist in creating a harmonious and satisfying environment by:

- facilitating social interactions between residents

- promoting building-wide events; and

- listening to residents' concerns.[296]

Finally, it appears the key factors influencing the success or otherwise of higher density housing for older adults are the location, whether people feel safe and whether there are opportunities for social interaction. In fact, some argue that location is of the utmost importance and that 'age segregation is not a substitute for a safe location'.[115] Locating higher density housing in walkable areas with nearby transport, services and amenities is likely to encourage active lifestyles. However, satisfaction is likely to be enhanced if there is

also access to nature or POS and opportunities for selective interaction. Locating housing for older adults in areas in which they feel safe is critical, to ensure residents do not constrain their physical and social activities. There are advantages of age-segregated housing for older adults in terms of facilitating the delivery of services.[115] However, researchers assessing the success or otherwise of age-segregated high-rise housing in Singapore concluded that it had 'a deleterious impact on the quality of life of the elder people'.[115] As satisfaction is a key factor influencing mental health outcomes, providing higher density through low-rise housing is likely to be preferable to high-rise housing, in terms of increasing satisfaction[114,295] and helping to create a sense of community.[296]

In summary, mobility, perceived and actual safety and opportunities for socialisation are key factors to be considered in planning housing for older adults. The provision of facilities and services, including POS, that encourage physical and social activities will help to promote good health, and prevent or delay the onset of chronic disease.

Residential and neighbourhood satisfaction is protective of mental health. Generally, high-rise living is associated with lower levels of satisfaction and sense of community in older adults. It is therefore recommended that the densification of housing intended for older adults be achieved through low- to mid-rise developments. In fact, elderly residents of both low- and high-rise buildings report a preference for this style of housing.

Feelings of safety and perception of crime were considered in *Section 7.8: Insecurity: crime and fear of crime*, but are of particular importance and relevance to the elderly. Evidence suggests that elderly residents of high- and low-rise developments may have different fears, with people living in low-rise housing having lower levels of fear. Fear of crime may decrease when congregate services are offered, when management is responsive, and in the presence of a 'social leader' (i.e. someone who helps coordinate residents and creates social capital).

However, in older adults the location and design of higher density housing may be more important than density *per se*, as has been repeatedly identified throughout this report.

9. Discussion and conclusions

The purpose of this report was to undertake a narrative review of the literature addressing the following questions:

- What are the intended and unintended consequences of increased density?

- What constitutes 'good' levels of density from a health and active living perspective?

- What type of amenity is associated with positive health and physical activity outcomes, in higher residential density areas?

9.1 What are the intended and unintended consequences of increased density?

If planned effectively, increasing population density has the potential to produce numerous benefits to the environment and the community by:

- increasing the use of active modes of transport and public transport

- reducing vehicle miles travelled

- improving air quality

- reducing traffic congestion

- providing more affordable housing closer to amenities; and

- reducing the footprint of cities by reducing the amount of space required for each person.

However, despite good intent, it is easy to get this wrong without careful consideration. The evidence suggests that the success or otherwise of the implementation of policies to increase population density depends on three main factors:

- the **building** (i.e. its location, construction, design, management and maintenance)

- the **socioeconomic and cultural** make-up of residents and the local neighbourhood; and

- the **quality and amenity of the neighbourhood** environment in which higher density housing is located.

There are numerous historical and contemporary examples of poorly planned density that, despite good intent, have caused enormous harm to residents (see Figure 9.1). This should give cause for caution, and illustrates why the health sector needs to carefully consider its position when supporting increases in density.

(i) The implosion of Pruitt Igoe

Source: Ramroth WG[298]

(ii) High-density housing in Auckland

Source: Karen Witten, Massey University

(iii) High-density housing in Canberra

Source: Billie Giles-Corti

(iv) Medium-density housing along railway tracks, New Zealand

Centre for the Built Environment and Health
Source: Brenna Waghorn, Auckland Regional Council[299]

Figure 9.1 Examples of high-density housing that has not, or may not, optimise outcomes for residents

As suggested by the UK CABE, 'badly designed places impose costs on their occupiers, their neighbours and on society'.[232,p.7]

However, as the evidence in this review suggests, the impact of increased density on the health and wellbeing of residents goes beyond design: poorly located and inadequately managed places can also cause preventable harm. Figure 9.2 summarises the evidence review in terms of the mechanisms through which increased population density might influence health. It highlights the key building, social, environmental and neighbourhood factors that should be addressed to produce good outcomes for residents and the community.
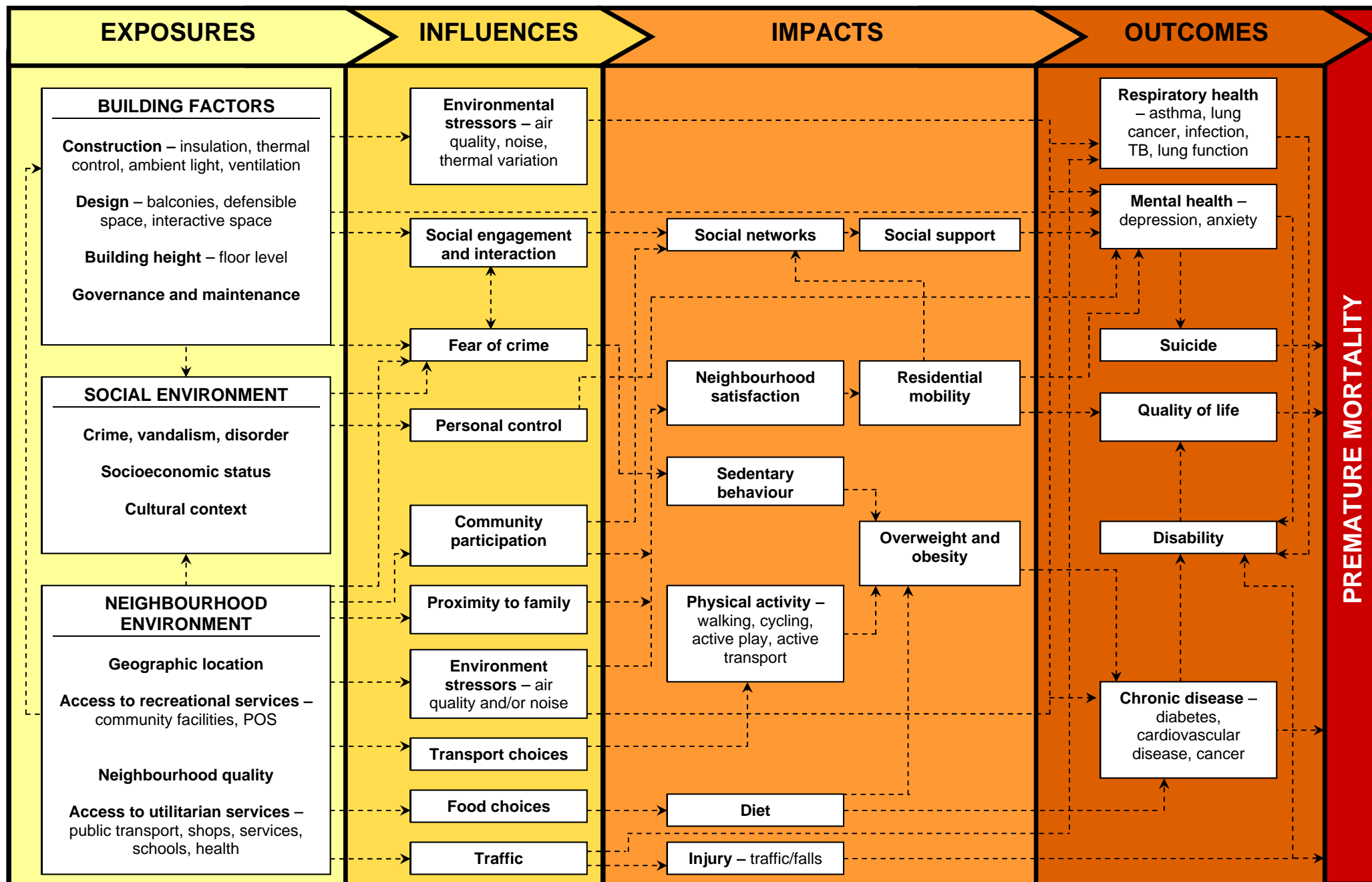
Figure 9.2 The mechanisms through which higher density housing can influence health, including the key aspects of higher density housing that should be considered (i.e. building, social and neighbourhood)

9.2 What constitutes 'good' levels of density from a health and active living perspective?

What constitutes 'good' levels of density depends on a range of factors. There appears to be more potential harm associated with living in high-rise housing; however, this may depend upon who lives there, how well it is designed and built, and where it is located. For example, high-rise inner-city housing, occupied by employed adults with no children, may well work very well. Moreover, high-rise housing in high socioeconomic areas with good neighbourhood amenity, built-in security, shared facilities (e.g. recreational space), opportunities for selective interactions, and structures addressing building and social governance, may also work well for people who can afford to live there.

However, to optimise outcomes across the spectrum of current and future residents, there appears to be a strong preference and desirability for families, for example, to live on the lower floors of medium-density housing of no higher than three to five storeys. Moreover, this accommodation should be large enough to avoid issues of over-crowding, and allow families to be co-located to create a sense of community. Achieving higher densities through lower rise development would appear to be optimal not only for families, but also older adults (see Figure 9.3).

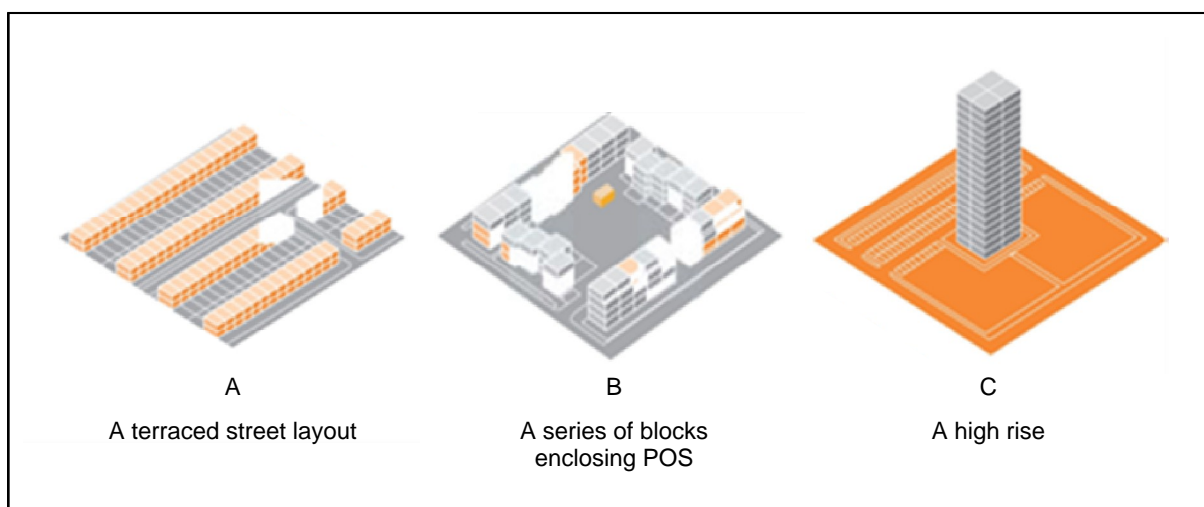| A	B	C
A terraced street layout	A series of blocks enclosing POS	A high rise

Figure 9.3 Different architectural forms that achieve the same density (i.e. 75 dwellings per hectare)

(Source: Modified from Greater London Authority[300])

9.3 What type of amenity is associated with positive health and physical activity outcomes in higher residential density areas?

The evidence suggests that it is optimal for higher density housing to be located away from roads with heavy traffic, but also within easy access of public transport, shops, services and a hierarchy of POS. This includes on-site open space that can be surveilled by parents as their children play. Moreover, desirable building design features include:

- ensuring adequate noise insulation and breeze-ways that optimise ventilation

- designing balconies so that they do not overlook roads with heavy traffic

- using CPTED features that enhance territoriality and promote natural surveillance

- providing opportunities for selective (but not enforced) interactions between residents (including children); and

- co-locating families on the same levels.

These design features will provide for the daily transport and recreational needs of residents, and also assist in creating a sense of community and protecting the health of residents.

References

1. Cervero R, Kockelman K. Travel demand and the 3Ds: density, diversity, and design. Transport Res D-Tr E 1997; 2(3):199-219.

2. Lee C, Moudon AV. The 3Ds + R: quantifying land use and urban form correlates of walking. Transport Res D-Tr E 2006; 11(3):204-215.

3. Churchman A. Disentangling the concept of density. J Planning Literature 1999; 13(4):389-411.

4. Kerr J, Rosenberg D, Sallis JF, Saelens BE, Frank LD, Conway TL. Active commuting to school: associations with environment and parental concerns. Med Sci Sport Exer 2006; 38(4):787-793.

5. Handy S, Cao X, Mokhtarian P. Self-selection in the relationship between the built environment and walking. J Am Plann Assoc 2006; 72(1):55-74.

6. Cao X, Handy S, Mokhtarian P. The influences of the built environment and residential self-selection on pedestrian behaviour: evidence from Austin, TX. Transportation 2006; 33(1):1-20.

7. Shigematsu R, Sallis JF, Conway TL, Saelens BE, Frank LD, Cain KL, et al. Age differences in the relation of perceived neighborhood environment to walking. Med Sci Sport Exer 2009; 41(2):314-321.

8. Rodriguez DA, Evenson KR, Roux AVD, Brines SJ. Land use, residential density, and walking. The multi-ethnic study of atherosclerosis. Am J Prev Med 2009; 37(5):397-404.

9. Lee C, Moudon A. Correlates of walking for transportation or recreation purposes. J Phys Activ Health 2006; 3(Suppl 1):S77-S98.

10. Braza M, Shoemaker W, Seeley A. Neighborhood design and rates of walking and biking to elementary school in 34 California communities. Am J Health Promot 2004; 19(2):128-136.

11. Rosenberg D, Ding D, Sallis JF, Kerr J, Norman GJ, Durant N, et al. Neighborhood environment walkability scale for youth (NEWS-Y): reliability and relationship with physical activity. Prev Med 2009; 49(2-3):213-218.

12. Ewing R, Schroeer W, Greene W. School location and student travel - analysis of factors affecting mode choice. Transport Res Rec 2004; (1895):55-63.

13. Frank LD, Kerr J, Chapman J, Sallis J. Urban form relationships with walk trip frequency and distance among youth. Am J Health Promot 2007; 21(4):305-311.

14. MacDonald JM, Stokes RJ, Cohen DA, Kofner A, Ridgeway GK. The effect of light rail transit on body mass index and physical activity. Am J Prev Med 2010; 39(2):105-112.

15. Nelson N, Foley E, O'Gorman D, Moyna N, Woods C. Active commuting to school: how far is too far? Int J Behav Nutr Phys Act 2008; 5(1):1.

16. Besser LM, Dannenberg AL. Walking to public transit steps to help meet physical activity recommendations. Am J Prev Med 2005; 29(4):273-280.

17. Cole R, Leslie E, Bauman A, Donald M, Owen N. Socio-demographic variations in walking for transport and for recreation or exercise among adult Australians. J Phys Activ Health 2006; 3:164-178.

18. Khattak AJ, Rodriguez D. Travel behavior in neo-traditional neighborhood developments: a case study in USA. Transport Res A-Pol 2005; 39(6):481-500.

19. Plaut PO. Non-motorized commuting in the US. Transport Res D-Tr E 2005; 10(5):347-356.

20. Riva M, Gauvin L, Apparicio P, Brodeur JM. Disentangling the relative influence of built and socioeconomic environments on walking: the contribution of areas homogenous along exposures of interest. Soc Sci Med 2009; 69(9):1296-1305.

21. McMillan TE. The relative influence of urban form on a child's travel mode to school. Transport Res A-Pol 2007; 41:69-79.

22. Grow H, Saelens BE, Kerr J, Durant N, Norman G, Sallis J. Where are youth active? Roles of proximity, active transport, and built environment. Med Sci Sport Exer 2008; 40(12):2071-2079.

23. Larsen K, Gilliland J, Hess P, Tucker P, Irwin J, He MZ. The influence of the physical environment and sociodemographic characteristics on children's mode of travel to and from school. Am J Public Health 2009; 99(3):520-526.

24. De Bourdeaudhuij I, Sallis JF, Saelens BE. Environmental correlates of physical activity in a sample of Belgian adults. Am J Health Promot 2003; 18(1):83-92.

25. Gauvin L, Richard L, Craig CL, Spivock M, Riva M, Forster M, et al. From walkability to active living potential: An "ecometric" validation study. Am J Prev Med 2005; 28(2, Supplement 2):126-133.

26. Suminski RR, Poston WSC, Petosa RL, Stevens E, Katzenmoyer LM. Features of the neighborhood environment and walking by US adults. Am J Prev Med 2005; 28(2):149-155.

27. Li F, Harmer PA, Cardinal BJ, Bosworth M, Acock A, Johnson-Shelton D, et al. Built environment, adiposity, and physical activity in adults aged 50-75. Am J Prev Med 2008; 35(1):38-46.

28. Page AS, Cooper AR, Griew P, Jago R. Independent mobility, perceptions of the built environment and children's participation in play, active travel and structured exercise and sport: the PEACH Project. Int J Behav Nutr Phys Act 2010; 7:17.

29. Hoehner CM, Ramirez LKB, Elliott MB, Handy SL, Brownson RC. Perceived and objective environmental measures and physical activity among urban adults. Am J Prev Med 2005; 28(2):105-116.

30. Krizek KJ, Johnson PJ. Proximity to trails and retail: effects on urban cycling and walking. J Am Plann Assoc 2006; 72(1):33-42.

31. Ball K, Bauman A, Leslie E, Owen N. Perceived environmental aesthetics and convenience and company are associated with walking for exercise among Australian adults. Prev Med 2001; 33(5):434-440.

32. Carnegie MA, Bauman A, Marshall AL, Mohsin M, Westley-Wise V, Booth ML. Perceptions of the physical environment, stage of change for physical activity, and walking among Australian adults. Res Q Exerc Sport 2002; 73(2):146-155.

33. King D. Neighbourhood and individual factors in activity in older adults: results from the neighbourhood and senior health study. J Aging Phys Act 2008; 16:144-170.

34. King W, Brach J, Belle S, Killingsworth RE, Fenton M, Kriska A. The relationship between convenience of destinations and walking levels in older women. Am J Health Promot 2003; 18(1):74-82.

35. Shores KA, West ST, Theriault DS, Davison EA. Extra-individual correlates of physical activity attainment in rural older adults. J Rural Health 2009; 25(2):211-218.

36. Salvador EP, Florindo AA, Reis RS, Costa EF. Perception of the environment and leisure-time physical activity in the elderly. Rev Saúde Pública 2009; 43(6):972-980.

37. Nagel CL, Carlson NE, Bosworth M, Michael YL. The relation between neighborhood built environment and walking activity among older adults. Am J Epidemiol 2008; 168(4):461-468.

38. Gauvin L, Riva M, Barnett T, Richard L, Craig CL, Spivock M, et al. Association between neighborhood active living potential and walking. Am J Prev Med 2008; 167(8):944-953.

39. Transportation Research Board. Does the built environment influence physical activity? Examining the evidence. Washington, DC: Transportation Research Board, 2005.

40. National Institute for Health and Clinical Excellence. Promoting or creating built or natural environments that encourage and support physical activity. NICE, 2008.

41. Heart and Stroke Foundation of Canada. Position statement: the built environment, physical activity, heart disease and stroke. Ottawa, Canada: Heart and Stroke Foundation Canada, 2007.

42. Tanaka A, Takano T, Nakamura K, Takeuchi S. Health levels influenced by urban residential conditions in a megacity - Tokyo. Urban Stud 1996; 33(6):879-894.

43. Takano T, Nakamura K, Watanabe M. Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. J Epidemiol Community Health 2002; 56(12):913-918.

44. Galle OR, Gove WR, Miller-McPherson J. Population density and pathology: what are the relationships for man? Science 1971; 176(4030):23-30.

45. Martikainen P, Kauppinen TM, Valkonen T. Effects of the characteristics of neighbourhoods and the characteristics of people on cause specific mortality: a register based follow up study of 252 000 men. J Epidemiol Community Health 2003; 57(3):210-217.

46. Factor RM, Waldron I. Contemporary population densities and human health. Nature 1973; 243(5407):381-384.

47. Levy L, Herzog A. Effects of crowding on health and social adaptation in the city of Chicago. Urban Ecol 1978; 3(4):327-354.

48. Sugiyama T, Healy GN, Dunstan DW, Salmon J, Owen N. Joint associations of multiple leisure-time sedentary behaviours and physical activity with obesity in Australian adults. Int J Behav Nutr Phys Act 2008; 5:35.

49. Sugiyama T, Leslie E, Giles-Corti B, Owen N. Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? J Epidemiol Community Health 2008; 62(5):e9.

50. Papas MA, Alberg AJ, Ewing R, Helzlsouer KJ, Gary TL, Klassen AC. The built environment and obesity. Epidemiol Rev 2007; 29(1):129–143.

51. Robertson-Wilson J, Giles-Corti B. Walkabililily, neighbourhood design, and obesity. In: Townsend T, Alvanides S, Lake A, editors. Obesogenic environments: complexities, perceptions and objective measures UK: Wiley-Blackwell, 2010.

52. Ewing R, Schmid T, Killingsworth R, Zlot A, Raudenbush S. Relationship between urban sprawl and physical activity, obesity and morbidity. Am J Health Promot 2003; 18(1):47-57.

53. Ewing R, Schieber RA, Zegeer CV. Urban sprawl as a risk factor in motor vehicle occupant and pedestrian fatalities. Am J Public Health 2003; 93(9):1541-1545.

54. Chaix B, Ducimetiere P, Lang T, Haas B, Montaye M, Ruidavets JB, et al. Residential environment and blood pressure in the PRIME Study: is the association mediated by body mass index and waist circumference? J Hypertens 2008; 26(6):1078-1084.

55. van Hooijdonk C, Droomers M, Deerenberg IM, Mackenbach JP, Kunst AE. Higher mortality in urban neighbourhoods in the Netherlands: who is at risk? J Epidemiol Community Health 2008; 62(6):499-505.

56. Adar S, Kaufman J. Cardiovascular disease and air pollutants: evaluating and improving epidemiological data implicating traffic exposure. Inhal Toxicol 2007; 19(S1):135-149.

57. Mahoney MC, Labrie DS, Nasca PC, Wolfgang PE, Burnett WS. Population density and cancer mortality differentials in New York state, 1978–1982. Int J Epidemiol 1990; 19(3):483-490.

58. Yang C-Y, Hsieh Y-L. The relationship between population density and cancer mortality in Taiwan. Jpn J Cancer Res 1998; 89(4):355-360.

59. Cerin E, Leslie E, Bauman A, Owen N. Levels of physical activity for colon cancer prevention compared with generic public health recommendations: population prevalence and sociodemographic correlates. Cancer Epidem Biomar 2005; 14(4):1000-1002.

60. Baker S, Whitfield R, O'Neill B. Geographic variations in mortality from motor vehicle crashes. New Engl J Med 1987; 316(22):1384-1387.

61. Clark DE. Effect of population density on mortality after motor vehicle collisions. Accident Anal Prev 2003; 35(6):965-971.

62. Hu G, Wen M, Baker TD, Baker SP. Road-traffic deaths in China, 1985–2005: threat and opportunity. Inj Prev 2008; 14(3):149-153.

63. Frumkin H, Frank L, Jackson R. Urban sprawl and public health. Designing, planning and building for healthy communites. Washington, DC: Island Press, 2004.

64. Randolph B. Delivering the compact city in Australia: current trends and future implications. Sydney: City Futures Research Centre, 2006.

65. Leaderer BP, Belanger K, Triche E, Holford T, Gold DR, Kim Y, et al. Dust mite, cockroach, cat, and dog allergen concentrations in homes of asthmatic children in the Northeastern United States: impact of socioeconomic factors and population density. Environ Health Perspect 2002; 110(4):419.

66. Lovasi GS, Quinn JW, Neckerman KM, Perzanowski MS, Rundle A. Children living in areas with more street trees have lower prevalence of asthma. J Epidemiol Community Health 2008; 62(7):647-649.

67. Broms K, Norback D, Eriksson M, Sundelin C, Svardsudd K. Effect of degree of urbanisation on age and sex-specific asthma prevalence in Swedish preschool children. BMC Public Health 2009; 9:303-313.

68. Duhme H, Weiland SK, Keil U, Kraemer B, Schmid M, Stender M, et al. The association between self-reported symptoms of asthma and allergic rhinitis and self-reported traffic density on street of residence in adolescents. Epidemiology 1996; 7(6):578-582.

69. Edwards J, Walters S. Hospital admissions for asthma in preschool children: relationship to major roads in Birmingham, United Kingdom. Arch Environ Health 1994; 49(4):223-227.

70. Wjst M, Reitmeir P, Dold S, Wulff A, Nicolai T, von Loeffelholz-Colberg EF, et al. Road traffic and adverse effects on respiratory health in children. BMJ 1993; 307(6904):596.

71. Gehring U, Cyrys J, Sedlmeir G, Brunekreef B, Bellander T, Fischer P, et al. Traffic-related air pollution and respiratory health during the first 2 yrs of life. Eur Respir J 2002; 19(4):690-698.

72. Kim J, Smorodinsky S, Lipsett M, Singer B, Hodgson A, Ostro B. Traffic-related air pollution near busy roads: the East Bay Children's Respiratory Health Study. Am J Respir Crit Care Med 2004; 170(5):520-526.

73. Oosterlee A, Drijver M, Lebret E, Brunekreef B. Chronic respiratory symptoms in children and adults living along streets with high traffic density. Occup Environ Med 1996; 53(4):241-247.

74. Ramos RG, Talbott EO, Youk A, Karol MH. Community urbanization and hospitalization of adults for asthma. J Environ Health 2006; 68(8):26-32.

75. Hao J, Wang L. Improving urban air quality in China: Beijing case study. J Air Waste Manag Assoc 2005; 55(9):1298-1305.

76.	High Density Livability Guide. Fact sheet 1: Thermal comfort and natural ventilation. Brisbane: Queensland University of Technology and Northshore Hamilton, 2010.

77.	Evans GW, Wells NM, Moch A. Housing and mental health: a review of the evidence and a methodological and conceptual critique. J Soc Issues 2003; 59(3):475-500.

78.	Evans G. The built environment and mental health. J Urban Health 2003; 80(4):536-555.

79.	Halpern D. Mental health and the built environment: more than bricks and mortar? London: Taylor & Francis, 1995.

80.	Kruger DJ, Reischl TM, Gee GC. Neighborhood social conditions mediate the association between physical deterioration and mental health. Am J Community Psychol 2007; 40(3-4):261-271.

81.	Freeman H. Mental health and high-rise housing. In: Burridge R, Ormandy D, editors. Unhealthy housing: research, remedies and reform Hoboken: Spon Press, 1993.

82.	Hur M. Factors that influence residents' satisfaction with neighborhoods. Environ Behav 2008; 40(5):619-635.

83.	Appleyard D. Livable streets. Berkeley, California: University of California Press, 1981.

84.	Stafford M. Association between fear of crime and mental health and physical functioning. Am J Public Health 2007; 97(11):2076-2081.

85.	Cozens PM, Saville G, Hillier D. Crime prevention through environmental design (CPTED): a review and modern bibliography. Journal of Property Management 2005; 23(5):328-356.

86.	Brown B, Altman I. Territoriality, defensible space and residential burglary: an environmental analysis. J Environ Psychol 1983; 3(3):203-220.

87.	Maller C, Townsend M, Brown P, St Leger L. Healthy parks, healthy people. The health benefits of contact with nature in a park context. Melbourne: Deakin University, 2002.

88.	Ulrich R, Simons R, Losito B, Fiorito E, Miles M, Zelson M. Stress recovery during exposure to natural and urban environments. J Environ Psychol 1991; 11:201-230.

89.	Dehring C, Dunse N. Housing density and the effect of proximity to public open space in Aberdeen, Scotland. Real Estate Econ 2006; 34(4):553-566.

90.	Gruber K. Assessment of neighborhood satisfaction by residents of three housing types. Soc Indic Res 1987; 19(3):303-315.

91.	Kaplan R, Kaplan S. The experience of nature: a psychological perspective. New York: Cambridge University Press, 1989.

92.	Kaplan S. The restorative benefits of nature: toward an integrative framework. J Environ Psychol 1995; 15:169-182.

93.	Grahn P, Stigsdotter U. Landscape planning and stress. Urban Forestry & Urban Greening 2003; 2:1-18.

94.	Hartig T, Mang M, Evans G. Restorative effects of natural environment experiences. Environ Behav 1991; 23(1):3-26.

95.	Giles-Corti B, Broomhall MH, Knuiman M, Collins C, Douglas K, Ng K, et al. Increasing walking: how important is distance to, attractiveness, and size of public open space? Am J Prev Med 2005; 28(2 Suppl 2):169-176.

96.	Li F, Fisher KJ, Brownson RC, Bosworth M. Multilevel modelling of built environment characteristics related to neighbourhood walking activity in older adults. J Epidemiol Community Health 2005; 59(7):558-564.

97.	Ellaway A, Macintyre S, Bonnefoy X. Graffiti, greenery, and obesity in adults: secondary analysis of European cross sectional survey. BMJ 2005; 331(7517):611-612.

98.	Sugiyama T, Francis J, Middleton N, Owen N, Giles-Corti B. Associations of recreational walking with attractiveness, size and proximity of neighborhood open spaces Am J Public Health 2010; 100(9):1752-1757.

99.	Kweon B, Sullivan W, Wiley A. Green common spaces and the social integration of inner-city older adults. Environ Behav 1998; 30(6):832-858.

100.	Kim J, Kaplan J. Physical and psychological factors in sense of community - new urbanist Kentlands and nearby orchard village. Environ Behav 2004; 36:313-340.

101.	Kawachi I, Kennedy BP, Lochner K, Prothrow-Stith D. Social capital, income inequality, and mortality. Am J Public Health 1997; 87(9):1491-1498.

102.	Berkman LF, Syme SL. Social networks, host resistance, and mortality: a nine-year follow-up study of Alameda County residents. Am J Epidemiol 1979; 109(2):186-204.

103. Kawachi I, Berkman L. Social ties and mental health. J Urban Health 2001; 78(3):458-467.

104. Ineichen B, Hooper D. Wives' mental health and children's behaviour problems in contrasting residential areas. Soc Sci Med 1974; 8(6):369-374.

105. Evans GW, Lercher P, Kofler WW. Crowding and children's mental health: the role of house type. J Environ Psychol 2002; 22(3):221-231.

106. Lazarou C, Panagiotakos DB, Panayiotou G, Matalas AL. Overweight and obesity in preadolescent children and their parents in Cyprus: prevalence and associated socio-demographic factors – the CYKIDS study. Obes Rev 2008; 9(3):185-193.

107. Tester JM. The built environment: designing communities to promote physical activity in children. Pediatrics 2009; 123(6):1591-1598.

108. Giles-Corti B, Kelty SF, Zubrick SR, Villanueva KP. Encouraging walking for transport and physical activity in children and adolescents: How important is the built environment? Sports Med 2009; 39(12):995-1009.

109. Whitzman C, Mizachi D. Vertical living kids. Melbourne: University of Melbourne and VicHealth, 2009.

110. Ip J, Rose K, Morgan I, Burlutsky G, Mitchell P. Myopia and the urban environment: findings in a sample of 12-year-old Australian school children. Investigative Ophthalmology Vis Sci 2008; 49(9):3858-3863.

111. Cohen S, Glass DC, Singer JE. Apartment noise, auditory discrimination, and reading ability in children. J Exp Soc Psychol 1973; 9(5):407-422.

112. Elsley S. Children's experience of public space. Children & Society 2004; 18(2):155-164.

113. Piro FN, Noss O, Claussen B. Physical activity among elderly people in a city population: the influence of neighbourhood level violence and self perceived safety. J Epidemiol Community Health 2006; 60(7):626-632.

114. Lawton MP, Nahemow L, Teaff J. Housing characteristics and the well-being of elderly tenants in federally assisted housing. J Gerontol 1975; 30(5):601-607.

115. Burby R, Rohe W. Providing for the housing needs of the elderly. J Am Plann Assoc 1990; 56(3):324-340.

116. Giles-Corti B, Foster S, Shilton T, Falconer R. The co-benefits for health of investing in active transportation. New South Wales public health bulletin 2010; 21(5-6):122-127.

117. Australian Bureau of Statistics. 3222.0 Population Projections, Australia, 2006 to 2101. Canberra: Australian Bureau of Statistics, 2008.

118. Department of Infrastructure and Transport. Our cities - the challenge of change. Background and research paper. Canberra: Department of Infrastructure and Transport, 2010.

119. Department of Sustainability, Environment, Water, Population, and Communities. A sustainable population strategy for Australia. Canberra: Commonwealth of Australia, 2010.

120. Department of Planning and Local Government. The 30-year plan for Greater Adelaide. A volume of the South Australian Planning Strategy. Adelaide: Government of South Australia, 2010.

121. Department of Planning and Community Development. Melbourne 2030: a planning update. Melbourne @ 5 million. Melbourne: Victorian Government, 2008.

122. Queensland Department of Infrastructure and Planning. South East Queensland Regional Plan 2009-2031. Brisbane: Queensland Department of Infrastructure and Planning, 2009.

123. NSW Department of Planning. Metropolitan plan for Sydney 2036. Sydney: NSW Government, 2010.

124. ACT Planning and Land Authority. The Canberra spatial plan. Canberra City: ACT Planning and Land Authority, 2004.

125. Department of Planning, WA Planning Commission. Directions 2031 and beyond. Metropolitan planning beyond the horizon. Perth: Western Australian Planning Commission, 2010.

126. Planning and Infrastructure. Metropolitan plan for Sydney 2036. Strategy direction D: housing Sydney's population. Sydney: NSW Government, 2010.

127. Frank LD, Pivo G. Impacts of mixed use and density on utilization of three modes of travel: single-occupant vehicle, transit, and walking. Transport Res Rec 1994; 1466:44-52.

128. Forsyth A. Measuring density: working definitions for residential density and building intensity. Minnesota: Design Center for American Urban Landscape, 2003.

129. Cardew R. Residential densities in Sydney: defining and measuring residential densities. Australian Planner 1996; 33(2):105-113.

130. Buxton M, Scheurer J. Density and outer urban development in Melbourne. Urban Policy & Research 2007; 25(1):91-111.

131. National Heart Foundation of Australia, Planning Institute Australia, Australian Local Government Association. Design principle - mixed density: Healthy Spaces & Places, 2009.

132. The Canberra Spatial Plan. Glossary. Canberra: ACT Planning and Land Authority, 2007 [28 October 2008]; Available from: http://apps.actpla.act.gov.au/spatialplan/6_glossary/index.htm.

133. Butland B, Jebb S, Kopelman P, McPherson K, Thomas S, Mardell J, et al. Foresight. Tackling obesities: future choices - project report. London: Government Office for Science, 2007.

134. National Preventative Health Taskforce. Australia: the healthiest country by 2020. National Preventative Health Strategy - the roadmap for action. Canberra: Commonwealth of Australia, 2009.

135. National Heart Foundation of Australia. Blueprint for an active Australia. Key government and community actions required to increase population levles of physical activity in Australia - 2010-2013. Melbourne: National Heart Foundation of Australia, 2009.

136. National Heart Foundation of Australia. Position statement: the built environment and walking. Melbourne: National Heart Foundation of Australia, 2009.

137. US Department of Health and Human Services. Physical activity and health. A report of the Surgeon General. Atlanta, Georgia: USDHHS, Centres for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, 1996.

138. World Health Organization. Global surveillance, prevention and control of chronic respiratory diseases: a comprehensive approach. Geneva, Switzerland: WHO, 2007.

139. World Health Organization. Global strategy on diet, physical activity and health. Geneva, Switzerland: WHO, 2004. Report No.: WHA57.17.

140. World Health Organization. Global health risks: mortality and burden of disease attributable to selected major risks. Geneva, Switzerland: WHO, 2009.

141. Begg S, Vos T, Barker B, Stevenson C, Stanley L, Lopez AD. The burden of disease and injury in Australia, 2003. Canberra: AIHW, 2007. Contract No.: PHE82.

142. World Health Organization. Obesity and overweight. Geneva, Switzerland: WHO, 2006. Contract No.: Fact sheet 311.

143. World Health Organization. Obesity. Preventing and managing the global epidemic. WHO Technical Report Series 894. Geneva, Switzerland: WHO, 2000.

144. Booth M, Wake M, Armstrong T, Chey T, Hesketh K, Mathur S. The epidemiology of overweight and obesity among Australian children and adolescents 1995-97. Australian and New Zealand Journal of Public Health 2001; 25(2):162-169.

145. Harten N, Olds T. Patterns of active transport in 11-12 year old Australian children. Australian and New Zealand Journal of Public Health 2004; 28:167-172.

146. Bradshaw R. School children's travel - the journey to school. Geography 2001; 86:77-78.

147. French S, Story M, Jeffery R. Environmental influences on eating and physical activity. Ann Rev Public Health 2001; 22:309-335.

148. Panter JR, Jones AP, van Sluijs EM. Environmental determinants of active travel in youth: a review and framework for future research. Int J Behav Nutr Phys Act 2008; 5:34.

149. van der Ploeg HP, Merom D, Corpuz G, Bauman AE. Trends in Australian children traveling to school 1971-2003: burning petrol or carbohydrates? Prev Med 2008; 46(1):60-62.

150. Woodward A, Lindsay G. Changing modes of travel in New Zealand cities. In: Howden-Chapman P, Stuart K, Chapman R, editors. Sizing up the city. Urban form and transport in New Zealand Wellington: New Zealand Centre for Sustainable Cities centred at University of Otago, 2010.

151. Department of Health. 2009 Annual Report of the Chief Medical Officer. London: Department of Health, 2009.

152. Swinburn B, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritising environmental interventions for obesity. Prev Med 1999; 29(6 Pt 1):563-570.

153. Hill JO, Melanson EL. Overview of the determinants of overweight and obesity: current evidence and research issues. Med Sci Sport Exer 1999; 31(11 Suppl):S515-521.

154. Hill JO, Peters JC. Environmental contributions to the obesity epidemic. Science 1998; 280(5368):1371-1374.

155. Giles-Corti B, Robertson-Wilson J, Wood L, Falconer R. The role of the changing built environment in shaping our shape. In: Pearce J, Witten K, editors. Geographies of obesity environmental understandings of the obesity epidemic Surrey: Ashgate Publishing, 2010.

156. Falconer R, Giles-Corti B. Smart development: designing the built environment for improved access and health outcomes. In: Newman P, editor. Transitions. Pathways towards sustainable urban development in Australia Collingwood, Victoria: CSIRO, 2008.

157. Laird P, Newman P. How we got here: the role of transport in the development of Australia and New Zealand. In: Laird P, Newman P, Bachels M, Kenworthy J, editors. Back on track: rethinking transport policy in Australia and New Zealand Sydney: UNSW Press, 2001.

158. Davison G. Car wars: how the car won our hearts and conquered our cities. Crows Nest, NSW: Allen & Unwin, 2004.

159. Owen N, Cerin E, Leslie E, duToit L, Coffee N, Frank LD, et al. Neighborhood walkability and the walking behavior of Australian adults. Am J Prev Med 2007; 33(5):387-395.

160. Owen N, Humpel N, Leslie E, Bauman A, Sallis JF. Understanding environmental influences on walking: review and research agenda. Am J Prev Med 2004; 27(1):67-76.

161. Frank LD, Schmid TL, Sallis JF, Chapman J, Saelens BE. Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. Am J Prev Med 2005; 28(2, Suppl 2):117-125.

162. Kligerman M, Sallis JF, Ryan S, Frank LD, Nader PR. Association of neighborhood design and recreation environment variables with physical activity and body mass index in adolescents. Am J Health Promot 2007; 21(4):274-277.

163. van Dyck D, Cardon G, Deforche B, De Bourdeaudhuij I. Lower neighbourhood walkability and longer distance to school are related to physical activity in Belgian adolescents. Prev Med 2009; 48:516-518.

164. Frank LD, Sallis JF, Conway TL, Chapman JE, Saelens BE, Bachman W. Many pathways from land use to health: associations between neighborhood walkability and active transportation, body mass index, and air quality. J Am Plann Assoc 2006; 72(1):75-87.

165. Doyle S, Kelly-Schwartz A, Schlossberg M, Stockard J. Active community environments and health. J Am Plann Assoc 2006; 72(1):19-31.

166. Berrigan D, Troiano RP. The association between urban form and physical activity in U.S. adults. Am J Prev Med 2002; 23(2, Suppl 1):74-79.

167. Berke EM, Koepsell TD, Moudon AV, Hoskins RE, Larson EB. Association of the built environment with physical activity and obesity in older persons. Am J Public Health 2007; 97(3):486-492.

168. Roemmich JN, Epstein LH, Raja S, Yin L, Robinson J, Winiewicz D. Association of access to parks and recreational facilities with the physical activity of young children. Prev Med 2006; 43(6):437-441.

169. McDonald N. Children's mode choice for the school trip: the role of distance and school location in walking to school. Transportation 2008; 35:23-35.

170. Saelens BE, Handy SL, Saelens BE, Handy SL. Built environment correlates of walking: a review. Med Sci Sport Exer 2008; 40(7 Suppl):S550-566.

171. Sugiyama T, Leslie E, Giles-Corti B, Owen N. Physical activity for recreation or exercise on neighbourhood streets: associations with perceived environmental attributes. Health Place 2009; 2009(15):1058-1063.

172. Sugiyama T, Ward-Thompson C. Associations between characteristics of neighbourhood open space and older people's walking. Urban Forestry & Urban Greening 2008; 7(1):41-51.

173. Lee IM, Ewing R, Sesso HD. The built environment and physical activity levels: the Harvard Alumni Health Study. Am J Prev Med 2009; 37(4):293-298.

174. Hou N, Popkin BM, Jacobs Jr DR, Song Y, Guilkey D, Lewis CE, et al. Longitudinal associations between neighborhood-level street network with walking, bicycling, and jogging: The CARDIA study. Health Place 2010; 16(6):1206-1215.

175. Berry TR, Spence JC, Blanchard CM, Cutumisu N, Edwards J, Selfridge G. A longitudinal and cross-sectional examination of the relationship between reasons for choosing a neighbourhood, physical activity and body mass index. Int J Behav Nutr Phys Act 2010; 7:57.

176. Boone-Heinonen J, Guilkey D, Evenson K, Gordon-Larsen P. Residential self-selection bias in the estimation of built environment effects on physical activity between adolescence and young adulthood. Int J Behav Nutr Phys Act 2010; 7(70):1-11.

177. Krizek KJ. Pretest-posttest strategy for researching neighborhood-scale urban form and travel behavior. Transport Res Rec 2000; 1722:48-55.

178. Ludwig JP, Sanbonmatsu LP, Gennetian LP, Adam EP, Duncan GP, Katz LP, et al. Neighborhoods, obesity, and diabetes - a randomized social experiment. New Engl J Med 2011; 365(16):1509.

179. Wells NM, Yang Y. Neighborhood design and walking: a quasi-experimental longitudinal study. Am J Prev Med 2008; 34(4):313-319.

180. Ogilvie D, Foster CE, Rothnie H, Cavill N, Hamilton V, Fitzsimons CF, et al. Interventions to promote walking: systematic review. BMJ 2007; 334(7605):1204.

181. Lee R, Cervero R. Research basis for proposed criteria of the TOD Housing Program. The effect of housing near transit stations on vehicle trip rates and transit trip generation. A review of available evidence. California: University of California, Institute of Urban and Regional Development, 2007.

182. McCormack GR, Giles-Corti B, Bulsara M. The relationship between destination proximity, destination mix and physical activity behaviors. Prev Med 2008; 46(1):33-40.

183. Infrastructure Australia Major Cities Unit. State of Australian Cities. Canberra: Commonwealth of Australia, 2010.

184. Newman P, Kenworthy J. Urban design to reduce automobile dependence. Opolis 2006; 2(1):35-52.

185. Hoffmann B, Moebus S, Stang A, Beck EM, Dragano N, Möhlenkamp S, et al. Residence close to high traffic and prevalence of coronary heart disease. Eur Heart J 2006; 27(22):2696-2702.

186. Hoek G, Brunekreef B, Goldbohm S, Fischer P, van den Brandt PA. Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. Lancet 2002; 360(9341):1203-1209.

187. World Health Organization. WHO strategy for prevention and control of chronic respiratory diseases. Geneva, Switzerland: WHO, 2002.

188. World Health Organization. The World Health Report 2002: Reducing risks, promoting healthy life. Geneva, Switzerland: WHO, 2002.

189. World Health Organization. Active aging: a policy framework. Geneva, Switzerland: WHO, 2002.

190. World Health Organization. What triggers an asthma attack? Geneva, Switzerland: WHO, 2008.

191. Burrows B, Martinez FD, Halonen M, Barbee RA, Cline MG. Association of asthma with serum IgE levels and skin-test reactivity to allergens. New Engl J Med 1989; 320(5):271-277.

192. Peat JK, Tovey E, Toelle BG, Haby MM, Gray EJ, Mahmic A, et al. House dust mite allergens. A major risk factor for childhood asthma in Australia. Am J Respir Crit Care Med 1996; 153(1):141.

193. Rosenstreich DL, Eggleston P, Kattan M, Baker D, Slavin RG, Gergen P, et al. The role of cockroach allergy and exposure to cockroach allergen in causing morbidity among inner-city children with asthma. New Engl J Med 1997; 336(19):1356-1363.

194. Sporik R, Holgate ST, Platts-Mills TAE, Cogswell JJ. Exposure to house-dust mite allergen (Der p I) and the development of asthma in childhood. New Engl J Med 1990; 323(8):502-507.

195. Zandbergen PA. Methodological issues in determining the relationship between street trees and asthma prevalence. J Epidemiol Community Health 2009; 63(2):174-175.

196. Riediker M, Williams R, Devlin R, Griggs T, Bromberg P. Exposure to particulate matter, volatile organic compounds, and other air pollutants inside patrol cars. Environ Sci Technol 2003; 37(10):2084-2093.

197. Zhu Y, Hinds W, Kim S, Siontas C. Concentration and size distribution of ultra-fine particles near a major highway. J Air Waste Manage 2002; 52:1032-1042.

198. Roemer W, van Wijnen J. Daily mortality and air pollution along busy streets in Amsterdam, 1987-1998. Epidemiology 2001; 12(6):649-653.

199. The Health Effects Institute. Traffic-related air pollution: a critical review of the literature on emissions, exposure and health effects: The Health Effects Institute, 2010.

200. Yang W, Omaye ST. Air pollutants, oxidative stress and human health. Mutat Res 2009; 674(1-2):45-54.

201. Heinrich J, Wichmann HE. Traffic related pollutants in Europe and their effect on allergic disease. Curr Opin Allergy Clin Immunol 2004; 4(5):341-348.

202. Braback L, Forsberg B. Does traffic exhaust contribute to the development of asthma and allergic sensitization in children: findings from recent cohort studies. Environ Health 2009; 8(1):17.

203. Samet J, Krewski D. Health effects associated with exposure to ambient air pollution. J Toxicol Env Health 2007; 70(3-4):227-242.

204. Schwartz J. Long-term effects of exposure to particulate air pollution. Clin Occup Environ Med 2006; 5(4):837-848.

205. Department of Transport and Regional Services. Health impacts of transport emissions in Australia: economic costs: Commonwealth of Australia, 2005.

206. Jalaludin B, Morgan G, Lincoln D, Sheppeard V, Simpson R, Corbett S. Associations between ambient air pollution and daily emergency department attendances for cardiovascular disease in the elderly (65+ years), Sydney, Australia. J Expo Sci Environ Epidemiol 2006; 16(3):225-237.

---

207. American Thoracic Society. What constitutes an adverse health effect of air pollution? Am J Respir Crit Care Med 2000; 161:656-673.

208. Guite HF, Clark C, Ackrill G. The impact of the physical and urban environment on mental well-being. Public Health 2006; 120(12):1117-1126.

209. Lercher P, Evans GW, Meis M, Kofler WW. Ambient neighbourhood noise and children's mental health. Occup Environ Med 2002; 59(6):380-386.

210. Duvall D, Booth A. The housing environment and women's health. J Health Soc Behav 1978; 19:410-417.

211. Evans GW, Wells NM, Chan HYE, Saltzman H. Housing quality and mental health. J Consult Clin Psych 2000; 68(3):526-530.

212. Evans GW, Saegert S, Harris R. Residential density and psychological health among children in low-income families. Environ Behav 2001; 33(2):165-180.

213. Evans GW, Neil JS, Paul BB. Crowding and other environmental stressors. International Encyclopedia of the Social and Behavioral Sciences Oxford: Pergamon, 2001. p. 3018-3022.

214. Evans G, Saltzman H, Cooperman J. Housing quality and children's socioemotional health. Environ Behav 2001; 68:389-399.

215. Elton PJ, Packer JM. A prospective randomized trial of the value of rehousing on the grounds of mental ill-health. J Chron Dis 1986; 39(3):221-227.

216. Elton PJ, Packer JM. Neurotic illness as grounds for medical priority for rehousing. Public Health 1987; 101(4):233-242.

217. Wilner DM, Walkley RP. The effects of housing on physical and mental-health. Am J Orthopsychiat 1962; 32(2):304-305.

218. Carp FM. Impact of improved housing on morale and life satisfaction. Gerontologist 1975; 15(6):511-515.

219. Carp FM. Long-range satisfaction with housing. Gerontologist 1975; 15(1):68-72.

220. Amick DJ, Kviz FJ. Social alienation in public housing. The effects of density and building types. Ekistics 1975; 39(231):118-120.

221. Wilcox B, Holahan C. Social ecology of the megadorm in university student housing. J Ed Psychology 1976; 68:453-458.

222. McCarthy D, Saegert S. Residential density, social overload, and social withdrawal. In: Aiello J, Baum A, editors. Residential crowding and density New York: Plenum, 1979.

223. Churchman A, Ginsberg Y. The image and experience of high rise housing in Israel. J Environ Psychol 1984; 4:27-41.

224. Gillis AR. High-rise housing and psychological strain. J Health Soc Behav 1977; 18(4):418-431.

225. Newman O. Defensible space. London: Architectural Press, 1972.

226. Kearns RA, Smith CJ. Housing stressors and mental-health among marginalized urban populations. Area 1993; 25(3):267-278.

227. Whitley R, Prince M. Fear of crime, mobility and mental health in inner-city London, UK. Soc Sci Med 2005; 61(8):1678-1688.

228. Green G, Gilbertson JM, Grimsley FJ. Fear of crime and health in residential tower blocks. Eur J Public Health 2002; 12(1):10-15.

229. Covington JM, Taylor RB. Fear of crime in urban residential neighborhoods: implications of between and within-neighborhood sources for current models. Sociol Quart 1991; 32(2):231.

230. Hale C. Fear of crime: a review of the literature. Int Rev Victimol 1996; 4:79-150.

231. Comerio MC. Pruitt-Igoe and other stories. J Archit Edu 1981; 34(4):26-31.

232. Commission for Architecture and the Built Environment. The cost of bad design. London: CABE, 2006.

233. Skogan W, Maxfield M. Coping with crime: individual and neighborhood reactions. Beverley Hills: Sage Publications, 1981.

234. Wood L, Shannon T, Bulsara M, Pikora T, McCormack G, Giles-Corti B. The anatomy of the safe and social suburb: an exploratory study of the built environment, social capital and residents' perceptions of safety. Health Place 2008; 14(1):15-31.

235. Austin DM, Furr LA, Spine M. The effects of neighborhood conditions on perceptions of safety. J Crim Just 2002; 30(5):417-427.

236. Foster S, Giles-Corti B, Knuiman M. Neighbourhood design and fear of crime: a social-ecological examination of the correlates of residents' fear in new suburban housing developments. Health Place 2010; 16(6):1156-1165.

237. Nasar J. A model relating visual attributes in the residential environment to fear of crime. J Environ Syst 1982; 11(3):247-255.

238. Perkins DD, Meeks JW, Taylor RB. The physical environment of street blocks and resident perceptions of crime and disorder: implications for theory and measurement. J Environ Psychol 1992; 12:21 - 34.

239. Caughy M, O'Campo P, Patterson J. A brief observational measure for urban neighborhoods. Health Place 2001; 7(3):225-236.

240. Lee RE, Booth KM, Reese-Smith JY, Regan G, Howard HH. The Physical Activity Resource Assessment (PARA) instrument: evaluating features, amenities and incivilities of physical activity resources in urban neighborhoods. Int J Behav Nutr Phys Act 2005; 2(13).

241. Witten K. Intensification, housing affordability and families: learning from the Auckland CBD. In: Abrahamse W, Witten K, editors. Growth misconduct Wellington, New Zealand: NZ Centre for Sustainable Cities, University of Otago, 2011.

242. Crowe T. Crime prevention through environmental design. Newton, MA: Butterworth-Heinemann, 1991.

243. Foster S, Giles-Corti B, Knuiman M. Creating safe walkable streetscapes: does house design and upkeep discourage incivilities in suburban neighbourhoods? J Environ Psychol 2011; 31:79-88.

244. Poyner B. Design against crime: beyond defensible space. Cambridge, UK: University Press, 1983.

245. Greenberg SW, Rohe WM, Williams JR. Safety in urban neighborhoods: a comparison of physical characteristics and informal territorial control in high and low crime neighborhoods. Popul Environ 1982; 5(3):141-165.

246. Beavon DJK, Brantingham PL, Brantingham PJ. The influence of street networks on the patterning of property offences. In: Clarke R, editor. Crime Preventions Studies New York: Criminal Justice Press, 1994.

247. Brantingham PL, Brantingham PJ. Nodes, paths and edges: considerations on the complexity of crime and the physical environment. J Environ Psychol 1993; 13:3-28.

248. Brown MB. Modelling the spatial distribution of suburban crime. Economic Geography 1982; 58(3):247-261.

249. Bowes DR. A two-stage model of the simultaneous relationship between retail development and crime. Econ Dev Q 2007; 21(1):79-90.

250. Peterson RD, Krivo LJ, Harris MA. Disadvantage and neighborhood violent crime: do local institutions matter? J Res Crime Delinq 2000; 37(1):31-63.

251. Gorman DM, Speer PW, Gruenewald PJ, Labouvie EW. Spatial dynamics of alcohol availability, neighborhood structure and violent crime. J Stud Alcohol 2001; 62:628-636.

252. Schweitzer JH, Kim JW, Macklin JR. The impact of the built environment on crime and fear of crime in urban neighborhoods. J Urban Technol 1999; 6(3):59-73.

253. Smith WR, Frazee SG, Davison EL. Furthering the integration of routine activity and social disorganization theories: small units of analysis and the study of street robbery as a diffusion process. Criminology 2000; 38(2):489-524.

254. Gruenewald PJ, Freisthler B, Remer L, LaScala EA, Treno A. Ecological models of alcohol outlets and violent assaults: crime potentials and geospatial analysis. Addiction 2006; 101(5):666-677.

255. Roncek DW, Lobosco A. The effect of high schools on crime in their neighbourhoods. Soc Sci Quart 1983; 64(3):598-613.

256. Wilcox P, Quisenberry N, Cabrera D, Jones S. Busy places and broken windows? Toward defining the role of physical structure and process in community crime models. Sociol Quart 2004; 45(2):185-207.

257. Loukaitou-Sideris A. Hot spots of bus stop crime. J Am Plann Assoc 1999; 65(4):395-411.

258. de Vries S, Verheij R, Groenewegen P, Spreeuwenberg P. Natural environments - healthy environments? An exploratory analysis of the relationship between greenspace and health. Environ Plann A 2003; 35:1717-1731.

259. Rappe E, Kivela S, Rita H. Visiting outdoor green environments positively impacts self-rated health among older people in long-term care. HortTechnology 2006; 16:55-59.

260. Hall T. Where have all the gardens gone? An investigation into the disappearance of backyards in the newer Australian suburb. Brisbane: Griffith University, 2007.

261. Hall T. The life and death of the Australian backyard. Melbourne: CSIRO Publishing, 2010.

262. Frumkin H. Beyond toxicity: human health and the natural environment. Am J Prev Med 2001; 20(3):234-240.

263. Sugiyama T, Healy GN, Dunstan DW, Salmon J, Owen N. Is television viewing time a marker of a broader pattern of sedentary behavior? Ann Behav Med 2008; 35(2):245-250.

264. Francis J. Associations between public space and mental health in new residental developments. Perth, WA: The University of Western Australia, 2010.

265. Ulrich R. View through a window may influence recovery from surgery. Science 1984; 224:420-421.

266. Mitchell R, Popham F. Greenspace, urbanity and health: relationships in England. J Epidemiol Community Health 2007; 61(8):681-683.

267. Foster S, Giles-Corti B, Knuiman M. Does fear of crime discourage walkers? A social-ecological exploration of fear as a deterrent to walking in new suburbs. J Phys Activ Health (under review).

268. Veal A. Open space planning standards in Australia: in search of origins: U-Plan Project Paper 1 Second Edition. Lindfield, NSW: University of Technology Sydney, 2009.

269. Stephenson G, Hepburn J. Plan for the metropolitan region Perth and Fremantle. Perth, Western Australia: Government Printing Office, 1955.

270. Giles-Corti B, King AC. Creating active environments across the life course: "thinking outside the square". Brit J Sport Med 2009; 43(2):109-113.

271. Western Australian Planning Commission. Liveable neighbourhoods: a Western Australian Government Sustainable Cities Initiative. Perth, WA: Western Australian Planning Commission, 2007.

272. Innocenti Research Centre. Building child friendly cities: a framework for action. Florence, Italy: UNICEF, 2004.

273. Becker FD. Children's play in multifamily housing. Environ Behav 1976; 8(4):545-574.

274. Hillman M, Adams J, Whitelegg J. One false move... a study of children's independent mobility. London: PSI Publishing, 1990.

275. Nordström M. Children's views on child-friendly environments in different geographical, cultural and social neighbourhoods. Urban Studies 2010; 47(3):514-528.

276. Boarnet MG, Day K, Anderson C, McMillan T, Alfonzo M. California's safe routes to school program - impacts on walking, bicycling, and pedestrian safety. J Am Plann Assoc 2005; 71(3):301-317.

277. Timperio A. Personal, family, social, and environmental correlates of active commuting to school. Am J Prev Med 2006; 30(1):45-51.

278. Giles-Corti B, Wood G, Pikora T, Learnihan V, Bulsara M, Van Niel K, et al. School site and the potential to walk to school: the impact of street connectivity and traffic exposure in school neighborhoods. Health Place 2011; 17(2):545-550.

279. Dunton GF, Kaplan J, Wolch J, Jerrett M, Reynolds KD. Physical environmental correlates of childhood obesity: a systematic review. Obes Rev 2009; 10(4):393-402.

280. Peterson C. Looking forward through the lifespan: developmental psychology. 4th ed. Sydney: Prentice Hall, 2004.

281. Carver A, Timperio A, Crawford D. Playing it safe: the influence of neighbourhood safety on children's physical activity - a review. Health Place 2008; 14(2):217-227.

282. de Vries SI, Bakker I, van Mechelen W, Hopman-Rock M. Determinants of activity-friendly neighbourhoods for children: results from the SPACE study. Am J Health Promot 2007; 21(4):312-659.

283. Kelty S, Giles-Corti B, Zubrick SR. Healthy body, healthy mind: why physically active children are healthier physically, psychologically and socially. In: Beaulieu N, editor. Physical activity and children: new research Hauppauge, NY: Nova Science Publishers Inc, 2008.

284. Foster S, Giles-Corti B. The built environment, neighborhood crime and constrained physical activity: an exploration of inconsistent findings. Prev Med 2008; 47(3):241-251.

285. Min B, Lee J. Children's neighborhood place as a psychological and behavioral domain. J Environ Psychol 2006; 26(1):51-71.

286. World Health Organization. Global age-friendly cities: a guide. Geneva, Switzerland WHO, 2007.

287. Swan W. Australia to 2050: future challenges. The 2010 intergenerational report. Barton, ACT: Commonwealth of Australia, 2010.

288. Nelson ME, Rejeski WJ, Blair SN, Duncan PW, Judge JO, King AC, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Circulation 2007; 116(9):1094-1105.

289. World Health Organization. Towards policy for health and ageing. Geneva, Switzerland: WHO, 2002.

290. Freedman VA, Grafova IB, Rogowski J. Neighborhoods and chronic disease onset in later life. Am J Public Health 2011; (1):79-86.

291. Diez Roux A. Residential environments and cardiovascular risk. J Urban Health 2003; 80(4):569-589.

292. Learnihan V, Van Neil K, Giles-Corti B, Knuiman M. Effect of scale on the links between walking and urban design. Geographical Research 2011; 49(2):183-191.

293. Grafova IB, Freedman VA, Kumar R. Neighborhoods and obesity in later life. Am J Public Health 2008; 98(11):2065-2071.

294. King WC, Belle SH, Brach JS, Simkin-Silverman LR, Soska T, Kriska AM. Objective measures of neighborhood environment and physical activity in older women. Am J Prev Med 2005; 28(5):461-469.

295. Devlin AS. Housing for the elderly: "cognitive considerations". Environ Behav 1980; 12:451.

296. Zaff J, Devlin As. Sense of community in housing for the elderly. J Community Psychol 1998; 26(4):381-398.

297. Normoyle JB, Foley JM. The defensible space model of fear and elderly public housing residents. Environ Behav 1988; 20:50.

298. Ramroth WG. Planning for disaster: how natural and man-made disasters shape the built environment. New York: Kaplan Publishing, 2007.

299. Waghorn B. Urban intensification in Auckland: are we growing smarter? In: Witten K, Abrahamse W, Stuart K, editors. Growth misconduct? Avoiding sprawl and improving urban intensification in New Zealand Wellington, New Zealand: Steele Roberts Aotearoa New Zealand, 2011.

300. Greater London Authority. Housing for a compact city. London: Greater London Authority, 2003.

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