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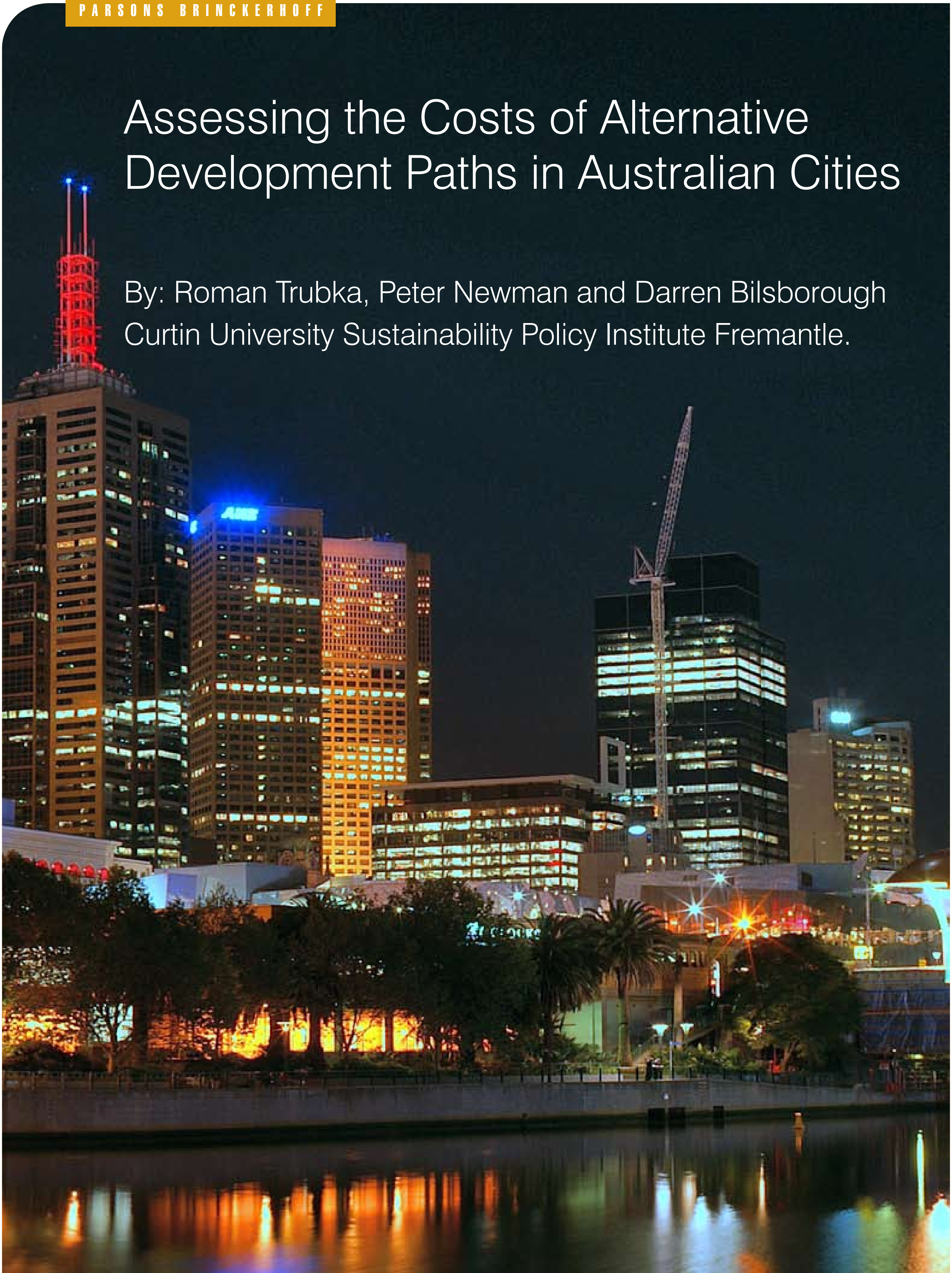
Assessing the Costs of Alternative Development Paths in Australian Cities

By: Roman Trubka, Peter Newman and Darren Bilsborough
Curtin University Sustainability Policy Institute Fremantle.



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Abstract

This paper explores the economic impacts associated with two iconic development types (urban redevelopment and fringe development) as their embodied costs are broken down into the categories of infrastructure provision, transportation costs, greenhouse gas emissions and health costs. The findings show that there are substantial cost savings associated with urban redevelopment. By far, the largest figures are associated with infrastructure and transportation while GHG emissions and health constitute smaller portions of total costs, although the latter do have serious implications in terms of the attainability of national emissions reductions targets (redevelopment will save 4,400 tonne of GHG per year for 1,000 dwellings) and the Australian population's health and well being (now one of the most obese populations in the world). Emissions and health savings are closely related to active forms of travel that are only realizable in areas with high levels of amenity and servicing and high levels of transit access. Their cost savings over a 50 year urban lifetime are quite modest, $19.32 million and $4.23 million for 1000 dwellings, but if these more walkable, low emission developments are pursued then the savings in transport and infrastructure for 1000 dwellings are in the order of $86 million up-front for infrastructure and $250 million for annualized transportation costs over 50 years. A simple model is developed from these assessments that can be used to predict urban development costs associated with any proposed development in Australian cities or with the associated urban development from any major infrastructure decisions.

Executive Summary

The purpose of this research is to develop a tool to assess the economic costs in urban development decisions in Australia by comparing inner-city redevelopment and conventional fringe development. The associated costs taken into consideration for the assessment include infrastructure provision, transportation costs, greenhouse gas emissions, and inactivity-related health costs and are estimated for a development of 1,000 dwellings. The proposed approach can be used to assess these costs in any development or in any infrastructure decision that would lead to different development patterns.

Costs associated with infrastructure provision were mainly drawn from a study titled Future Perth that was commissioned by the Western Australian Planning Commission. The report surveyed 22 studies from the United States, Canada, and Australia on infrastructure costs associated with inner, middle, and outer city developments. For the purpose of this report, the consumer price index and labour price index were consulted to inflate the 1999 prices contained within Future Perth to 2007 Prices. The resulting cost of up-front infrastructure provision for an inner city and fringe development in 2007 prices were $50.5 million and $136.0 million respectively.

Transportation costs were drawn from a previous study by Newman and Kenworthy (1992) that reported annual costs associated with private vehicle depreciation and operating costs, annual road infrastructure costs, transit costs, time costs, and externalities. The annual costs were inflated to 2007 prices and then capitalized over a 50-year period. The present value of annually recurring transportation costs for an inner city and fringe development were valued at $256.8 million and $507.1 million respectively.

Unlike infrastructure and transportation costs, assessing the economic costs of transport greenhouse emissions associated with urban infill and fringe developments has not yet been done. The source of the data used was a study by Chandra (2006) that attempted to model daily per capita greenhouse emissions as a function of various urban form parameters in the cities of Melbourne, Sydney, and Perth. For the purpose of this assessment, the data was modelled for the following three combined parameters: distance to CBD, activity intensity, and transit accessibility. In this model, activity intensity came out as insignificant – a likely result of density being a proxy for developing closer to a CBD. The data was run again after removing activity intensity from the model. The resulting equation was **y = .073x -.25z + 4.35**, where 'y' is the daily per capita greenhouse emissions in kg CO_2-e, 'x' is the distance to the CBD and 'z' is the transit accessibility measured as a percentage of the area characterized by a transit servicing of greater than 15 minutes as well as evening and weekend services. The model explains 73.4% of the variance in greenhouse emissions. Finally, factoring in a social cost of $170 per tonne CO_2-e for a development of 1000 dwellings resulted in a capitalized cost of $17.39 million and $36.70 million respectively for inner city and fringe developments over a 50-year period.

The inactivity-related health component of the report was similar to the greenhouse gases component in that it is a newly related subject to the economic impacts of urban form, possibly to an even greater extent than greenhouse. A methodology for calculating the health-related savings potential of developing active travel neighbourhoods was devised and subsequently a capitalized value of $4.2 million was calculated over 50-years. The health component was calculated as a savings potential, not an incurred cost, because inactivity-related health costs are not exclusively caused by urban form. The relationship between active modes of travel and urban form is very complex and multidimensional, leaving many experts on the subject still speculating about the underlying causal factors. This component of the assessment is concluded by the illumination of a number of other considerations still needing attention, especially the productivity improvements at work associated with people who live more actively in their daily lives rather than sitting in a car.

Consolidating the costs attaches a price on inner city redevelopment of approximately $309 million and $653 million for fringe development. These estimates include the up-front costs of infrastructure provision and the capitalization of recurring transport, greenhouse gas, and activity-related health costs. What the separate component costs suggest is that greenhouse gas and health costs are unlikely to catalyze urban reform on an economic basis because of their relatively small economic appraisal. They do, however, reflect important issues facing policy makers that must be met for many reasons. If achieved through urban development then they will only constitute a minor economic benefit but there will be a very substantial economic benefit from the transport and infrastructure cost savings. Thus greenhouse and health benefits comprise a companion rationale for developing in areas of higher density, transit accessibility, and mixed-use which have a strong economic base.

A simple model was derived from these assessments that can be used to predict costs associated with any urban development in Australian cities. The model reduces to a simple relationship between urban development costs and distance to the CBD which is a surrogate for the character of urban development: **y = 5.68x + 306.56** where y is the cost of development in millions of dollars and x is the distance to CBD.

1. Introduction

Australian cities are under focus as the Federal Government begins to invest in urban infrastructure and questions are raised about the fuel, greenhouse gas and health impacts of such investment. This paper examines two alternative approaches to urban development: redevelopment in walkable, transit oriented developments and fringe development in conventional low-density car dependent suburbs. Redevelopment is based around present urban areas that are already well served by public transport but can also include new developments, so long as transit accessibility, walkability, and density are implemented in the planning and design process. Table 1 sets out the two development types according to some of their defining characteristics. More detailed data can be referred to in Appendix 2, based on Sydney and Melbourne local government areas.

Table 1 Representative characteristics of two opposing iconic urban forms

	Urban redevelopments	Fringe developments
Daily per capita GHG emissions (kg CO2-e)	0–4	8–10 and up
Distance to CBD (Km)	<10	>40
Activity Intensity (pop. + jobs per ha)	>35	<20
Transit Accessibility (% with >15min service)	>80%	<20%

The two development types are based on the four or five core/inner local governments in Melbourne and Sydney as well as their four or five fringe local governments. Table 2 sets out some other transport data that characterizes Melbourne's local area differences, particularly showing how much more walkable and transit oriented the core/inner area is. These are also wealthier areas as Table 2 indicates.

Table 2 Trips per day per person by area, Melbourne

	Core	Inner	Middle	Outer/fringe
Car	2.12	2.52	2.86	3.92
Transit	0.66	0.46	0.29	0.04
Walk/bike	2.62	1.61	1.08	0.81
Income >$70,000	12%	11%	10%	6%

This paper will examine the economic costs associated with these two iconic developments. It will first assess the physical planning costs associated with the different transport and infrastructure requirements. Then it will examine two new areas of public policy – greenhouse gas emissions and activity-related health costs. These are the subjects of increasing interest and their economic costs can be compared with the more traditional costs of physical planning.

2. Infrastructure costs

Background

The economic assessment of infrastructure costs associated with urban sprawl is not a recent concept. Such assessments have been done in Australia as early as the 1970's and numerous assessments have been done since; however, the most recent studies in Australia that could be found were from 2001 and 2002 and simply capitalized the costs reported in previous assessments to then current values. The challenge in interpreting the assessments is that infrastructure costs are so heavily dependent on area-specific factors. For instance, road costs among different prospective development areas may vary based on the necessity for major arterial roads, costs for sewerage and water infrastructure could vary immensely depending on terrain and trenching conditions, and many infrastructure components will differ depending on the level and degree of excess capacity. It is also difficult to determine who bares the costs of new infrastructure developments because of constantly changing government-induced fees, taxes, policies, and building standards.

Despite the area-specific nature of calculating development costs, the evidence suggests that initial capital costs and operating costs of sprawling developments outweigh the costs associated with inner-city redevelopment. Perhaps the most significant infrastructure category to mark an economic difference in provisioning is road construction. In many cases it can make up 50% of the cost difference between the two iconic development forms (SGS, 2003). The provisioning of water and sewerage infrastructure is another expensive infrastructure requirement. Markedly in these two categories, but in the others to some degree as well, inner-city redevelopment offers significant cost savings by either utilizing excess capacity or requiring less of the service because of shorter distances and greater compactness.

Calculating the costs of infrastructure

For determining the infrastructure costs of inner city and fringe developments, the main source of data was drawn from a paper prepared for the Western Australia Planning Commission in 2001. The report, titled Future Perth, was compiled by Environmental Resource Management Pty Ltd (ERM) with the intent to identify the economic cost differences between developments in inner, middle and fringe areas. It reviewed the information produced by 22 studies across Australia, America, and Canada and sorted the cost findings into three different measures of urban form: inner, middle, and outer.

The Future Perth report drew on studies that ranged between the years of 1972 to 2000 but adjusted the reported costs to 1999 prices. The same would have been done for the purpose of this study in terms of capitalizing those reported values by a standard inflation rate to 2007 prices, however, since 2002 the prices of materials and labour in construction have increased disproportionately to the general consumer price and labour price indices. The main reason for the labour price increase is largely attributed to the mining operations in Australia drawing away a lot of skilled labour. To account for this, infrastructure costs were inflated according the Australian Bureau of Statistics' (ABS) reported price indices for the years 1999 to 2007. Table 3 shows how some of these categorical costs have changed between those years.

Table 3 Changes in infrastructure costs

Labour Wage Increases	Jun-99	Jun-07	Index Change	% Change
Electrical	83.1	114.8	31.7	38.1%
Gas	83.1	114.8	31.7	38.1%
Water	83.1	114.8	31.7	38.1%
Construction	83.8	115.7	31.9	38.1%
Transportation	86.8	110.8	24	27.6%
Government Administration and Defence	84.4	113.4	29	34.4%
Health and Community	85.9	113.5	27.6	32.1%
Property and Business	83.3	111.4	28.1	33.7%
Education	83.8	113.5	29.7	35.4%
Price Increases of Supplies				
Weighted Avg. of 6 Cap Cities	119.2	148.3	29.1	24.41%
Consumer Price Index				
CPI	122.3	157.5	35.2	28.78%

Source: ABS

When consolidating and capitalizing the residential development costs reported in Future Perth, the appropriate price increase was matched to each category according to the type of industry it fell into and if it was likely to include a labour component, a materials component, or both. Table 4 displays the economic breakdown of inner city and urban fringe initial capital costs in 2007 prices.

Table 4 Economic breakdown of inner city and urban fringe initial capital costs (2007)

	Inner	Outer
Roads	$5,086,562	$30,378,881
Water and Sewerage	$14,747,616	$22,377,459
Telecommunications	$2,576,106	$3,711,851
Electricity	$4,082,117	$9,696,505
Gas	$0	$3,690,843
Fire and Ambulance	$0	$302,509

	Inner	Outer
Police	$0	$388,416
Municipal Services	Not Reported	Not Reported
Education	$3,895,458	$33,147,274
Health	$20,114,867	$32,347,327
Total	$50,502,726	$136,041,065

The costs above represent the higher estimates reported by the studies surveyed by Future Perth. In the case of the inner-city provision of fire, ambulance, and police infrastructure, none of the Future Perth studies reported estimates. This was explained as being a likely result of excess capacity utilization. Cities typically have staffing ratios that they maintain of police officers to residents, but these costs are covered incrementally and would likely appear as operating costs, not needing new investments in physical infrastructure. Municipal services price estimates we not provided for either of the two urban forms, but this was merely for the reason than none of the surveyed studies researched these costs. What should be most duly noted of the above estimates is that the up-front capital costs are likely to be entirely borne by the public sector, not the developer. Under varying development provisioning recuperation schemes, some of these costs may be shifted to the developer; however, the costs are predominantly borne by government.

The Future Perth study also reviewed the operating costs reported by the numerous studies; however, they were incomplete. The majority of studies in the report either did not research operating costs, reported costs only for certain infrastructure items, or only reported them for one type of urban form. Aggregating the costs did not give a comprehensive depiction of infrastructure operating costs associated with inner city and fringe developments and therefore, they have not been included in this assessment.

3. Transportation costs

Background

Transportation is a derived need, meaning that people typically travel for some purpose other than for the simple reason of traveling, yet Australian cities are reaching an expansiveness necessitating many residents to commit upwards of an hour or two daily for commuting purposes. The embodied private, public, and external costs associated with the proliferation of roadways are substantial and have largely been driven by auto dependence, a byproduct of fringe development. In many sprawling suburbs, predominantly in the United States, the private costs of transportation have led to home values dropping and in some cases to a point where homes have been boarded up and abandoned. This should be a signifier that there are limits to growth and housing affordability does come at a cost.

Associated costs of transportation

The transportation costs associated with both inner-city and fringe development were drawn from a study by Newman and Kenworthy (1999) which, together with infrastructure constituted part of an economic assessment of urban form. The estimated costs were calculated as functions of vehicle kilometers traveled and covered all of private, public and external costs. Table 5 displays a summary of the costs in 2007 prices, which constitute the recurring annual costs of a development of 1,000 dwellings.

Table 5 Summary of costs (2007)

	Inner	Outer
Capital Cost of Cars	$2,990,802	$8,628,654
Fuel Costs	$1,203,925	$3,255,349
Other Operating Car Costs	$1,476,392	$4,259,675
Time Costs (total)	$0	$0
Private Transport	$3,116,810	$8,210,448
Public Transport	$3,041,538	$0
Walking and Cycling	$0	$0
Road Costs	$1,216,597	$3,508,806
Parking Costs	$2,184,489	$7,709,869
Externalities (total)	$243,731	$703,250
Fatalities	$73,368	$211,693
Injuries	$23,627	$68,172
Property Damage	$38,549	$111,228
Air Pollution	$90,777	$261,925
Noise Pollution	$17,409	$50,232
Transit Costs (Capital & Op)	$3,136,540	$470,481
Total	**$18,610,824**	**$36,746,532**

Newman & Kenworthy Study Transportation Costs (2007 Prices) 1,000 dwellings

The capital costs of cars are represented as annual depreciation figures. The increased wear of longer trip distances in outer-city developments is why the operating and capital costs of cars appear much higher that in inner areas. The higher fuel costs are also a reflection of longer trip distances but are likely to also be underestimated in this account because of more recent spikes in oil prices.

Parking costs represent a significant expenditure that can frequently be overlooked. The higher cost associated with fringe development is due to more parking spaces being required for fringe than inner-city residents. In Perth, the parking requirement for inner-areas is approximately four spaces, while outer areas require approximately 10 (Newman and Kenworthy, 1999). The level of parking provision is representative of the greater diversity of car trips and the greater proportion of trips requiring private transport that is characteristic of fringe areas.

To account for the annual stream of costs associated with transportation, the NPV was calculated over a period of 15 years as well as 50 years. The 15-year annuity was calculated as a reference point to numerous other economic assessments of development expenditures that tend to use a 15-year time period. The 50-year annuity was calculated for the purpose of this economic assessment to synchronize with the other sections. A discount rate of 7% was used for all of the transportation-related costs as suggested by the U.S. Department of Transportation (1994). The high rate is used because empirical evidence suggests that immediate benefits are valued higher than future benefits, hence a lower present value of future costs. Discount rates are frequently debated, however, Tables 6 and 7 present the values with a 7% rate to stay consistent with a generally agreed upon value.

Table 6 15 Year NPV

	Inner	Outer
Transport (7%)	$136,309,097	$226,100,382
Roads & Parking (7%)	$30,976,806	$102,178,732
Externalities (7%)	$2,219,884	$6,504,143
Total	$169,505,787	$334,783,257

Table 7 50Year NPV

	Inner	Outer
Transport (7%)	$206,542,055	$342,598,098
Roads and Parking (7%)	$46,937,535	$154,826,095
Externalities (7%)	$3,363,675	$9,705,379
Total	$256,843,265	$507,129,572

4. Greenhouse Gases

Background

It is well known and documented that the combustion of fossil fuels is leading to anthropogenic increases of CO2 equivalents (CO2-e) in the earth's atmosphere and as a result, global warming has become a primary international concern. The United Nations Framework Convention on Climate Change initiated the Kyoto Protocol, an international treaty designed to limit global greenhouse gas emissions, in 1997. When Australia ratified this agreement in December 2007, it made a commitment to limit its greenhouse gas emissions to 108% of its 1990 levels in the 2008/12 period. Under the "Business As Usual" scenario it has been predicted that Australia's greenhouse gas emissions would reach 124% of its 1990 levels over the Kyoto period. Additionally, the federal government has made a commitment to reduce greenhouse gas emissions 80% by 2050. Urban development priorities can make a big difference as to whether this will be possible to reach.

Currently, transportation in Australia accounts for 14% of total GHG production and road transport is responsible for 88% of this figure (12.3% of total GHG production) (AGDCC, 2007). Projections for this sector are based on demographic indicators such as GDP and population forecasts, vehicle technology and the future travel behaviours of Australian residents. According to these variables, GHG emissions in this sector are expected to increase by 42% of the 1990 level during the Kyoto period, reaching 88 million tones per annum (AGDCC, 2007).

Approaches identified to reduce the effects of GHG emissions from transportation have been identified as either technological in nature or demand based. The limits in technological solutions is that they can often be too expensive, simply shift the GHG production to elsewhere in the supply chain (e.g. with biofuels and hydrogen power), are not viable on a public scale, and are susceptible to the rebound effect (increased efficiency leads to increased use and hence no/marginal net benefit). Demand based solutions reduce the need for private travel and in some cases, remove the need for motorized travel altogether. This can be achieved through urban planning by bringing people closer to their desired destinations and making non-motorized modes of travel more attractive. Both solutions have their benefits and deficiencies depending on the time frame of reference; however, they are not mutually exclusive. An opportunity exists for urban planning and technological development to combine and produce sustainable outcomes on a city scale.

Setting a price for GHG production

At the moment, carbon offsetting is not mandatory in Australia but many offset providers are emerging to service those wishing to voluntarily reduce or erase their share of CO2-e production. The Australian government is currently investigating schemes and methods for creating an economic system to reduce and/or limit greenhouse gas production. The two most prominent alternatives are to either create an emissions trading scheme (ETS) or impose a carbon tax.

The purpose of the Garnaut Climate Change Review was to develop a proposed model for an emissions trading scheme in Australia to address the market failure of unpriced greenhouse gas emissions. Inherent in an ETS is a market-based approach to the pricing of carbon permits. The government would set a limit to the amount of CO2-e that could be produced within a given year and an independent third party (referred to as the Independent Carbon Bank in the Garnaut Review) would administer the issuance of permits according to parameters established by legislation. As such, the market would determine the price for carbon and emissions intensive firms would be faced with paying high carbon prices. This would be the case until they are able to adjust their emissions output over time as they invest in less carbon intensive production processes. The benefit of this scenario is that a known (set) level of CO2-e production is determined for every year; however, a shortcoming is that the price is uncertain and can fluctuate throughout the year, making it more difficult for budgeting and planning purposes. Furthermore, critics argue that it would be very expensive and inefficient to create a new administration to govern the market processes, it would be very difficult to monitor and restrict the levels of carbon produced, and that the scheme would not be revenue neutral as individuals could buy and resell the permits at a personal profit without some mechanism to prevent it.

More recently, in May 2008, the first emissions permits were sold to Westpac at $19 per ton but are not to take effect until 2012. This sale was an indicator that an emissions trading market is taking shape and that some companies are thinking of buying permits to pre-empt the official scheme (which is due to start in 2010) to minimize risk and establish prices. At this point the emerging scheme only concerns larger industry but the Garnaut ETS is designed to include all fossil fuels.

The alternative, being a tax on carbon, in theory would use current government tax administering systems and add a set tax onto carbon producing products/services. Such a system has started already in British Columbia, Canada where a tax of $10 per tonne was set for the first year (2008) and will increase annually by $5 until 2012 when the plan is set to be reassessed. The tax scheme is revenue neutral and will use the funds to reinvest in sustainability initiatives.

Amidst all the taxation and trading schemes slowly emerging it is difficult to arrive upon a price for carbon emissions, especially since carbon offsetting is not mandatory at this stage. Voluntary carbon offsets in Australia can be purchased for a price within the range of A$8 to A$40 but this depends on a variety of criteria (Ribon and Scott, 2007). Generally, bio-sequestration carbon offsets are cheaper than ones investing into renewable energy and technologies, but much of the difference in price can also depend on whether or not the offset is assured or certified by a reputable authority.

For the purpose of calculating the economic impact of greenhouse gas production as a function of urban form, deciding upon a cost for emissions production is fairly subjective. For the first time in human history we are concerning ourselves with creating financial accountability for heating the earth's atmosphere. On a national scale, the only figure that Australia, or any nation, has to answer to is the UNFCCC and the Kyoto Protocols Compliance Committee. Still, it is difficult to devise a value for greenhouse gas abatement from the effects of this committee because the compliance mechanism is not financial in nature. Failing to meet the agreed upon GHG reductions means that a party must make up the difference between its emissions and its assigned amount during the second commitment period, plus make up for an additional 30% as a penalty. Additionally, there is the consequential stigma of being labeled as a non-compliant nation and the suspension of international GHG trading privileges. The compliance mechanism for the Kyoto Protocol is stringent and rigorous, however, does not include a direct financial figure as a penalty.

In 2002, the UK Government Economic Service presented a review of available literature on the estimated social costs of carbon. Within a range of 35–140£ /tCO2-e the paper suggests an average social cost of 70£/tCO2-e or roughly A$175 in 2000 prices (DEFRA 2002). In 2007 prices this value would be more in the area of A$215. A social cost of carbon (SCC) can be defined as the cost of impacts (market and non-market) associated with the additional production of a unit of greenhouse gas emissions. It represents what society should be willing to pay today to avoid the carbon damages from emissions produced today and their contribution to world emissions in the future. Agreements such as the Kyoto Protocol allow economists to envision global SCC and marginal abatement cost (MAC) functions, even though most nations still act unilaterally. A more recent publication up for peer review by DEFRA (2007) suggests the use of a shadow price of carbon (SPC) over an SCC, but the SPC is particular to the policies and activities of the UK and not the world, and more specifically in this case not for Australia. The more recent Stern Review (2006) suggests that the social cost of carbon on an business as usual trajectory would equate to approximately $85 US per tonne or roughly $A115.

In light of the pricing variances, the economic assessment of urban form as a function of greenhouse gas production is subject to the same kind of uncertainty. Where carbon credits only reflect the value of traded emissions rights and not the social cost of carbon, they fail to reflect the incremental damage being done. The social cost estimates provided by DEFRA and the Stern Review are both shown to be complex and insightful in their estimations. In light of this, the ensuing calculation has been made using a mid-ranged emissions cost of A$170 per tonne[1]. It should be known that although they are likely to be among the most comprehensive estimated values to date, they are still subject to much uncertainty in the scientific and financial methods utilized in their estimations. Furthermore, the cost of CO2-e per tonne represents a social cost of producing a tonne of carbon, not the price of abating it, which can also vary greatly depending on the type of abatement method and the scale involved.

The effect of urban form and transport provision factors on Australian cities' GHG emissions

There are some simple observations that can be made about transport: the further that people live from their frequented travel destinations, the less likely they are to accomplish that travel through active means, whether it is by walking or bicycle. Areas with poor or no transit access are reliant on private vehicle travel. The more people living or working in a particular area, the more viable public transport becomes to that place. Data and literature supporting these statements can be easily found. For example, a study by Newman and Kenworthy (2006) highlights that if an activity intensity of 35 persons and jobs per hectare is not an attribute of a given district, then the inadequate population level does not efficiently and effectively support public transit.

To determine greenhouse gas emissions for the two iconic developments a predictive model had to be made. A subjective method does not reliably show the trend that develops between transport greenhouse gas

[1] *There are numerous estimates spanning vast ranges for a suggested social cost of carbon. In the report by DEFRA (2002) the studies surveyed suggest prices in the range of roughly $7 to $300. This variability should be considered when interpreting the greenhouse gas costs associated with urban form as calculated in this report.*

emissions and various urban form parameters, nor is it able to report on the explanatory significance of any of the parameters of interest. A predictive model in this sense had to be developed where urban form characteristics could be proven on some account to be associated with transport emissions.

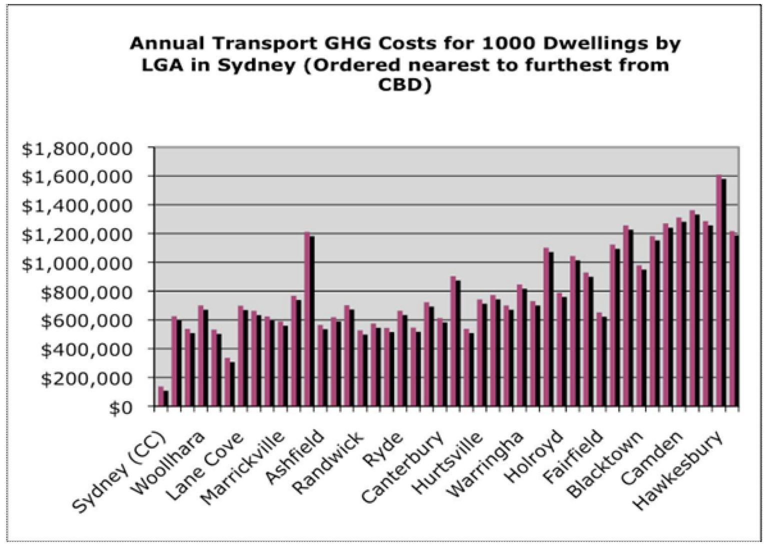
To establish a quantitative model for how urban form in Australian cities affects per capita CO2-e production, data and information was drawn from a study previously done at Murdoch University's ISTP department in Western Australia (Chandra, 2006). The study measured fuel use (and therefore GHG production) at the local government level in the Australian cities of Sydney, Perth, and Melbourne. The Perth data are very old so they were not used in the key conclusions. The patterns that evolved were compared to factors such as density (persons per ha), jobs (jobs per ha), activity intensity (persons plus jobs per ha), permeability (number of intersections per ha), distance to CBD (kms), and transit accessibility (measuring areas well served by public transit). A summary of the results of the top three explanatory parameters is as follows:

1. **The distance to the CBD was the dominant factor in explaining daily per capita GHG emissions (explains 71% of the variance in Sydney and Melbourne).** This single variable alone is a very powerful determinant of vehicle energy use and emissions production. From the data a formula was generated to model GHG emissions as a function of distance to a city center's CBD and it proved to hold in Perth as well as Sydney and Melbourne. The formula is **$y = x/10 + 3$**, where y represents daily per capita GHG emissions in kg CO2-e and x represents the distance to the CBD in kms. The limitation of the formula is most evident in comparing its estimation against outliers such as Blue Mountain and Mornington (ex-urban areas) where their emissions tend to be much higher than prediction, a potential result of poor servicing.

2. **Activity Intensity (persons plus jobs per ha) explained 56% of the variance in Melbourne and 71% in Sydney.** The difference in explanatory significance is perhaps because Sydney has a larger variation in density across its LGA's. Sydney's CBD has an activity intensity of roughly 330 persons per ha and Melbourne's is closer to 100.

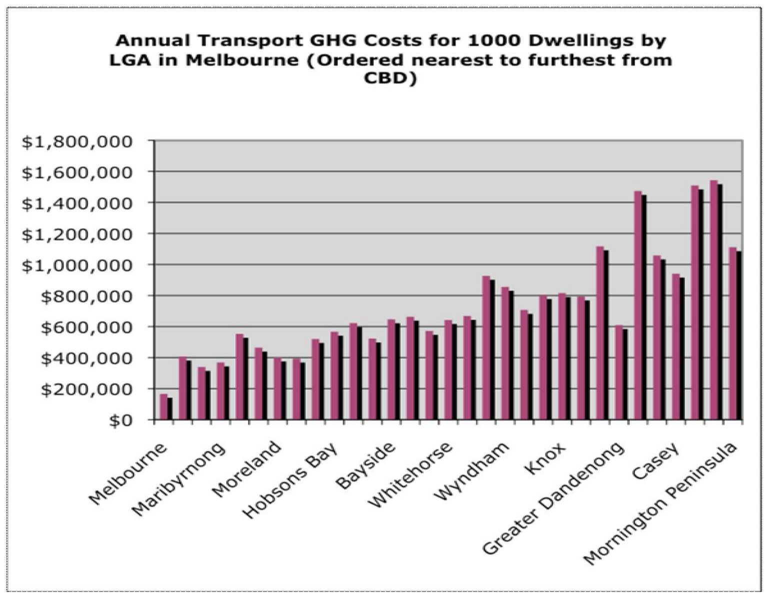
3. **Public Transit Access has similar statistical significance to Activity Intensity as it explains 61% of the variance in Melbourne and 58% of the variance in Sydney.** Public transit ties in closely with activity intensity because an efficient transit system needs a higher population level to support it. This parameter is defined as the proportion of an LGA that has a transit service frequency of greater than 15 minutes as well as service on weeknights and weekends.

The data from this study was made available for this work. Before another model was attempted, spreadsheets were made for Sydney and Melbourne on which their local government areas were ordered from nearest to furthest from their respective central business districts (see Appendix 1). For each respective local government area (LGA), data was entered for actual daily per capita transport CO2-e production. Another column was added calculating the daily transport CO2-e emissions costs for 1000 dwellings and finally another column calculating an annual figure for these values. The cost attributed to the generation of 1 tonne of CO2-e was set at A$170. The resulting information when graphed appears as follows:



Source: Chandra, 2006

FIGURE 1



Source: Chandra, 2006

FIGURE 2

The revealed trend clearly shows that daily per capita CO2-e emissions increase in suburbs that are more distant from their city centers. Consequently, abatement costs and/or other costs associated with greenhouse emissions would be much greater in fringe developments.

Basing an economic assessment on distance to CBD alone creates a fairly good prediction of per capita greenhouse gas emissions and therefore associated costs, but it was thought that working other variables into the model could improve its effectiveness. The data from Chandra's report was run again several times with different parameters. Seeing as distance to CBD, activity intensity, and transit access are the three variables of distinct interest, a simple linear regression was done for each of them with combined data for Sydney and Melbourne.

Distance to CBD

The relationship of ‘distance to CBD’ to daily per capita greenhouse gas emissions is quite clear in this linear regression. The R-squared value of 0.68 is quite high, implying that distance to CBD explains about 68% of the variance in greenhouse gases. There is, however a fair bit of dispersion around the line. In particular it tends to highly overestimate per capita GHG emissions for CBD residents where the factors relating to the ease of walking become very obvious.

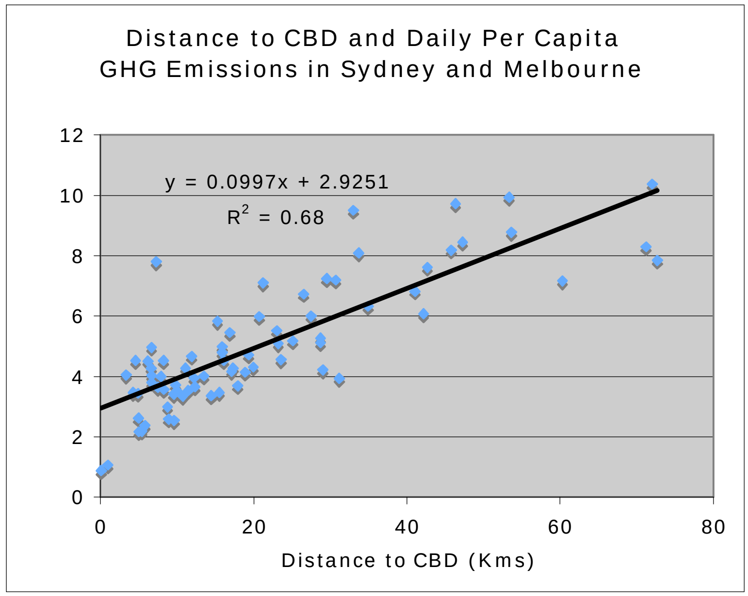


FIGURE 3

Activity Intensity

The exponential relationship of activity intensity to daily per capita GHG emissions is quite clear in this regressed scatter plot, but with an R-squared value of 0.6016 it is a less effective predictor than distance to CBD is alone. By observing the trend-line it is evident that there is an activity intensity level of roughly 35 persons and jobs per hectare above which GHG emissions are most dramatically reduced. This is consistent with findings from Newman and Kenworthy (1999, 2006).

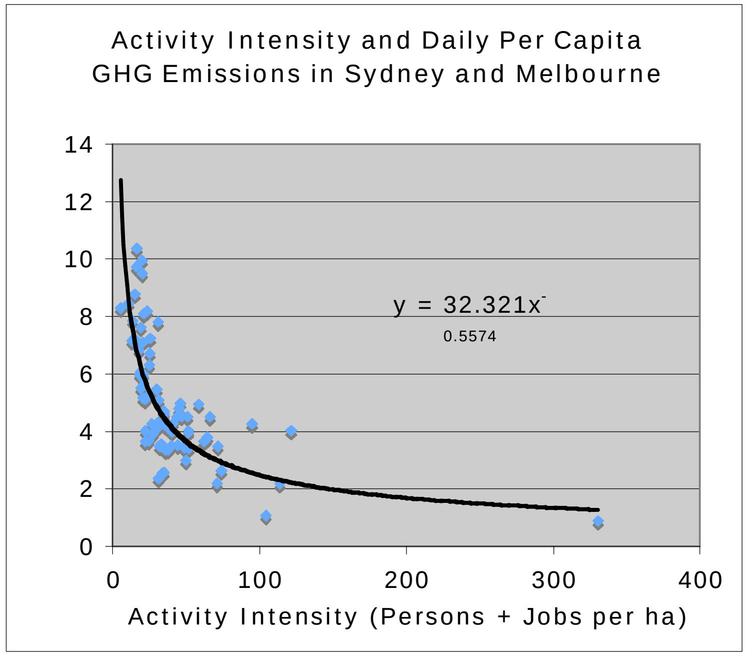


FIGURE 4

Transit Access

The parameter of transit access also seems to be a fairly good predictor of CO2-e emissions with a similar R-squared to activity intensity. The majority of the variance seems to be in areas of poor transit access. Again, alone it does not seem to be as strong of a predictor of emissions as distance to CBD.

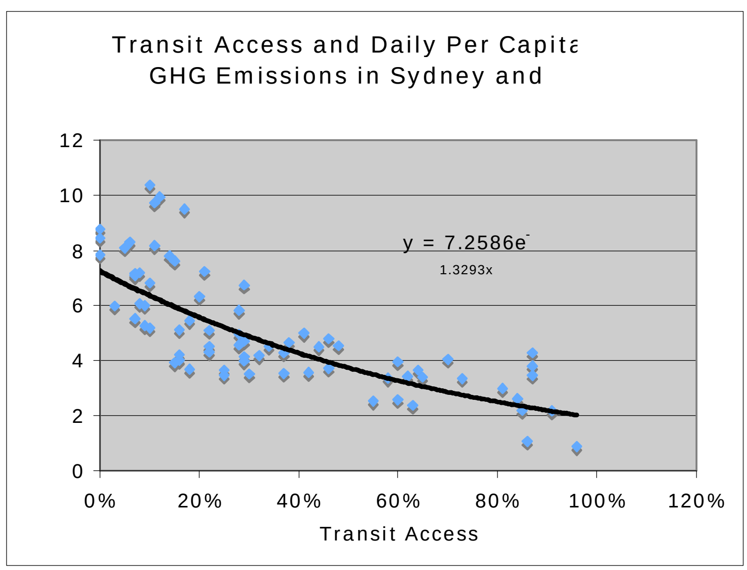


FIGURE 5

Modelling GHG Emissions as a Function of Combined Parameters: Distance to CBD, Activity Intensity and Transit Access

Running a multiple regression analysis of the three parameters together resulted in the highest R-squared value of all the combinations. Unfortunately, activity intensity as a parameter comes out highly insignificant with a p-value of -0.5503 and a very low coefficient of -0.002 so it could not be used.

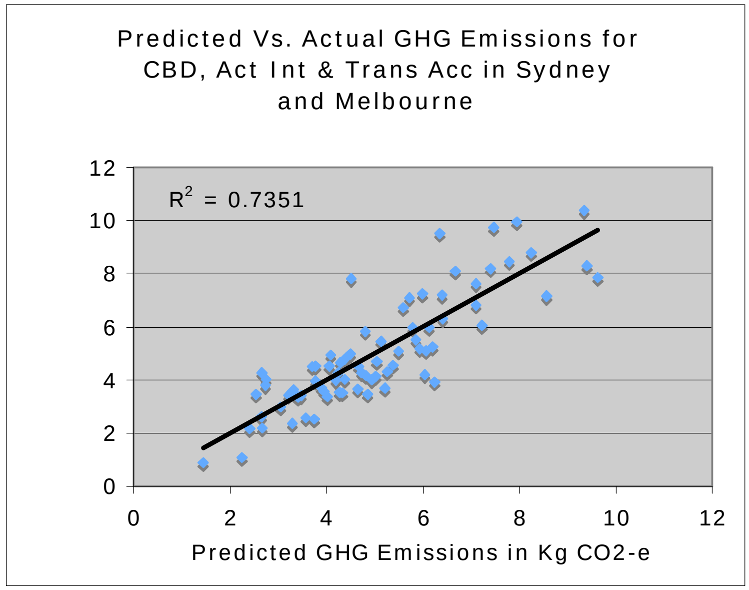


FIGURE 6

Table 8 Equation Coefficients and Measures of Significance

	Coefficients	P-value
Intercept	4.378977791	1.43714E-15
To CBD	0.072638909	7.29533E-10
Activity Intensity	-0.002294408	0.58383295
Transit Access	-2.283445538	0.004059228

Table 9 Regression statistics

Regression statistics	
Multiple R	0.857360598
R Square	0.735067195
Adjusted R square	0.723872852
Standard error	1.101840135
Observation	75

This was an expected outcome as activity intensity is a surrogate of distance to CBD. In other words, it is characteristic of most modern cities that the inner cores would be high in number of residents and jobs and that this intensity would diminish as distance from the city center increases. Activity intensity was withdrawn from the model and another attempt was made at modeling GHG emissions with just distance to CBD and transit access.

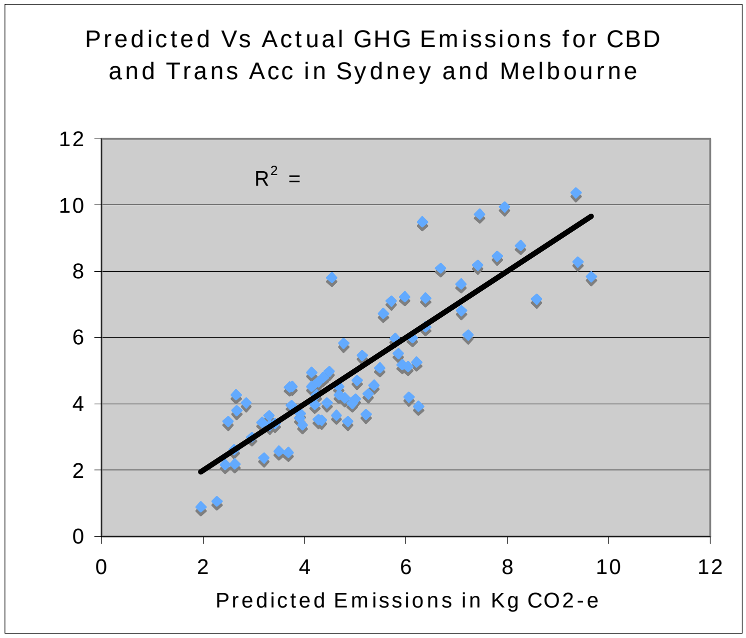


FIGURE 7

Table 10 Equation Coefficients and Measures of Significance

	Coefficients	P-value
Intercept	4.352057741	9.7997E-16
To CBD	0.072942718	4.97433E-10
Transit Access	-2.502090507	0.000280457

Table 11 Regression statistics

Regression statistics	
Multiple R	0.856701321
R Square	0.733937153
Adjusted R Square	0.726546519
Standard Error	1.096492744
Observations	75

The resulting analyses produced the equation **y = .073x – 2.5z + 4.35**, where 'y' is the daily per capita GHG emissions, 'x' is the distance to the CBD, and 'z' is the level of transit service expressed as a percentage of the area covered. The results were significant at the 95% level and the equation generated accounts for 73.4% of the variance in CO2-e.

Calculating GHG Emissions costs for two opposing iconic developments

The equation **y = .073x – 2.5z + 4.35** is useful in estimating the daily per capita GHG emissions for any given area where the distance to the city center and the transit accessibility is known. For the purpose of this economic assessment, however, it was used to estimate the GHG gas costs for the two polar developments types: inner-city type redevelopments and fringe developments. For this the equation had to be changed to accommodate the economic reporting requirements.

The desired end estimate of the equation was to predict the annual economic CO2-e emissions impact for a development of 1000 dwellings. By adjusting the equation to achieve this we get the following:

Y = (365 days/yr)(Price/kg CO2-e)(# of Dwellings)(Ppl/Dwelling)(.073x - .25z + 4.35)
= (365)(0.170)(1000)(2.5)(.073x - .25z + 4.35)
= 155,125(.073x - .25z + 4.35)
where Y = annual cost, x = distance to CBD, and z = transit accessibility

The next critical step was to choose values for the variables in the equation to represent the two opposing urban forms of interest. The furthest LGA from the city centre of Melbourne in the data was measured at just over 60km and of Sydney it was nearly 73km, while the transit accessibility for the most distant LGAs was 7% and 0% for the two cities respectively. Averages were taken of these respective figures to represent the inputs for estimating the annual cost of CO2-e production in a greenfield neighborhood. The figures for inner-city type developments we determined a little differently. Choosing the immediate centre would perhaps be an ambitious suggested location for a new development of 1000 dwellings (although still very possible as demonstrated by Vancouver and envisioned in projects like Northbridge Port Quay and the Gateway project in Perth), therefore a development within a 30 minute walking distance (3 km) from the city centre was chosen. For both Sydney and Perth this represents roughly a transit accessibility of 85%. It is feasible to imagine developments in various parts of the city that demonstrate the kind of central/inner-core urban form where 85% of the development has a transit service of better than 15 minutes. Taking these inputs into account, the estimated daily per capita GHG emissions and the annual emissions costs for 1000 dwellings (at A$170/tonne) for the two opposing city forms were estimated as follows:

Daily Emissions:	**Y(Outer) = [.073(66.5) - .25(.035) + 4.3]** **= 9.2 kg CO2-e per capita**
	Y(Inner) = [.073(66.5) - .25(.035) + 4.3] **= 4.4 kg CO2-e per capita**
Annual Costs: Y(Outer)	**= 155,125[.073(66.5) - .25(.035) + 4.3]** **= 155,125(9.19575)** **= A$1,426,490**
Y(Inner)	**= 155,125[.073(3.0) - .25(.85) + 4.3]** **= 155,125(4.3565)** **= A$675,802**

For the most part, the estimates are quite accurate against the actual data for the two cities, however, the formula tends to overestimate the per capita GHG emissions (and therefore costs) of inner-city type areas while providing a more accurate estimate as distance to CBD increases. Actual data from Sydney and Melbourne reports daily per capita emission of roughly 2.5 kg CO2-e for local government areas assuming the same parameter values placed in the equation. This is likely due to the higher walking trips in the inner core. This disparity for inner area estimates in the end adds a conservative property to the economic comparison between the two urban forms.

When applying the formula, the annual greenhouse gas emissions associated with the two iconic development types for a development of 1000 units is 8,400 tonnes for the fringe and 4,000 tonnes for the redevelopment (2,300 tonnes if the actual average core/inner value is taken).

Next, the present value of the recurring greenhouse gas costs was calculated over a 50-year period at a 3% discount rate[2]. For fringe developments this equates to a greenhouse gas social cost of A$36.70 million and for inner-city type developments this equates to A$17.39 million.

The costs are sizeable, yet compared to the magnitude of the costs associated with transport and infrastructure, greenhouse costs alone are unlikely to catalyze urban planning reform. The cost savings are, however, indicative of a benefit that is aligned with the growing attention that the Australian government must give to reducing national emissions. A model or tool of this sort is in itself useful to planners who can then build accordingly to reduce greenhouse gas emissions by known amounts.

5. Health-related costs

Introduction

Recent years have set the stage for increased interest in the topic of urban form's impact on public health. The view that car-dependency has led to the creation of obesogenic environments is now supported by a substantial number of studies and the case is being built for urban planning reform for active lifestyle improvements. Nations have made estimates of healthcare costs as experienced by the burden of inactivity among their populations; however, the economic assessment associating the costs of illness, inactivity, and urban form to an urban planning mindset has yet to been done. The allotting of more residential zones in greenfield areas is a further commitment to car-dependency and inactive travel but has been the conventional model for residential growth since World War II[3] (Newman and Kenworthy, 1999). The environments that we create, aesthetically and functionally, have profound consequences on our emotional connectivity to the people around us and to our physical settings, affecting both our quality of life and the manner in which we interact with the cities we live in (Frank and Engelke, 2005; Stokols et al., 2003). In addition to psychological effects, research has also been able to link aspects of the built environment directly to human activity patterns and travel choices for both non-discretional travel and leisure (Frank and Engelke, 2005). The purpose of this research is to economically quantify the health benefit of refocusing future development to inner city type areas where transit and active means of travel can make for a healthier population. We have defined an 'active travel' neighborhood as one that is conducive to both cycling and walking, which in daily life activities could lead to most able bodied people engaging in at least 30 minutes of active travel per day.

2 A capitalisation period of 50 years was chosen for the entire economic assessment of urban form under the assumption that 50 years is a reasonable average life expectancy of a residential development. Beyond 50 years, the decision to redevelop an area may be made once again.

3 The term 'Walking Cities' is associated with pre-World War II times. Auto Cities are said to have formed after the war as personalized transport by car became more widespread, allowing people to travel further, faster.

Background

A growing body of evidence suggests that neighborhoods characterized by low density, poor connectivity, and poor access to shops and services, are associated with low levels of walking. Moreover, sprawling areas of low walkability have been linked to obesity and numerous other chronic illnesses (Giles-Corti, 2006; Sturm and Cohen, 2004). Between the years 1980 and 2000, obesity levels have increased among males (10%) and females (12%) in Australia as measured by a BMI (Body Mass Index) of equal to or greater than 30 kg/m^2 (ANZOS, n.d.). Over the same period, the portion of overweight Australians increased 17.5% and 18% for males and females respectively, measured by a BMI equal to or greater than 25 kg/m^2 (ANZOS, n.d.). Although not all obesity is attributable to urban form, one study has documented in its research that each additional hour spent in a car per day was associated with a 6% increase in the odds of being obese, while each additional kilometer walked per day was associated with a 4.8% reduction in the odds of being obese (Frank et al., 2006). This can have significant implications, as another study has shown that individuals in the least walkable environments drive the most per day (74 kms), while those in the most walkable environments drive the least (43 kms) (Frank et al. 2007).

Obesity is not the only link to urban form. Other illnesses and costs to the healthcare system arise from inactivity such as falls, coronary heart disease, type-2 diabetes, depression, stroke, colon cancer, and breast cancer on which Econtech[4] reported a cost of $1.5 billion to the Australian healthcare system in 2007 (Econtech, 2007). Furthermore, it is stated that about 54.2% of Australian adults were found to be insufficiently active according to National Physical Activity guidelines in the year 2000 (Econtech, 2007). This suggests an opportunity to substantially reduce direct and indirect costs due to inactivity in Australia by facilitating incidental activity with urban planning. A joint American-Canadian study found that residents of more walkable environments are 2.4 times more likely to meet or exceed the recommended minimum levels of moderate activity than people in the most sprawling areas (Frank et al., 2005), further showing a potential for urban planning policy intervention for healthcare savings.

Recent advances in research on urban form have researchers starting to identify and separately measure utilitarian active forms of travel from leisure forms of conveyance to acknowledge that sometimes both are accomplished in the same outing, yet also may be affected differently by certain aspects of urban form. In other words, they record and measure how urban form affects walking for the sake of transportation distinctly from walking for the sake of leisure, then cumulatively measure if there is a net gain or loss in active living in walkable neighborhoods. Multidimensional measures of urban sprawl are another advancement in urban planning research. They allow for a more objective measure of urban form to be made and thus explain the relationship to travel behaviour with more confidence. This is done by agglomerating urban features such as density, land-use-mix, proximity, connectivity, and degree of centering to make indexes for experimental designs. All have been proven to be associated with increased active travel. Newman and Kenworthy in their research found that 35 people and jobs per hectare was the threshold density for decreased auto dependence and beyond that, travel by car lessens and active travel and transit use begin to increase (2006). Other research, such as that by Sturm and Cohen, has closely linked overall physical health to urban density. They found that a difference in their sprawl index of 100 points, which would be the difference between Riverside, CA (very sprawled) and Boston, MA (not sprawled), was associated with 200 fewer chronic illnesses per 1000 persons (a reduction of 15%) (Sturm and Cohen, 2004).

All this implies that a step towards designing our cities around active transport instead of the automobile can have some profound effects on physical and possibly mental health. As a result, an increase in discretional

4 Econtech is an Australian consultancy contracted by Medibank Private, Australia's government-owned private health insurer.

and non-discretional active transport has the potential to identifiably benefit social capital and public health while saving the healthcare system considerable money.

Data and method for calculation

The tool is best described as a *cost of illness approach* to economically appraising the health impacts of urban form. Other methods exist such as a *years of life lost* (YLL) *approach* or agreeing on a standard 'value of a statistical life;' however, the *cost of illness approach* worked best with the available information and allows for the least assumptions to be made.

In the process of the economic assessment, information was drawn upon from two separate areas of study. One was the cost of inactivity in Australia and the other was the variation in active travel among cities of differing urban form. The overall calculation is done in a series of parts, starting with a top-down approach to place a value on an hour of moderate-intensity activity per person. Next, the hourly per person savings estimate is attributed to an expected increase in activity levels characteristic of active travel neighborhoods and finally, the healthcare savings for the development of a high-density, mixed-use development of 1000 dwellings is calculated. Any assumptions made in the calculations or variables not accounted for will either be summarized through the following sections or referred to at the end of the document.

Identifying the value of physical activity in Australia

In 2007, Medibank Private contracted Econtech to produce a report on the direct inactivity costs of Australian adults. This value was estimated at $1.5 billion[5] and included the following seven illnesses: falls, coronary heart disease, type 2 diabetes, depression, stroke, colon cancer, and breast cancer (Econtech, 2007). An adult was defined as anyone of the age 18 and over and the value represented the potential savings that could be achieved if more adults became sufficiently active. Their report quoted the 2000 National Physical Activity Survey in stating that 54.2% of Australia's adult population is not getting enough physical activity to remain healthy. Using this figure and assuming that the $1.5 billion estimate can be applied to the inactive portion of the adult population, an overall value of $2.8 billion[6] was estimated for the physical activity related component of health for all Australian adults.

Indirect costs are more difficult to calculate because of the complexity of the assumptions required and therefore an objective figure could not be obtained. Health Canada's *Economic Burden of Illness*, however, assigned an overall ratio to its economic health assessment that measured indirect costs as 54.3% of the total cost of illness (1993). This approach took into account productivity losses due to mortality and short and long-term disability. Using this ratio would estimate Australia's indirect cost of inactivity at $1.78 billion[7], the total cost of inactivity at $3.82 billion[8], and the total value of all Australian adults meeting recommended activity levels at $6.1 billion.

Australia's National Public Health Partnership estimates that indirect costs would more than double direct costs but provides no numerical value (Bauman et al., 2002). To be conservative and simply say that indirect

5 *The cost of inactivity in Australia was last calculated in 1993/94 and valued at $377.4 million in 1993 dollars and did not include falls and causally related diseases. Accounting for inflation, falls, increased population, increased obesity levels, and increased inactivity levels would account for most of the difference between this value and the one produced by Econtech Pty. Ltd. for Medibank Private.*

6 *Calculated as .542/(1-.542)=(1.5*10^9)/x and isolated for 'x' to determine the value of the current Australian adult population meeting sufficient activity levels and then adding 1.5*10^9 for the value attributed to inactivity.*

7 *Calculated as .457/.543=(1.5*10^9)/x and isolated for 'x'.*

8 *No estimate was available for the health costs due to inactivity for Australians 17 and under, nor could any objective studies be found linking their activity levels and health to urban form; therefore, they are not accounted for in the calculation.*

costs would amount to double the value of direct costs would produce an estimate of $3 billion. This includes productivity loss and absenteeism at the workplace as well as losses in social capital. Using this estimate would translate into a total cost of $4.5 billion due to inactivity and a total value for all Australian adults of $8.3 billion.

For the purpose of this tool, the figure of $6.1 billion for the total value of activity among Australian adults is used in determining a lower estimate for the health savings of active travel neighborhoods and $8.3 billion is used in calculating the upper estimate. The implications of the indirect health cost components within these two figures and the substantial differences between them were deemed too significant to make the final calculation by disregarding one or the other.

Demographic Information

The population of Australia is roughly 21 million people (ABS, 2007). The cost of inactivity in Australia, however, was determined for the ages 18 and over. This had to be taken into account when calculating a value for each hour of moderate-intensity activity for the Australian adult population. According to data provided by the Australian Bureau of Statistics roughly 73.3%, or 15.4 million people, fall within this age group (based on WA's 2006 census data).

Furthermore, in 2007 the ABS produced a report on Australian social trends that estimated an average of 2.5 people living in each household in 2003-04. With 73.3% of Australia's population over the age of 17, it was estimated that each household contains an average of 1.83 persons within this age group. This figure is used in the overall calculation to determine the health-related savings in developing 1000 dwellings as inner city type developments.

Recommended minimum activity levels and associated savings

The National Physical Activity (NPA) guidelines for Australians recommends that one should engage in 30 minutes of moderate-intensity physical activity a day over at least 5 sessions per week to be considered physically active. These 2.5 hours per week can be met by walking 15 minutes to and from the bus during a standard workweek, or more generally by engaging in more active travel. This is the criterion on which the costs of inactivity are based. In the tool it is assumed that any increase in moderate activity is associated with a proportional decrease in health costs. In other words, it assumes that if the Australian adults that currently are insufficiently active begin to increase their activity levels by 50% of the required amount, then a cost reduction of 50% would be experienced. Furthermore it is assumed that if the entire adult population became sufficiently active according to NPA guidelines, then the costs of inactivity would be averted.

By knowing the adult population of Australia[9], the minimum recommended activity levels[10], and the estimated value of those activity levels being met by all adults[11], values of $3.02 (lower estimate) and $4.15 (upper estimate) were then determined for each hour that an individual engages in moderate physical activity[12]. The calculation does not account for varying proportions of inactive people by specific region or state. The usefulness of the tool is in its versatility in calculating the value of active lifestyles in urban settings, not in making a specific economic assessment of a specific neighborhood or demographic.

9 Adult population of Australia roughly 15.4 million (ages 18 and over)
10 Minimum moderate-intensity activity recommendation of 30 minutes per day, 5 sessions a week
11 Lower health-related savings estimate of $3.82 billion and upper estimate of $4.5 billion
12 Value in an hour of moderate-intensity activity per person = Total national savings potential / Adult population of Australia / Recommended hours of moderate-intensity activity per year

Estimated activity increase in active travel neighbourhoods

Keeping in mind that the goal of the tool was to monetize the benefits of developing an area that is well suited for active travel, it was important to quantify the health benefits that both cycling and walking could have as people convert to them and away from car dependency; however, studies that objectively measure physical activity with objectively measured urban form have focused on walking for active transport. Cycling-specific data correlated with objectively measured urban form could not be found. Information on walking, conversely, was more readily available and the assumption had to be made that the two would vary proportionally as functions of an area's suitability for active travel.

Research by Active Living Research in the US has shown that residents of more walkable areas spend about 30 minutes more per week (20% of the recommended amount) on walking trips than residents in sprawling areas (Active Living Research, 2005). Another study conducted by findings from SMARTRAQ in the US found that 19% more people (the difference between 37% and 18%) are likely to meet or exceed the recommended minimum activity quota of 2.5 hours per week (or 130 hrs per year) in highly walkable areas than people in the most sprawling neighborhoods (Frank, Schmid, Sallis, Chapman & Salaens, 2005). Total potential health-related savings were then calculated using the logic that if 19% more residents meet the NPA's minimum recommended level of moderate activity per week in active travel neighborhoods, then one could expect a 19% discount in inactivity-related health costs.

The annual difference in cumulative time spent walking between active travel and sprawling neighborhoods was then calculated as 19% x 1000 dwellings x 1.8325 adults per dwelling x 130 hrs per year per person, resulting in 45,262.75 hours. It should be known that this figure is not an estimated difference in total hours of activity between sprawling and walkable neighborhoods, simply an estimated difference in minimum activity level hours of walking between the two types of developments. It does not include hours that exceed the minimum recommended levels, nor does it include time spent on other recreational or non-discretional forms of activity.

As aforementioned, similar data for cycling was not available so it had to be calculated a little differently. Socialdata Australia provides some data on travel mode distributions among various Western Australian suburbs. A weighted average of bicycle trips as a proportion of walking trips was calculated and determined to be roughly 21% (Socialdata, 2008). Assuming that cycling levels remain proportionate to walking levels and that their average trip duration is approximately the same (Newman and Kenworthy, 1999), the increase in annual hours of cycling for transport was worked out to be 9,505 hours (21% of 45,262.75). Since the NPA guidelines do not distinguish between types of physical activity and simply recommends 'moderate-intensity activity,' it was also assumed that walking and cycling for transportation share the same level of benefit.

Estimated annual savings in developing an active travel neighbourhood

The savings benefit due to an increased level of walking in an active travel neighborhood was calculated at 45,262.75 hours times $3.02/hr and amounted to $136,694 for a development of 1000 dwellings. Similarly, the benefit due to cycling was calculated at 9,505 hours times $3.02/hr and amounted to $28,706. Summing the two came to a total of $164,399 per year in savings for a development of 1000 dwellings, which comprised the lower estimate. The upper estimate was calculated in the same fashion but substituted the savings rate of $3.02/hr with $4.15/hr, resulting in annual savings of $227,287 for 1000 dwellings in an active travel neighborhood. Thus, the savings in public health due to an active travel neighborhood of 1000 dwellings is estimated to be between $164,399 and $227,287 per year.

The final step was to discount the two annual figures over a period of time to acknowledge that the savings would be recurring. A few period lengths came to mind, such as using the turn-over period for a development, the average life expectancy for an Australian, the average life expectancy of a development, or even discounting the annual savings as perpetuities if making the assumption that the property will remain zoned for residences indefinitely. The decision was made to use a period of 50 years, which is considered the minimum duration that a residential building would be erected for. It is assumed that after 50 years the decision of if and how to redevelop the piece of land will be made once again.

In addition to deciding on the number of years over which to discount the annual savings, a discount rate of 3% was chosen to reflect Australia's average annual rate of inflation (Reserve Bank of Australia, 2007). A higher discount rate could have been used; however, since the figure represents a savings benefit and not an investment with associated risk, 3% was decidedly suitable. Conversely, a lower rate could have been used or future figures adjusted if other technological or medical considerations could be foreseen, but the tool assumes treatments for the associated illnesses will remain constant.

The final calculation after the aforementioned considerations estimates the present value of the economic health benefits for a development of 1000 dwellings at **$4,229,951** conservatively. The upper estimate is **$5,848,038**. These two numbers reflect the incremental economic health savings of developing 1000 residential dwellings when deciding to redevelop inner-city type areas as active travel neighborhoods as opposed to further expanding into greenfield areas.

Discussion of health-related costs

As aforementioned, the process undertaken for economically assessing the health impacts of urban form utilized a *cost of illness approach*. What the development process of this economic tool revealed was the scarcity of objective data available, more particularly with an Australian context, and the complexity of the subject matter at hand.

Critics of the view that urban form affects health and levels of activity commonly refer to neighborhood selection as the reason for measured differences among communities of varying walkability. They argue that those living in walkable areas choose to do so because they desire an environment conducive to active transport and would be active regardless of where they lived. A study by Frank, Saelens, Powell, and Chapman reveals that environment strongly influences active travel among individuals who prefer more walkable neighborhoods, but those who prefer car-dependant environments are affected to a lesser extent (Frank et al. 2007). Another study by Handy, Cao, and Mokhtarian found that a quasi-longitudinal design to their experiment revealed that over the time of one year after a move to a more walkable neighborhood, travel behaviours began to change more significantly (Handy, Cao and Mokhtarian, 2005). This may suggest that as people have become accustomed to car-dependant lifestyles, they can also re-adjust over time and adopt healthier transportation habits. Studies such as this also reveal that the increase in active travel may not be as large as some have determined, but still identify a strong positive relationship between urban form and activity levels. If this holds true, the calculation attributing a lower estimated savings potential of $4.2 million might be slightly overzealous in using a health cost reduction figure of 19%. But succumbing to this mentality would mean dismissing some other very convincing data.

The studies that reported activity increases and lower obesity rates in active travel neighborhoods originated in the United States. If studies of similar design had been conducted in Australia, that information would have been used instead; however, the differences between the two countries, given the subject matter, are not vast (Newman and Kenworthy, 1999). For Seattle and Perth, for instance, it is documented that cycling respectively comprises 2.3% (Nelson and Scholar, ca.2006) and 2.4% (Socialdata, 2008) of total trips. The share of total trips for walking is roughly 7% (Nelson and Scholar, ca.2006) and 11% (Socialdata, 2008) for Seattle and Perth respectively. The objective measurements of urban form include factors such as density, land-use mix, connectivity, and proximity, but they do not measure some very important travel-related design considerations. Copenhagen, Denmark has shown that it is possible to achieve a modal split of 27% for driving, 33% for transit, 36% for bicycling, and 5% for walking (Nelson and Scholar, ca.2006). This is a reflection of policy intervention, cultural characteristics, urban design and urban planning. Gehl Architects in Copenhagen have made some significant alterations and enhancements to cities around the world such as Sydney, Melbourne, Cape Town, London, Zurich and in their own city of Copenhagen, enhancing their urban realms for active transportation[13]. If more studies get conducted on different cities and eventually include factors such as kilometers of bike lanes and widths of pedestrian paths in their measures of walkability, then maybe a larger health cost reduction percentage than the one currently used in the calculation could be substituted. This tool only drew on the results of studies that suggest there are effects of urban sprawl on active transport and health. Other factors in the mindset of urban planning such as safety policy, bicycle schemes, education, economic incentives, traffic mitigation and infrastructure could all have a huge impact on active travel levels and potentially, health; however, the role of urban form remains a fundamental factor.

Similarly, the health effects of air pollution were not incorporated into the tool. This was for several reasons. If a dense neighborhood experiences so much traffic that it affects air quality and therefore health, it is very unlikely that it would be conducive to active travel modes and therefore would not rank very high on a walkability index. Furthermore, adverse health effects due to air pollution have not been objectively measured with objective measurements of urban form. Some may argue that air quality in suburban neighborhoods is superior to the polluted air in cities, but then pollution is most attributable to those who drive the most, namely suburban residents. Evidence also suggests that those most affected by air pollution are residents near major roadways (likely urban neighborhoods) and also by the incumbents of vehicles who spend the most time in private transport (Bray et al., 2005). There exist other factors in measuring the health costs/benefits of urban form that more conclusive research would be needed to answer. Some of these factors include:

- *An activity uptake period* – how long after a resident moves to a new active travel neighborhood it takes for them to engage in their maximum potential level of active transportation. This could occur immediately for some or take some time for those not familiar with the area or uninterested in non-motorized modes of travel. Education on local transit routes could quicken the process.

- *A benefit intake period* – of those at risk of inactivity-related illnesses, how long before their increased level of activity begins to influence their health status. If unknown, the WHO recommends a period of five years when making an economic assessment of new cycling paths. The walkability of a neighborhood, however, is likely less discrete than a bike path and activity uptake would likely be quicker than an obscure trail. More research would be required on this factor to introduce reliable figures into an equation.

- *Activity substitution* – if one begins to engage in more activity due to active modes of transportation, this could mean that they will reduce their time spent participating in other discretionary activities, therefore, experiencing no net benefit. Findings from TravelSmart in Perth seem to prove this wrong, however, more conclusive evidence needs to be sought (DPI, 2008).

Overall, the topic of the relationship between health and urban form becomes more complicated as more factors become considered. The format of the tool, however, need not change significantly to accommodate various other factors since the process would largely remain the same. For example, it may be possible to show that active travel neighborhoods are likely to include more aged housing as they are denser and more diverse. This would mean a higher proportion of people who critically need to maintain active lifestyles are

13 Gehl Architects has conducted Public Life studies in Melbourne (1993, 2004), Perth (1994), Copenhagen (numerous studies including 1996), London (2004), Zurich (2004), Stockholm (1990, 2005) and are currently undertaking studies in Sydney and New York (2007). This is not a comprehensive list. Further information can be found on their website: www.gehlarchitects.dk assisted in this, thus creating even higher health-related savings. If more people are estimated to meet the minimum activity requirements for health in a given neighborhood, then those additional hours need only to be multiplied by the hourly value of physical activity to determine an additional monetary gain. The procedure assessing the economic health impacts of urban form as derived ensues as follows:

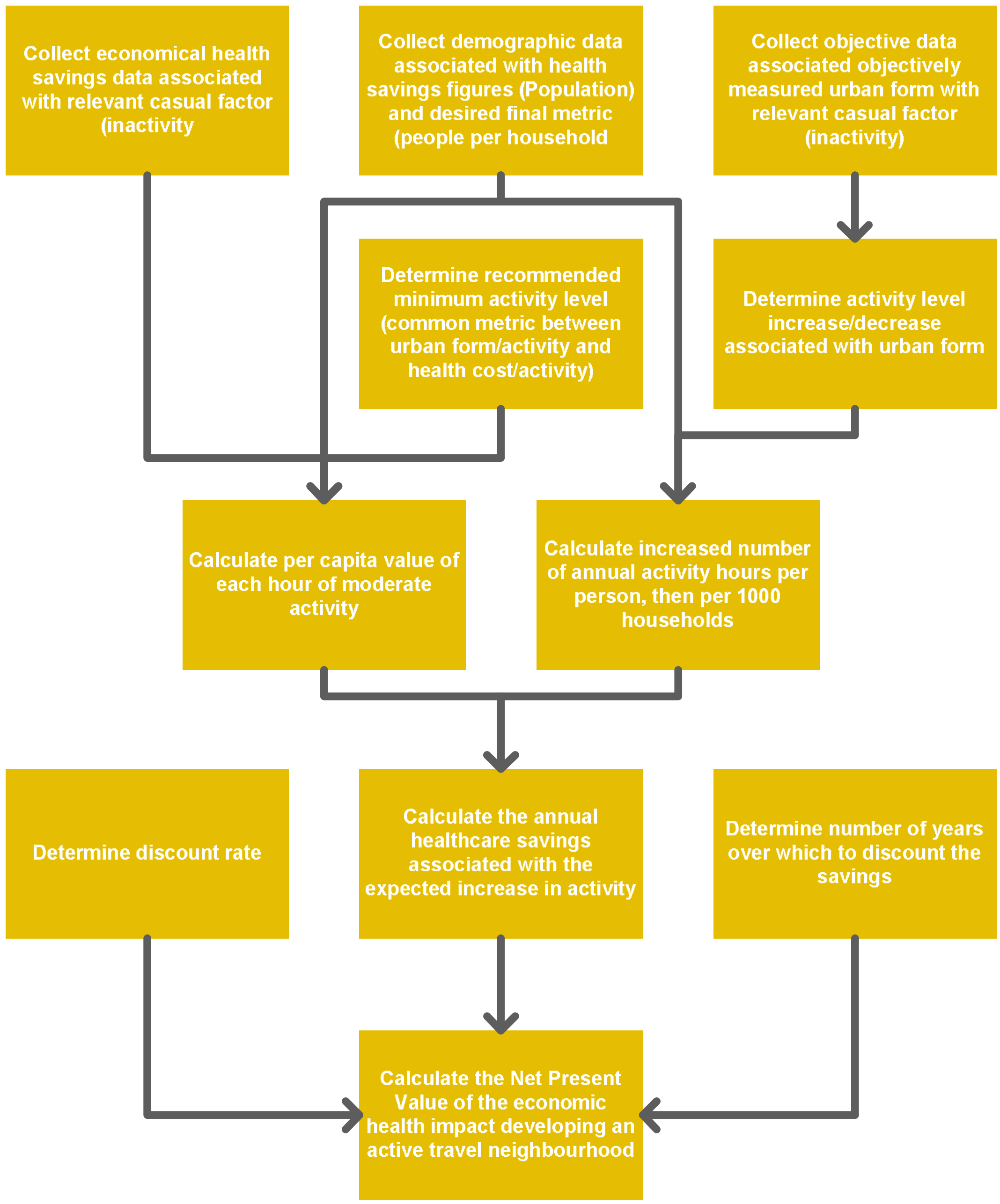


FIGURE 8

All things considered, a lower estimate of $4.23 million and an upper estimate of $5.85 million of potential health-related savings when developing active travel neighborhoods is a conservative estimate. With the inclusion of health costs of Australians under the age of 18 (a growing body of evidence also suggests that inactivity among children due to urban form has negative effects on their social, psychological and physical development), the mental health benefits of a more thriving social environment, and the inclusion of productivity gains at the workplace due to active travel modes to and from work, this assessed value would only increase. Furthermore, as policy decides to phase out private vehicle transport from urban design planning, additional sizeable economic health benefits could be expected. Currently, development situations in Australia have resulted in the public frequently choosing their car for travel as 78% respond that they do so because their destination is too far (James, John, McKaskill, 2001). Trips for shopping and services alone account for 26% of all driving trips in Western Australia; these amenities could easily be located closer to residents in tighter-knit communities where 66% of trips within a 3km radius are done by non-vehicular modes of transport (James, John, McKaskill, 2001).

The objective measurement of 20% more individuals meeting the recommended quota of moderate-intensity physical activity translates into considerable economic health-related savings from a conservative standpoint. In the future, other figures representing expected changes in active travel could be input into the tool as more objective studies linking urban form to activity levels report new findings, especially the productivity improvements associated with people who live more actively in their daily lives rather than sitting in a car. The way forward would be to continue to measure urban form's impacts on physical activity levels with factors that make active transport safer, more efficient, and more enjoyable while making driving a more unattractive option. Similarly, it would be interesting to investigate how these factors specifically influence travel behaviour among individuals who are predisposed to auto-dependent lifestyles, for therein potentially lies the greatest benefit in activity increase.

6. A cumulative economic impact statement of alternate development patterns

The preceding sections constitute an economic account of some of the costs associated with urban development. Moreover, they have revealed that there is a significant cost savings associated with consolidated and inner-city type developments. Unfortunately, consolidated development is often viewed in association with mere density, making the individual envisage nothing but countless rows of concrete buildings over 12 stories tall which are void of any character. Sustainable consolidated development means something very different to this image. It means social capital such as restaurants, cafes, and shared public spaces; efficient and effective public transport; infrastructure designed to entice one to cycle or walk; and enough amenities to create viable, thriving city centers in close proximity to residential dwellings. Density in this context often need not be more than a few stories. The key here, however, is to realize the multitude of benefits associated with curtailing sprawl and focusing future development in established areas. The benefits are bundled and reconcile the interests of intergovernmental departments, as it is a type of solution to numerous issues that does not result in setbacks to one department while benefiting another. For instance, a decision to build new roadways by a traffic authority with the intentions of speeding up road transport will likely be counterproductive to Australia meeting the Kyoto target greenhouse gas reductions, or the National Physical Activity Taskforce meeting its 5% increase in sufficiently active Australians target.

The more conservative cumulative economic benefits of redeveloping inner-city type areas are summarized below in Table 12.

Table 12 Estimate development costs for 1000 dwellings

	Inner	Outer
Infrastructure		
Roads	$5,086,562	$30,378,881
Water and Sewerage	$14,747,616	$22,377,459

	Inner	Outer
Telecommunications	$2,576,106	$3,711,851
Electricity	$4,082,117	$9,696,505
Gas		$3,690,843
Fire and Ambulance		$302,509
Police		$388,416
Education	$3,895,458	$33,147,274
Health (Hospitals, etc.)	$20,114,867	$32,347,327
Transport		
Transport & Travel Time	$206,542,055	$342,598,098
Roads & Parking	$46,937,535	$154,826,095
Externalities	$2,219,884	$9,705,379
Greenhouse Gas	$17,388,226	$36,703,251
Health (from activity)		
Direct		$1,933,088
Indirect		$2,296,863
Total	$323,590,426	$684,103,839

The costs figures displayed in Table 12 represent an estimated savings potential through consolidated development but are not necessarily what could be expected from every development situation. Many of the estimates were made conservatively but as aforementioned, infrastructure costs may vary depending on excess capacity levels and area-specific requirements, greenhouse gas costs are dependant on legislation and the emerging carbon trading scheme, and health savings are dependant on the types of mode-specific infrastructure put into place combined with incentive schemes and public education. Furthermore, it should be noted that the infrastructure costs are up-front costs that require payment upon initial development. The transport, greenhouse gas, and health costs are present values calculated over a 50-year period and could be considered as operating costs of the respective types of development, except for health (from activity) which was calculated as a savings potential (hence it being omitted from the inner-city side of the economic overview).

Despite the variations that can be expected from these types of calculations, the data provided indicate very substantial differences in costs between fringe and redevelopment types of development. The dominant factors are infrastructure and transportation costs but the greenhouse and health impacts are important in policy decisions as they are part of a global and local governance system that will only want to see them reduced, not increased. The key to achieving the benefits reviewed is to view the inner-city redevelopment as a form dependent on a number of factors. Density is a prerequisite for mixed-use development to generate a viable patronage to support shops and services as well as for making transit servicing economically viable, while proximity increases physical transportation mode share and the efficiency of transit systems while reducing transport energy use. The synergies are numerous and as shown, can be economically quantified.

The values of infrastructure, transportation, greenhouse gas and activity-related health for the different iconic development types have been calculated from models that can be used to predict values for any other planned development. This type of approach should become standard practice in evaluating different development projects.

7. Applying the model

The only component of the assessment with sufficient objective measures of urban form to develop a predictive model was greenhouse gases. This model is somewhat simpler to develop than attempting the same for infrastructure or transportation because greenhouse gas costs are directly derived from a single dependent variable, being daily vehicle kilometers traveled. Conversely, infrastructure and transportation costs are comprised of numerous costs, all of which do not necessarily share the same cost driver. Creating a predictive model in this circumstance would require a lot of specific data. Health-related costs on the other hand, were calculated as a function of the proportion of the population meeting minimum activity levels as a result of active transport and therefore, one dependant variable; however, an entire data set based on activity levels and objectively measured urban form was not available to create a predictive model. In other words, the methodology and the calculation of health-related costs drew on secondary data whose source data was not accessible.

The greenhouse gas emissions cost can be predicted with 73.4% of the variance explained by using the following equation:

y = (365 days/yr)(Price/kg CO2-e)(# of Dwellings)(Ppl/Dwelling)(.073x - .25z + 4.35)
= (365)(0.170)(1000)(2.5)(.073x - .25z + 4.35)
= 155,125(.073x - .25z + 4.35)
where y = annual cost, x = distance to CBD, and z = transit accessibility

By substituting a different price per kg CO2-e in the disaggregated form of the equation above, the greenhouse gas costs of a new development under different pricing conditions can be calculated. Similarly, occupants per dwelling or any of the other assumed variables could be altered in the disaggregated equation to adjust for varying assumptions.

Assuming a linear relationship between distance to CBD and the cumulative cost of infrastructure, transportation, greenhouse emissions and health, one can make a rough model inclusive of all four components. While this may not be a robust, statistical model, it utilizes a logic that is based on the framework of other urban form assessments where costs are calculated for a development on a basis of them being positioned in the core, inner, middle, or outer locations of a city. Using the economic values of inner city and fringe developments generated in this report as two points on which to plot a linear relationship of development costs to distance to CBD, the resulting equation appears as follows:

Cumulative Equation: y = 5,677,376x + 306,558,296
Where y is the cost of development in dollars and x is the distance to CBD
Shortened equation: y = 5.68x + 306.56
Where y is the cost of development in millions of dollars and x is the distance to CBD

Plugging in a value for ‘x’ of 3km from the CBD for inner-city-redevelopments and 66.5 km for fringe developments, the equation generates cost figures as they appear in **Section 5**, the cumulative impact statement (inner = $323 million and outer = $684 million). The equation also suggests that with every additional 10km from the CBD that a development of 1000 dwellings is planned, the public costs increase by $56.77 million, or $56,773 per unit. The largest cost figures associated with residential development are transport related and as depicted in the greenhouse gas modeling, this is best represented as a linear relationship. It is reasonable to assume that any developments in the middle suburbs will generate costs near the predicted values of the linear equation noted above.

The predictive value of the formula can be used by making assumptions about the character of a development proposal such as a very dense, mixed use TOD on a rail line but at a long distance from the CBD, e.g. the Dandenong Transit City in Melbourne which would be more like an inner city kind of development. Other developments that are near the city but are not well served by transit and are not very dense and mixed would be more like a middle suburb. In this way the greenhouse, health, transport and infrastructure costs associated with any urban development could be given a first cut response through the use of this tool.

The clear policy implication from this work is that although land values are higher closer in to the centre of the city, the economic value in development that helps concentrate the city is considerably more than the economic value in spreading it out. As Australian urban policy to build the future will require reductions in greenhouse gases and more healthy, active lifestyles, then this formula is able to reassure us that such green city building will actually improve the Australian economy and not be a drain on it.

The other application of this formula is in assessing infrastructure decisions. No infrastructure, especially transport, is ever just about serving the direct users of that infrastructure. Cities are built around infrastructure whether it be roads, rail, pipes for water or power, and increasingly wires for high speed ICT. The decisions on building infrastructure can be assessed in terms of their benefits and costs to the industry they are directly serving but should also be assessed in terms of the city forms they are helping to create. Outer area ring roads will facilitate suburban fringe development whereas light rail built with TODs will create inner city type development. All infrastructure decisions should include a component that estimates the indirect costs associated with the ensuing urban development. This can be facilitated by our simple model.

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Appendix 1

GHG Emissions Costs by LGA assuming a cost of A$25 per tonne CO2-e

Findings from Sydney

LGA	Distance from CBD km	GHG emissions car CO2-e kg/day	Car emissions per capita kg/capita/day	GHG cost per day $/1000 dwellings/day	GHG cost per year $/1000 dwellings/yr	Share of total cost %	GHG savings per year $/1000 dwellings/yr
Sydney (CC)	0.10	17,695	0.889	$55.56	$20,280.31	0.38%	$216,330.94
North Sydney	3.40	228,084	4.034	$252.13	$92,025.63	1.75%	$144,585.63
Leichhardt	4.30	216,510	3.467	$216.69	$79,090.94	1.50%	$157,520.31
Woollhara	4.60	229,842	4.516	$282.25	$103,021.25	1.95%	$133,590.00
Mosman	4.90	88,898	3.434	$214.63	$78,338.13	1.49%	$158,273.13
South Sydney	5.00	200,239	2.171	$135.69	$49,525.94	0.94%	$187,085.31
Lane Cove	6.20	138,528	4.504	$281.50	$102,747.50	1.95%	$133,863.75
Waverly	6.60	259,363	4.275	$267.19	$97,523.44	1.85%	$139,087.81
Drummoyne	6.70	132,690	4.024	$251.50	$91,797.50	1.74%	$144,813.75
Marrickville	6.70	279,022	3.800	$237.50	$86,687.50	1.64%	$149,923.75
Willoughby	6.70	293,790	4.950	$309.38	$112,921.88	2.14%	$123,689.38
Hunters Hill	7.30	99,129	7.810	$488.13	$178,165.63	3.38%	$58,445.63
Ashfield	7.50	143,874	3.643	$227.69	$83,105.94	1.58%	$153,505.31
Botany	7.90	143,281	3.991	$249.44	$91,044.69	1.73%	$145,566.56
Manly	8.20	170,071	4.525	$282.81	$103,226.56	1.96%	$133,384.69
Randwick	9.60	413,492	3.403	$212.69	$77,630.94	1.47%	$158,980.31
Burwood	9.80	111,118	3.709	$231.81	$84,611.56	1.60%	$151,999.69
Concord	10.00	94,393	3.513	$219.56	$80,140.31	1.52%	$156,470.94
Ryde	11.10	409,550	4.278	$267.38	$97,591.88	1.85%	$139,019.38
Rockdale	11.50	312,232	3.527	$220.44	$80,459.69	1.53%	$156,151.56
Strathfield	11.90	131,386	4.658	$291.13	$106,260.63	2.02%	$130,350.63
Canterbury	12.20	517,443	3.952	$247.00	$90,155.00	1.71%	$146,456.25

Findings from Sydney

LGA	Distance from CBD km	GHG emissions car CO2-e kg/day	Car emissions per capita kg/capita/day	GHG cost per day $/1000 dwellings/day	GHG cost per year $/1000 dwellings/yr	Share of total cost %	GHG savings per year $/1000 dwellings/yr
Ku-ring-gai	15.30	590,484	5.826	$364.13	$132,905.63	2.52%	$103,705.63
Auburn	15.50	195,499	3.468	$216.75	$79,113.75	1.50%	$157,497.50
Hurtsville	15.90	338,012	4.785	$299.06	$109,157.81	2.07%	$127,453.44
Kogarah	15.90	250,806	4.982	$311.38	$113,651.88	2.16%	$122,959.38
Parramatta	16.10	652,438	4.515	$282.19	$102,998.44	1.95%	$133,612.81
Warringha	16.90	702,831	5.455	$340.94	$124,442.19	2.36%	$112,169.06
Bankstown	19.30	779,676	4.708	$294.25	$107,401.25	2.04%	$129,210.00
Pittwater	21.20	374,942	7.101	$443.81	$161,991.56	3.07%	$74,619.69
Holroyd	23.20	436,193	5.086	$317.88	$116,024.38	2.20%	$120,586.88
Hornsby	26.50	982,347	6.730	$420.63	$153,528.13	2.91%	$83,083.13
Liverpool	27.50	924,301	5.991	$374.44	$136,669.69	2.59%	$99,941.56
Fairfield	29.00	764,935	4.204	$262.75	$95,903.75	1.82%	$140,707.50
Sutherland	29.50	1,471,140	7.244	$452.75	$165,253.75	3.13%	$71,357.50
Baulkham Hills	33.70	1,129,224	8.100	$506.25	$184,781.25	3.50%	$51,830.00
Blacktown	34.90	1,618,947	6.315	$394.69	$144,060.94	2.73%	$92,550.31
Cambelltown	42.70	1,111,737	7.622	$476.38	$173,876.88	3.30%	$62,734.38
Penrith	45.80	1,411,810	8.189	$511.81	$186,811.56	3.54%	$49,799.69
Camden	47.30	371,556	8.455	$528.44	$192,879.69	3.66%	$43,731.56
Gosford	53.70	1,358,030	8.781	$548.81	$200,316.56	3.80%	$36,294.69
Blue Mountains	71.20	616,266	8.292	$518.25	$189,161.25	3.59%	$47,450.00
Hawkesbury	72.00	633,436	10.372	$648.25	$236,611.25	4.49%	$-
Wyong	72.70	1,026,623	7.846	$490.38	$178,986.88	3.39%	$57,624.38
Total		**22,371,863**			**$5,272,881.25**	**100.00%**	

Findings from Brisbane

LGA	Distance from CBD km	GHG emissions car CO2-e kg/day	Car emissions per capita kg/capita/day	GHG cost per day $/1000 dwellings/day	GHG cost per year $/1000 dwellings/yr	Share of total cost %	GHG savings per year $/1000 dwellings/yr
Melbourne	1.00	72,560	1.070	$66.88	$24,409.38	0.73%	$202,506.57
Port Phillip	4.97	209,989	2.620	$163.75	$59,768.75	1.78%	$167,147.19
Yarra	5.41	148,770	2.187	$136.69	$49,890.94	1.49%	$177,025.00
Maribyrnong	5.81	142,019	2.376	$148.50	$54,202.50	1.62%	$172,713.44
Moonee Valley	8.31	378,122	3.563	$222.69	$81,280.94	2.43%	$145,635.00
Stonnington	8.75	261,513	2.992	$187.00	$68,255.00	2.04%	$158,660.94
Moreland	8.87	339,095	2.581	$161.31	$58,879.06	1.76%	$168,036.88
Darebin	9.63	314,038	2.536	$158.50	$57,852.50	1.73%	$169,063.44
Boroondara	10.72	503,250	3.350	$209.38	$76,421.88	2.28%	$150,494.07
Hobsons Bay	12.31	293,734	3.652	$228.25	$83,311.25	2.49%	$143,604.69
Brimbank	13.50	654,809	4.011	$250.69	$91,500.94	2.73%	$135,415.00
Glen Eira	14.49	397,819	3.367	$210.44	$76,809.69	2.29%	$150,106.25
Bayside	17.10	350,496	4.168	$260.50	$95,082.50	2.84%	$131,833.44
Banyule	17.28	488,445	4.276	$267.25	$97,546.25	2.91%	$129,369.69
Whittlesea	17.90	392,445	3.687	$230.44	$84,109.69	2.51%	$142,806.25
Whitehorse	18.90	582,401	4.138	$258.63	$94,398.13	2.82%	$132,517.82
Monash	19.93	675,837	4.307	$269.19	$98,253.44	2.93%	$128,662.50
Manningham	20.76	636,298	5.973	$373.31	$136,259.06	4.07%	$90,656.88
Wyndham	23.00	447,716	5.515	$344.69	$125,810.94	3.76%	$101,105.00
Kingston	23.56	584,181	4.558	$284.88	$103,979.38	3.10%	$122,936.57
Hume	25.11	654,918	5.175	$323.44	$118,054.69	3.52%	$108,861.25
Knox	28.69	745,187	5.257	$328.56	$119,925.31	3.58%	$106,990.63
Maroondah	28.73	493,494	5.116	$319.75	$116,708.75	3.48%	$110,207.19
Melton	30.70	350,424	7.201	$450.06	$164,272.81	4.90%	$62,643.13
Greater Dandenong	31.19	485,786	3.929	$245.56	$89,630.31	2.68%	$137,285.63
Nillumbik	33.00	453,164	9.501	$593.81	$216,741.56	6.47%	$10,174.38

Findings from Brisbane

LGA	Distance from CBD km	GHG emissions car CO2-e kg/day	Car emissions per capita kg/capita/day	GHG cost per day $/1000 dwellings/day	GHG cost per year $/1000 dwellings/yr	Share of total cost %	GHG savings per year $/1000 dwellings/yr
Frankston	41.09	736,346	6.822	$426.38	$155,626.88	4.65%	$71,289.07
Casey	42.20	993,651	6.066	$379.13	$138,380.63	4.13%	$88,535.32
Yarra Ranges	46.40	1,032,522	9.731	$608.19	$221,988.44	6.63%	$4,927.50
Cardinia	53.40	128,669	9.947	$621.69	$226,915.94	6.77%	$0.00
Mornington Peninsula	60.30	813,414	7.164	$447.75	$163,428.75	4.88%	$63,487.19
Total		14,761,112			$3,349,696.25	100.00%	

Appendix 2

Sydney and Melbourne Data: Daily per Capita CO2-e and Modelled Parameters

Suburb	GHG/capita	To CBD	Activity intensity	Transit access
Melbourne results				
Melbourne	1.070	1.00	104.491	86%
Port Phillip	2.620	4.97	74.37067	84%
Yarra	2.187	5.41	71.32699	85%
Maribyrnong	2.376	5.81	31.18083	63%
Moonee Valley	3.563	8.31	33.04913	42%
Stonnington	2.992	8.75	49.66764	81%
Moreland	2.581	8.87	34.94962	60%
Darebin	2.536	9.63	33.6832	55%
Boroondara	3.350	10.72	36.07256	73%
Hobsons Bay	3.652	12.31	22.11571	25%
Brimbank	4.011	13.50	22.11571	16%
Glen Eira	3.367	14.49	37.8036	58%
Bayside	4.168	17.10	30.5488	32%
Banyule	4.276	17.28	26.69309	37%
Whittlesea	3.687	17.90	24.69786	18%
Whitehorse	4.138	18.90	30.32901	29%
Monash	4.307	19.93	30.74724	22%
Manningham	5.973	20.76	18.33446	3%
Wyndham	5.515	23.00	19.19991	7%
Kingston	4.558	23.56	34.87298	28%
Hume	5.175	25.11	20.36164	10%
Knox	5.257	28.69	24.13857	9%
Maroondah	5.116	28.73	22.07024	16%
Melton	7.201	30.70	15.19053	8%

Suburb	GHG/capita	To CBD	Activity intensity	Transit access
Greater Dandenong	3.929	31.19	27.47892	15%
Nillumbik	9.501	33.00	20.12773	17%
Frankston	6.822	41.09	17.71661	10%
Casey	6.066	42.20	18.92039	8%
Yarra Ranges	9.731	46.40	16.0437	11%
Cardinia	9.947	53.40	19.82883	12%
Mornington Peninsula	7.164	60.30	13.20078	7%
Sydney results				
Sydney (CC)	0.889	0.10	330.6339	96%
North Sydney	4.034	3.40	121.8281	70%
Leichhardt	3.467	4.30	71.86342	87%
Woollhara	4.516	4.60	66.41607	22%
Mosman	3.434	4.90	48.7702	62%
South Sydney	2.171	5.00	113.8737	91%
Lane Cove	4.504	6.20	51.24671	44%
Waverly	4.275	6.60	95.10611	87%
Drummoyne	4.024	6.70	51.78653	16%
Marrickville	3.800	6.70	64.37259	87%
Willoughby	4.950	6.70	58.96366	28%
Hunters Hill	7.810	7.30	30.77002	14%
Ashfield	3.643	7.50	62.40785	64%
Botany	3.991	7.90	40.32756	29%
Manly	4.525	8.20	46.70056	48%
Randwick	3.403	9.60	52.13946	65%
Burwood	3.709	9.80	63.90592	46%
Concord	3.513	10.00	40.06209	30%
Ryde	4.278	11.10	40.98237	37%
Rockdale	3.527	11.50	44.24853	37%
Strathfield	4.658	11.90	34.91641	38%

Suburb	GHG/capita	To CBD	Activity intensity	Transit access
Canterbury	3.952	12.20	51.74705	60%
Ku-ring-gai	5.826	15.30	20.88535	28%
Auburn	3.468	15.50	31.85958	25%
Hurtsville	4.785	15.90	44.94621	46%
Kogarah	4.982	15.90	46.03009	41%
Parramatta	4.515	16.10	43.71826	34%
Warringha	5.455	16.90	29.96319	18%
Bankstown	4.708	19.30	34.55737	29%
Pittwater	7.101	21.20	20.54202	7%
Holroyd	5.086	23.20	31.12426	22%
Hornsby	6.730	26.50	25.35693	29%
Liverpool	5.991	27.50	20.89103	9%
Fairfield	4.204	29.00	35.95417	16%
Sutherland	7.244	29.50	25.4291	21%
Baulkham Hills	8.100	33.70	21.09561	5%
Blacktown	6.315	34.90	24.84111	20%
Cambelltown	7.622	42.70	19.0944	15%
Penrith	8.189	45.80	23.51239	11%
Camden	8.455	47.30	10.79457	0%
Gosford	8.781	53.70	15.06618	0%
Blue Mountains	8.292	71.20	5.30491	6%
Hawkesbury	10.372	72.00	16.30905	10%
Wyong	7.846	72.70	13.44757	0%

Appendix 3

Activity related health cost figures and calculations

Annual direct health costs/savings
Costs Due to Inactive Adult Population (54.2%) = $1,500,000,000 Savings Due to Active Adult Population (45.8%) = $1,267,527,677 Value of Activity for Adult Population (100%) = $2,767,527,680
Annual Indirect Health Costs/Savings
Costs Due to Inactive Adult Population (54.2%) = $3,288,331,576 @ 54.3% of total costs Costs Due to Inactive Adult Population (54.2%) = 5,535,055,360 @ 2x direct costs
Total Annual Health-Related Value of Activity Among Australian Adults
Lower Estimate = $2,767,527,680 + $3,288,331,567 = $6,055,859,256 Upper Estimate = $2,767,527,680 + $5,535,055,360 = $8,302,583,040
Adult Population of Australia (Ages 18 and Over)
Approximated Population Percentage = 73.3% Approximate Population = 15,400,000 Avg. Persons Per Household = 2.5 Avg. Adult Persons Per Household = 1.8325 Avg. Adult Persons Per 1000 Dwellings = 1832.5
Recommended Minimum Moderate-Intensity Physical Activity Levels
30min per Day Over At Least 5 days per Week; 2.5hrs Per Week; 130 Hrs Per Year
Hourly Value of Moderate Intensity Physical Activity Among Australian Adults
Direct Cost Estimate = $2,767,527,680 per year / 15,400,000 ppl / 130 hrs per yr = $1.38 per hr Indirect Cost Lower Est. = $3,288,331,576 per yr / 15,400,000 ppl / 130 hrs per yr = $1.64 per hr Indirect Cost Upper Est. = $5,535,055,360 per yr / 15,400,000 ppl / 130 hrs per yr = $2.76 per hr Total Lower Estimate = $6,055,859,265 per yr / 15,400,000 ppl / 130 hrs per yr = $3.02 per hr Total Upper Estimate = $8,302,583,040 per yr / 15,400,000 ppl / 130 hrs per yr = $4.15 per hr
Minimum Activity Hours Being Met By Walking In Neighbourhoods of 1000 Dwellings
Sprawling Neighbourhood (18% meeting target) = 18% x 1832.5 ppl x 130 hrs per yr per person = 42,880.50 Walkable Neighbourhood (37% meeting target) = 37% x 1832.5 ppl x 130 hrs per yr per person = 88,143.25 Difference in Hours (19%) = 88,143.25 – 42,880.50 = 45,262.75
Minimum Activity Hours Being Met By Cycling In Neighbourhoods of 1000 Dwellings
Sprawling Neighbourhood = 21% x 42,880.50 = 9,004.91 hrs Active Travel Neighbourhood = 21% x 88,143.25 = 18,510.08 hrs Difference in Hours = 18,510.08 - 9004.91 = 9,505.18 hrs

Annual Health Related Savings Associated with Active Travel Neighbourhoods
Lower Estimate (walking only) = 45,262.75 hrs x $3.02 per hr = $136,693.50
Upper Estimate (walking only) = 45,262.75 hrs x $4.15 per hr = $187,840.40
Lower Estimate (cycling only) = 9,505.18 hrs x $3.02 per hr = $28,705.64
Upper Estimate (cycling only) = 9.505.18 hrs x $4.15 per hr = $39,446.47
Lower Estimate (combined) = $135,693.50 + $28,705.64 = $164,399.14
Upper Estimate (combined) = $187,840.40 + $39,446.47 = $227,286.87
Estimated Health-Related Savings In Developing An Active Travel Neighbourhood of 1000 Dwellings (n=50, r=3%)
PV(A) = A/i [1-1/(1+i)^n]
Lower Estimate = $4,229,951
Upper Estimate = = $5,848,038

Our vision

PB will be a positive and highly influential force in the development and operation of infrastructure around the world. Through service to our clients and collaboration with colleagues, we will create a lasting legacy that improves the lives of people & communities.

Our values

We behave ethically, acting with integrity and respect.

We work with our clients to contribute to their success.

We care for our colleagues, encouraging their development, engagement and achievement.

We share knowledge with our colleagues to deliver professional excellence.

We act in a socially and environmentally responsible manner.

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