Bicycles and Agglomeration Economies: Implications for Melbourne's Growth

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Abstract

This paper examines the implications of transport infrastructure choices and agglomeration productivity effects for the city of Melbourne. Productivity is an important element of macroeconomics and has many elements that affect it. Some of these elements include the spatial arrangement of economies and mobility and access within those cities known as agglomeration economics. Few studies exist in the literature examining the connection between agglomeration economies and bicycle infrastructure. The central business district of Melbourne is forecast to have a 49% increase in jobs by 2031 and if the productivity improvements and the gains from increased job density are to eventuate, then it is clear additional transport infrastructure is necessary in Melbourne. While agglomeration economies suggest the forecast increase in job density in Melbourne would lead to a 2.5%-5.7% increase in productivity, this is unlikely due to transport constraints and congestion. While public transport provision has been shown to increase agglomeration economies, more bicycle infrastructure has the potential to generate significantly higher productivity in the range from 3.22% – 8.47% due to the increased general productivity, increased alertness, reduced sick days, better decision making and fewer task errors as well as generate savings from public health benefits

Keywords

Transportation, agglomeration economics, bicycle infrastructure, productivity

1. Introduction

The objective of this paper is to examine and describe the implications of transport infrastructure choices and agglomeration productivity effects to explore its possible inclusion in analysing transport project options, using the city of Melbourne as a case study. Productivity is an important element of macroeconomics and has many elements that affect it. Some of these elements include the spatial arrangement of economies and mobility and access within those cities. It has been suggested the development of cities has been due to the forces of agglomeration economies. Agglomeration economics is a relatively new field of economics examining the economics of productivity and proximity. Agglomeration economics and its connection with bicycle economics has not received a great deal of attention in the literature. Bicycle economics is a growing field of inquiry which explores the costs and benefits of bicycle riding and infrastructure investment. This includes a wide variety of benefits ranging from reduced morbidity and mortality, to increased social cohesion, greater access and reduced traffic congestion.

2. Literature Review

There are numerous examples in the literature of economic analyses of cycling and walking. This includes numerous reviews of other studies, though inclusion of cycling into transport project appraisal is rare.

2.1. Physical activity implications and health through active transport

Cost-benefit analysis of active transport projects (particularly walking and cycling) is uncommon. Despite this, of the studies completed they are nearly unanimous in their conclusions that considerable public health benefits can be realised through increased rates of active transport modes with the largest expected benefit from active transport relates to improvements in health from increased physical activity, reduced morbidity and mortality. Active transport is a form of physical activity due to the energy used by walking, cycling, or exerting oneself in getting from A to B (DHPAHIP, 2004). Many studies in the literature scrutinise what impact active transport has on health.

Saelensminde (2004) performed a cost benefit analysis of pedestrian and bicycle tracks in Norway examining changes from to walking and cycling away from private vehicles. Saelensminde examined included reductions in mortality, costs of health care provision and implications for productivity for certain musculoskeletal conditions, type 2 diabetes, high blood pressure, and several types of cancer with 50% of new pedestrians or cyclists assumed to receive the health benefits. Saelensminde found the cost benefit ratio of investments in cycle networks ranged between 4 and 5.

Another study to look at the health benefits of active transport was undertaken by BECA (2007) who calculated a figure per kilometre. They found the health benefits of cyclists and pedestrians who were not exercising before to be 40c/km and 80c/km respectively. BECA limited these benefits to $1000 per annum with the value of a statistical life being $3.05m.

Cavill et al. (2008) examined published and unpublished studies concerning economic valuations of transport infrastructure or policies related to walking and/or cycling and the valuation of health effects of these projects or policies. Their study included sixteen papers which included a wide variation in approaches and methods and health impacts examined it is not possible to directly compare the studies. Data was not transferable and issues of additional exercise versus total exercise and the associated issue of dose response relationship were significant issues in comparing studies. Cavill concluded a more consistent method to valuing health impacts of cycling infrastructure would greatly increase rigour and facilitate the comparison of different projects.

Genter et al (2008) examined the health benefits of active transport in New Zealand. As with nearly all other studies, they found significant amounts of research that show many medical conditions are reduced by regular physical activity such as cardiovascular disease, some cancers, obesity and type 2 diabetes. Included in the literature examined by Genter et al was a study by Frank et al (2004) that found every additional hour of commuting by private vehicle led to a 6% increase in the risk of becoming obese. Conversely Frank et al found for every additional kilometre of walking was correlated with a nearly 5% reduction in the same risk of obesity. Genter et al also found a wide variety in approaches and methods that limit the ability to directly compare studies. In addition to physical ailments, mental health benefits also appear to be related to quantities of physical activity as demonstrated by Lawlor and Hopker (2001) and Dunn et al (2001).

A report by the Centers for Disease Control and Prevention (CDC, 2012) found low levels of physical activity among Americans is a major contributor to rising rates of obesity, diabetes, heart disease, and stroke among other chronic diseases. They also found improved bicycling and walking facilities would lead to increased participation that also generates safety benefits related to reduced traffic injuries and fatalities, which also reduce medical costs and economic losses from injury or death. According to Cawley and Meyerhoefer (2009) these costs of obesity related health spending in the United States is between $147 and $210 billion per annum and represent 91% of all medical spending.

2.2. Productivity impacts of cycling

Many studies have found a positive link between levels of levels of physical activity and productivity. Mills et al (2007) explored the link between health programs in the workplace and productivity. They found a reduction in health risk factors and absenteeism and an increase in productivity of over 10%. This is consistent the conclusions of Pronk et al (2004) who examined the association between productivity and the amount of physical activity.

Weisbrod and Reno (2009) found businesses that have programs to encourage employees to commute via non-motorised modes are likely to see improved travel time reliability for employees which can lead to improved productivity. This is consistent with a report by the WHO (2010) which found physical activity in the workplace programs including walking and cycling to work reduces sick leave by up to 32% and increase productivity by 52%. Others found productivity gains to be a far more moderate 15% (ACFAL, 2003).These findings are consistent with work by the World Green Building council (WGBC, 2014) who found workers who exercise before work experience an increase of productivity of an average of 15 percent. These confirm the numerous other studies including Sjoberg (1983) and Siegel (2013) with consistent findings of a 4-15 percent increase in productivity as well as 27 percent fewer task errors for employees who are physically fit. Together with increased provision of facilities and increasing the convenience of cycling to work would save UK businesses approximately £13bn through fewer sick days and increased productivity according to Grous (2011).

2.3. Cost of transport modes

Purchasing, operating, and housing vehicles is costly and represents a significant portion of household income (Pucher and Buehler, 2008). However, these costs also extend to broader society with spending on road construction and expansion that raises peak-period speeds that can discourage use of alternative transport modes such as public transport and active transport (Downs, 1962)

According to Simmons et al. (2015) low user cost and affordability are among the many benefits of walking or bicycling, especially compared to owning and operating a private vehicle. Reduced travel costs result in a greater portion of pedestrians' and bicyclists' income that can be used for housing, necessities, and other consumer goods. In numerous cases, especially for trips less than 5km or in urban locations, cycling may be faster than driving and can create a benefit in time-savings as well.

Providing greater access to lower-cost travel options can also have a social equity benefit by increasing access to jobs, opportunities, and community amenities for lower-income populations (Litman, 2007).

3. Materials and Method

The data for this study was obtained from journey to work data published by the Victorian Government's Department of Economic Development, Jobs, Transport and Resources in addition to a study commissioned by the City of Melbourne examining potential jobs growth for the local government area while the economic theory is drawn from the academic literature. This data included

3.1. Productivity

> Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise output per worker (Krugman, 1997 p11)

Productivity is a way of measuring the production or service provision efficiency and is usually expressed as the ratio of output to inputs, i.e. output per unit of input. Productivity measures that do not incorporate all factors, but rather one or a selection, are called partial productivities. A commonly used example in economics is labour productivity, which is usually expressed as output per hour. Labour productivity can be a contentious topic and is considered a crucial factor in production performance of firms and nations. At the company level, other partial productivity measures include such things as worker hours, materials or energy per unit of production or service delivery (Eslake, 2011).

Increasing productivity can raise living standards as real income growth increases people's capacity to purchase more goods and services or enjoy more leisure time, improve housing and contribute to social and environmental programs. Businesses benefit from increased productivity as it enables them to increase their profitability. Increased productivity can bring about:

- Lower unit costs;
- Improved competitiveness and trade performance;
- Higher profits;
- Higher wages; and

- Economic growth.

However, according to the Australian Treasury (Dolman and Gruen, 2012) over the past decade Australia's multifactor productivity growth has slowed and in some cases plateaued. While labour productivity has increased over the same time frame, in recent years it also appears to have plateaued (Figure 1)

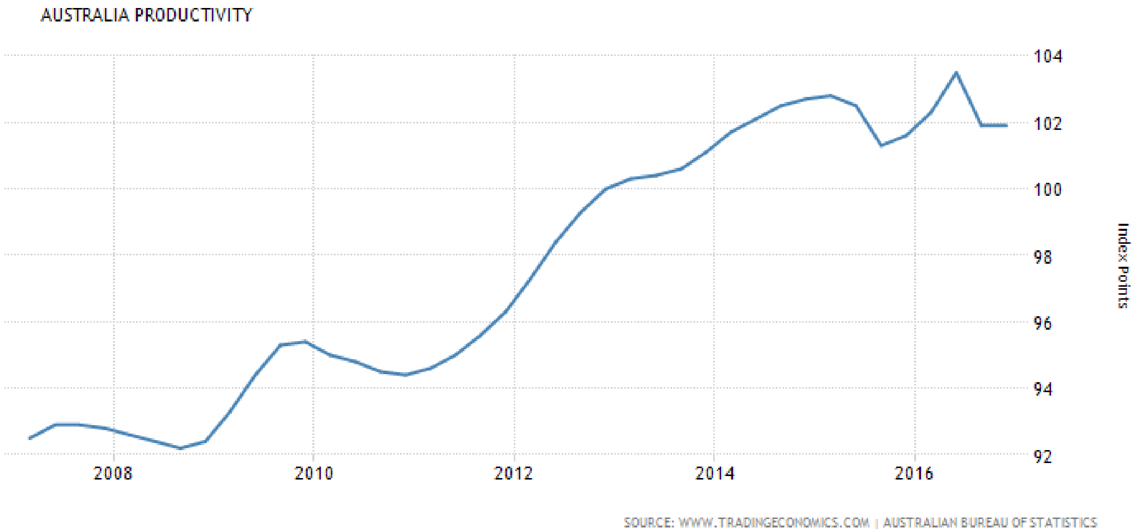

Figure 1: Productivity in Australia (Trading Economics, 2017)

3.1.1. Drivers of productivity growth

Certain factors are considered important for increasing growth. In the United Kingdom the Office for National Statistics (ONS) has identified five drivers that improve long-term productivity. These include investment (machinery, technology, equipment and buildings), innovation (successful exploitation of new ideas), skills (quantity and quality of different types of labour), enterprise (seizing of new business opportunities) and competition (creating incentives to innovate) (ONS, 2007). In addition to these drivers of productivity, an area of study into productivity growth has recently received increasing attention is agglomeration economies. Agglomeration economies are considered to be the advantages that businesses derive from situating themselves in close proximity to each other ('agglomerating') (Rosenthal and Strange, 2004).

3.2. Agglomeration Economies

Agglomeration economies can be thought of as the positive economic externalities that arise due to the size and density of cities and also the size and density of clusters of firms, such as central business districts or specialised industrial groupings. Evidence suggest that large, dense cities have arisen historically because firms and households want to locate near important nodes such as ports, as well as near other firms and households from whom they benefit and generate business (Fernández and Atienza, 2011).

3.2.1. Agglomeration Economies and Productivity

Some businesses locate themselves closely to other businesses in the same industry or near firms who are suppliers or purchasers of their products or services. Often households will locate near such groupings as will retailers to be near their customers. This co locating phenomenon is because firms are sometimes more productive due to increasing returns to scale when located near each other. This is known as external economies of agglomeration as each firm that locates near another firm in the same industry or will benefit the other firms in addition to itself (hence the benefit is external to the firm)(Puga, 2010).

Chatman and Noland (2011) suggest there are three aspects of agglomeration economies that help explain the phenomenon and how it relates to transport investment. The first aspect is whether the agglomeration economies are occurring within a particular industry or across industries. The second aspect concerns the mechanisms by which agglomeration economies occur and the third aspect is the spatial scale in which these mechanisms occur.

3.2.1.1. Within-Industry and Between-Industry Effects

Agglomeration economies due to businesses that locate near other firms in the same industry are known as Marshallian or localisation economies. Marshall (1920) described how firms in the same industry would locate near one another in order to share specialised inputs, a pool of skilled labour and have access to information generated by other firms in the same industry .

Between industry effects are known as Jacobsian or urbanisation economies. These are named after Jane Jacobs work on the economies of cities (Jacobs, 1969). This refers to agglomeration economies that are external to a firm or industry but internal to a city or region. These agglomeration economies are caused by local shared public goods, large markets as well as consumer benefits due to the diversity of retailers and services. Cities or regions which are diverse contain a broad range of suppliers and knowledge that new firms can utilise. Such interactions can lead diversified cities to be more productive than cities which have a single or limited focus. As such matching between firms and suppliers as well as businesses and potential employees is easier in a large, diversified city (Kolko, 2010).

3.2.1.2. Mechanisms of Agglomeration

Possible mechanisms for agglomeration have been described by Duranton and Puga (2004) for both localisation and urbanisation agglomeration economies. They describe three types of mechanisms: sharing, matching and learning.

Sharing Mechanisms

Expensive facilities and infrastructure with large economies of scale such as road and rail networks as well as ports and airports are shared by firms in a mutually beneficial way up to a point where significant congestion occurs (Combes et al., 2012)

Matching Mechanisms

The mechanism of matching involves buyers and sellers as well as employers and employees being able to find each other more easily. This is due to there being a larger pool of businesses, potential workers, suppliers and buyers. This lowers production costs by reducing the time it takes to match skills and tasks, find suitable employees as well as reduce travel times (Chatman and Noland, 2011).

Learning Mechanisms

Learning mechanisms include the generation and accumulation of knowledge which can be facilitated by bringing large numbers of learners and knowledgeable people together (Chatman and Noland, 2011).

3.2.1.3. Productivity Gains

In terms of the agglomeration effects, there is clear evidence linking the ‘effective density’ (time based accessibility) of economic activity with labour productivity (SGS, 2012). Figure 2 shows how each industry’s labour productivity in Melbourne improves as effective density doubles. According to the SGS study, a doubling of effective density leads to a 7% improvement in productivity, with other labour intensive industries showing much stronger relationships due to the mechanisms of agglomeration outlined above. This figure is within the range of results estimated in international studies of agglomeration that suggest effective density doubling can lead to labour productivity improvements in the range 3 to 11% (Ciccone, 2002, Ciccone and Hall, 1996, Brulhart and Mathys, 2008, Graham, 2007, Puga, 2010).

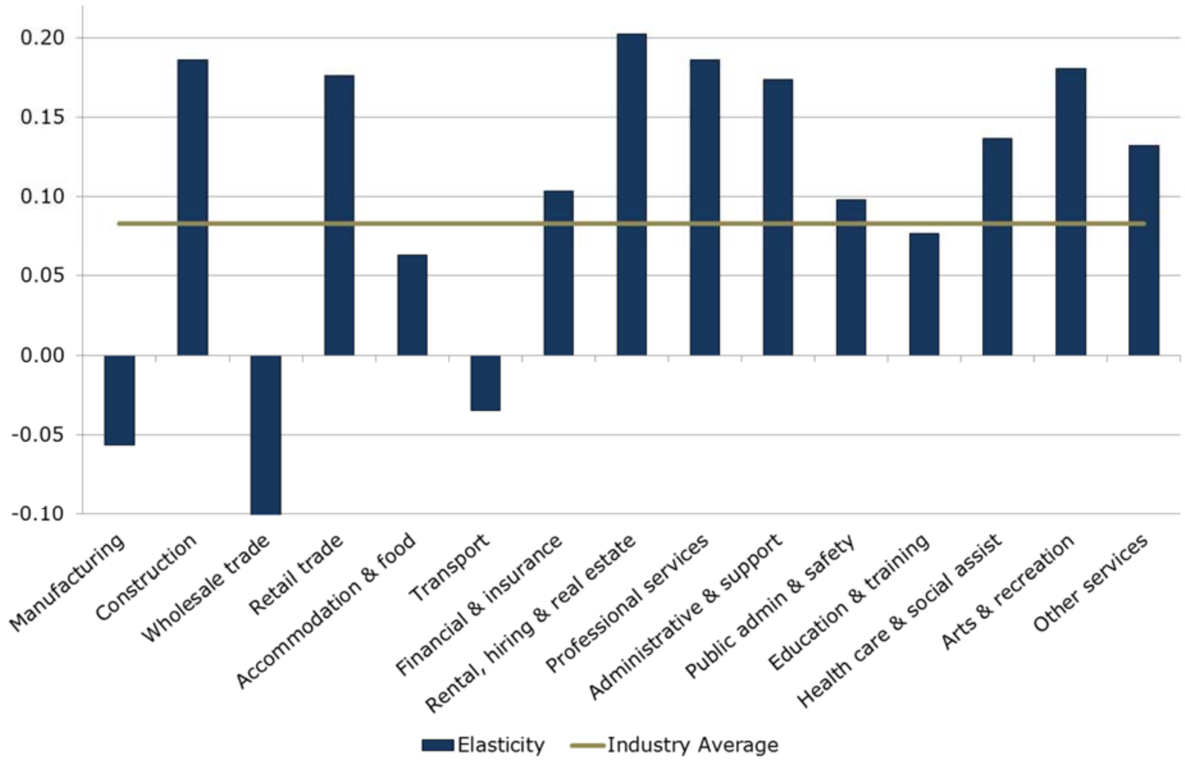

Figure 2: Agglomeration and Sectoral Productivity in Melbourne (SGS, 2012 p34)

3.2.2. Agglomeration and Transport

The external economies of agglomeration can help provide an explanation for the spatial structure of cities as well as the productivity of certain industries and competitiveness of particular regions. One important factor of agglomeration economies is travel time. Reduction in travel time from investment in transport infrastructure or improved services can increase connectivity between businesses and between businesses and their customers. A reduction in travel time can also lead to spatial densification whereby people can travel further in a given time leading to an effective spatial densification through temporal contraction rather than in increase in physical proximity. This can influence households' location decisions as they seek to take advantage of travel time reductions. Consequently transport investments are a very important factor in agglomeration economies, however, agglomeration is a function of accessibility rather than one type of transport mode or another (Chatman and Noland, 2011).

While transport plays a key role in agglomeration economies and driving productivity, much of this demand has been met by latent capacity in existing road, rail and bicycle networks. This elevates the importance of ensuring emerging transport capacity constraints are addressed. However, the degree to which transport improvements cause agglomeration economies is dependent upon the spatial, network and temporal characteristics for each particular transport mode and its spatial context.

3.2.2.1. Network and Synergistic Effects

Network effects from transport improvements are fundamental to economies of agglomeration. A network effect (also known as demand side economies of scale or network externality) is the effect that one individual has on the worth and usefulness of the service or good in question to other individuals. Therefore when a network effect exists, the value of a good or service is reliant on the quantity of others making use of it (Easley and Kleinberg, 2010).

A common example of a network effect is the telephone. When a single person possesses a telephone it provides little value to that person, however, the more people who own a telephone provide more utility for each other person. This is a positive externality and increased value for other phone owners. These positive network effects can also create a bandwagon effect as the network increases in value with increased levels of participation through a positive feedback mechanism (Easley and Kleinberg, 2010).

Transport systems usually exhibit network effects as their effectiveness and benefits increase as the system develops in size. This is the case with footpaths and bicycle lanes which can provide little value in isolation, however, as they connect more destinations through a network they provide access to many more destination and have a much greater value. This value is greater than the sum of the individual lanes through the network effect. This is especially the case where an individual path connects two separate networks. The one path effectively doubles the size of the network through one connection thus making the two networks one (Litman, 2015).

Strategies to improve transport systems between modes can also display synergies. These synergies also create greater total value than the sum of the individual impacts. For example, bike lanes by themselves may increase bicycle commuter mode share by 5%, and a program to reduce commuter trips alone may increase bicycle mode share by 5%. However, the combined effect of both of these programs may result in a 15% increase in bicycle commuting through the synergies involved. Regrettably transport planning usually evaluates projects and programs on an individual basis and as a consequence the network and synergistic benefits and the potential economies of agglomeration effects are not evaluated (Litman, 2015).

The opposite of this is traffic congestion which is an example of a diseconomy of agglomeration. Spatially constrained growth in private motor vehicles nearly always creates issues of crowding and traffic congestion (Graham, 2007).

3.3. Agglomeration Economies and Transport Mode Characteristics

Some key questions when assessing different types of transport infrastructure and the links to agglomeration are whether such an investment would: increase access to labour, increase links between companies, increase travel speed and decrease travel costs. Road, public transport (rail) and bicycle infrastructure are briefly examined below.

3.3.1. Road Transportation

All three forms of transport investment have the potential to increase access to labour. Road transportation is the mode that has expanded the most over the last 50 years in Australia and most developed countries (Figure 3), and now the spatial cover of road transportation is extensive. Road transport possesses significant advantages over other modes including the high relative speed of private vehicles with the major speed constraint being government-imposed speed limits. However, in congested areas this benefit disappears and average speed drops to low levels. One of road transportation's most important attributes is the flexibility of route choice once a network of roads is provided. Road transport has the ability to provide door to door service for both passengers and freight thus also increasing access to labour and links between companies

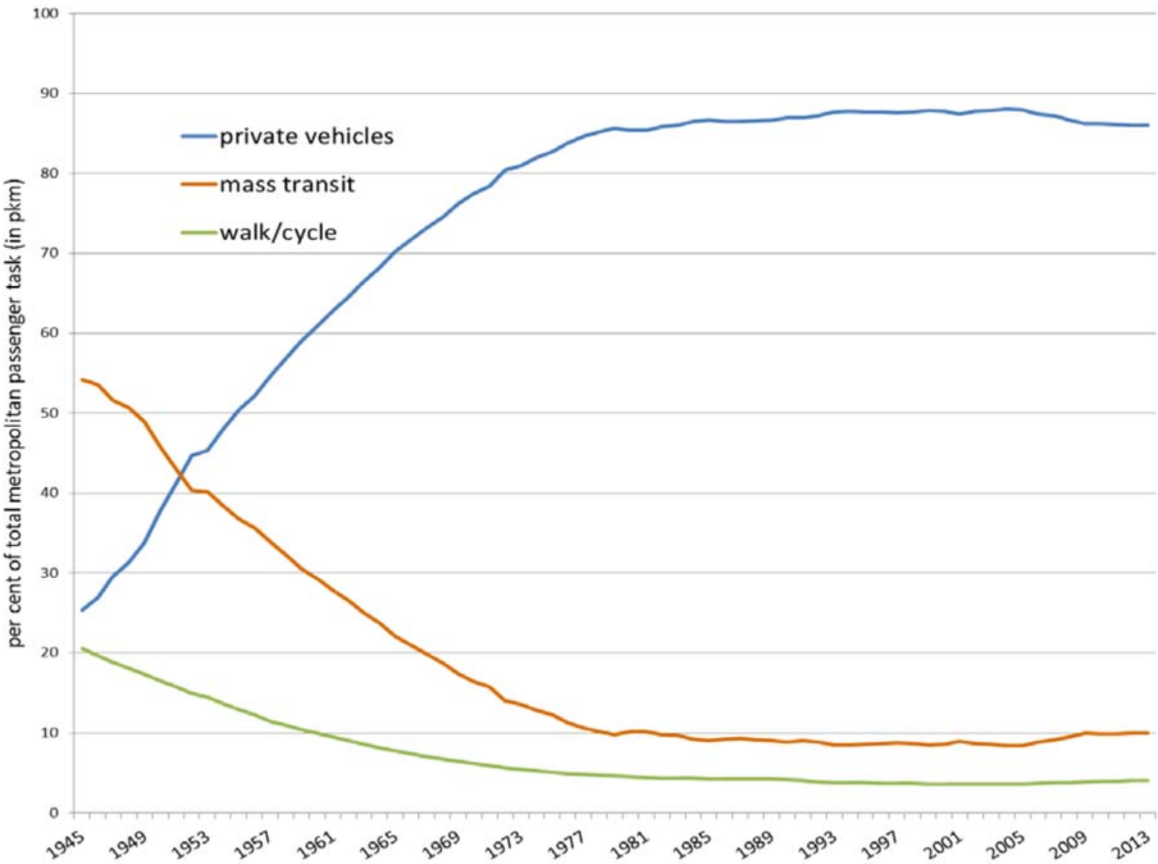

Figure 3: Australia Transport Mode Share (BITRE, 2013 p4)

These multiple advantages have made cars the mode of choice for a great number of trip purposes, and have led to their mode share dominance for short distance trips. However, the success of cars and trucks has given rise to a number of serious problems. Road congestion has become a feature of most urban areas around the world (Rodrigue and Slack, 2013). In addition, the mode is behind many of the major negative externalities linked to transportation which include air pollution, storm water runoff pollution, increased physical inactivity and associated health costs and a multiplication of road accidents leading to over 1.24 million deaths on the World's road per annum (WHO, 2015).

Road transportation usually has large construction and maintenance costs, both for vehicles and infrastructure. However, the capital costs of vehicles vary significantly from fairly small to extremely large. Small capital costs of vehicles make it comparatively easy for new users to purchase them; however, these costs are increasing. Low vehicle capital costs tend to mean innovations and new technologies can relatively quickly be incorporated into the sector through high turnover. Road infrastructure can be expensive to build, albeit with a wide range of costs, from a gravel road to a multi-lane highway. In most countries most roads are constructed as a public good by government authorities, while the vast majority of vehicles are privately owned. As a result the capital costs of road infrastructure are usually paid for by society and hence spread across the populace and do not rely on one source. Globally 95% of the financing of road infrastructure is provided by the public sector with the balance funded through tolls. An important characteristic of road transportation is that a substantial proportion of costs are externalised which is an indirect form of mobility subsidy. Car parking provision is also a significant issue as it consumes a large amount of valuable and this is often provided free of charge which also represents a subsidy for road transportation users (Rodrigue and Slack, 2013).

The public provision of road infrastructure which is free at the point of use bestows numerous advantages on private road users and can also lead to considerable problems as detailed above. The main advantage of this approach is that the user does not usually incur the full costs associated with private road transportation (i.e. the cost of road usage is below a theoretical real market price) (Rodrigue and Slack, 2013).

However, this does not include road based public transport. Buses have the potential to have the same network effect benefits and have the inherent flexibility of private motor vehicle use. However, they are also prone to the issue of congestion, thereby negating the increased access to labour, links between firms and travel speed. Congestion issues are considerably lessened with dedicated bus lanes, however, pressure from private vehicle users often limits supply of dedicated bus lanes (Vuchic, 1999).

3.3.2. Public Transportation (Rail)

The ability of trains to transport significant numbers of people over long distances is the mode's primary advantage. When a train has its full complement of passengers it is a high capacity service (easily up to 1000 people per train) at reasonable speed and therefore increase access to and for labour. While rail transportation can increase links between companies it does not do this to the same extent as road transportation, due to the inherent flexibility of road transportation once a network is in place. Rail does not suffer from the same issue of congestion in the manner that road transportation does (Rodrigue and Slack, 2013).

Capital costs of rail transportation are high due to expensive construction of track as well as the very high cost purchase of rolling, especially when compared with private road transportation.

Historically, investments in both tracks and rolling stock have been made by either by the public sector or the private sector obviously before any revenue has been generated by the infrastructure and because of this, the number of potential participants in the provision of rail transportation is necessarily small. A major issue for rail is the location of tracks in expensive urban locations which are large sunk costs (Rodrigue and Slack, 2013).

In comparison to road investments, rail transportation investments can increase the number of commuters who can efficiently access and egress places with large numbers of workers, e.g. central business districts. This assists higher rental occupancy rates and stimulates more development. This can potentially reduce growth in roads and parking to allow other productive uses of land (Vuchic, 1999, Ciccone, 2002).

3.3.3. Bicycle Transportation

Bicycle transportation has the potential to increase access to labour; but for a central business district this is limited to the immediate 5-10kms radius which is a typical cycling distance. However, bicycle transportation can also be integrated with other transport modes which increase access to labour and links between businesses beyond the 10km radius. Bicycle transportation is also able to increase links between companies due to its network effect common with road transportation which provides door to door transportation (Litman, 2015). Compared with road and rail transportation, bicycles and bicycle infrastructure take up very little space. Bicycle parking requires 10 times less space than car parking and hence bicycle parking infrastructure has a much lower cost (Aldred, 2014).

Capital costs and entry costs are very low due to the paths and lanes not requiring the heavy engineering necessary for cars and trucks. The cost of a bicycle often being more than an order of magnitude less than a motor vehicle, e.g. $400 vs $4000 (Infrastructure Australia, 2009).

Bicycles have to endure fewer delays in traffic jams than cars or buses. For example, during peak hour the average speed of a car in Bangkok – which is designed around private road vehicle transportation – is 8 km/h, while in Singapore – where provision has been made for bicycles and public transportation – the average car speed is 30 km/h. For short distances in central business districts, riding bicycle is usually faster than driving a car (Koh and Wong, 2012).

However, the quality of bicycle infrastructure can also affect vehicle trip generation in several ways:

- Poor quality cycling infrastructure forces people to drive for short trips. In urban areas a substantial portion of private vehicle use (10-30%) involves short trips that could easily change to cycling (Litman, 2015).
- Poor quality cycling infrastructure increases chauffeuring trips (trips made to transport a non-driver) which usually entrails empty return trips which also add to congestion (Litman, 2015).

Consequently, improving bicycle infrastructure can reduce automobile trip generation and therefore traffic congestion. These impacts tend to be greatest in commercial areas, and near schools and recreation centres, where many short trips begin and end.

Recent research into the productivity effects of bicycle commuting has identified a number of areas which are not usually accounted for in transport infrastructure provision.

- Workers who exercise before work experience an increase of productivity of an average of 15 percent (WGBC, 2014).
- In the United Kingdom, increased provision of facilities increasing the convenience of cycling to work would save UK businesses approximately £13bn through fewer sick days and increased productivity (Grous, 2011).
- Several studies show a 4-15 percent increase in productivity and 27 percent fewer task errors for employees who are physically fit (Sjoberg, 1983, Siegel, 2013).

The ability of a physically active executive group to make complex decisions has also been shown to increase dramatically compared to non-exercisers. Some research suggests that those who regularly exercise work at full efficiency all day. This translates to a 12.5% increase in productivity compared to those who do not exercise (Gabrow et al., 2010). Historically, the absence of these additional benefits in transportation project appraisal has had a tendency to undervalue bicycle transport infrastructure improvements. This is especially the case particularly early in the development period of new projects. The first few footpaths, bike lanes or encouragement programs are unlikely to generate a high economic return if evaluated individually, although once completed the network may provide very large benefits. This limited assessment of transport infrastructure is addressed by Gössling and Choi (2015) who examine typical cost benefits analyses and compare them when bicycle infrastructure is included. Their study shows that the costs to society of private car travel are more than six times higher than cycling with the costs of car use set to increase and the costs of cycling appear to be in decline.

3.3.4. Other Modal Factors

Investment in all transport modes have the potential to lead to greater agglomeration economies and hence greater productivity, however, one of the main negative externality of road transportation, congestion, has the potential to counteract economies of agglomeration more than the other modes discussed. In addition, the other modes have impacts on productivity beyond economies of agglomeration. The health effects of transportation are also a significant factor in productivity (Hansson et al., 2011).

The study 'Better Transportation Options=Healthier Lives' (RWJF, 2012) examined the connection between transportation options and health and wellbeing and found:

- Public transit users walk an average of 19 minutes getting to and from public transportation.
- Countries with lower rates of obesity have a strong correlation with rates of commuters who walk or cycle to work
- The risk of obesity increases 4 percent with every additional kilometre of car commute, and decreases 5 percent with every kilometre walked
- Lengthy commutes cost $100 billion each year in excess fuel costs and lost productivity (USA)

3.3.5. Factors Influencing an Individual's Decision to Cycle

There is extensive literature on the factors that affect an individual's decision to cycle or not. Many of these studies focus on the physical environment such as road design and cycling infrastructure. Consistent with many studies, Hunt and Abraham (2007) found that increasing the physical separation between cyclists and motor vehicles is positively correlated with increases in cycling and Buehler and Pucher (2012) conclude that bike path and bike lane supply are responsible for 33% of the variability in commuting by bicycle. Numerous other studies have found physical separation and safety as a result of physical separation to be the most important constraint on an individual's decision to cycle Garrard et al. (2011) and Fishman et al. (2012). Other significant factors relate to convenience rather than safety, with trip distance a recurring factor (Pucher and Buehler, 2008).

4. Agglomeration and Productivity in Transport Project Appraisal

As summarised by the Bureau of Infrastructure Transport and Regional Economics (Bitre) Traditional transport project appraisal includes benefits

5. Results

The effectiveness of transport improvements depends upon spatial, modal and temporal characteristics of the particular type of transportation investment. Given this is the case; a relevant case study is Melbourne and its projected growth for the next 20 years.

5.1. Melbourne Case Study

An illustrative case of potential agglomeration economies is in Melbourne, Australia. Melbourne is forecast to grow extensively in the next few decades with its population expected to grow from approximately 4 million in 2014 to 7.7 million people by 2050 (Vic Gov plan Melbourne 2014).

5.1.1. Melbourne CBD Projected Job Growth

Between 1996 and 2011, employment in Metropolitan Melbourne increased by approximately 560,000 jobs. The City of Melbourne contributed almost 30 per cent (an increase of 160,000 jobs) of that growth. The projections modelled by SGS Economics and Planning (2014) suggest that in the next 20 years, Metropolitan Melbourne will add over 900,000 jobs, of which one quarter will be within the City of Melbourne, i.e. an increase of 222,000 jobs in the next two decades.

SGS Economics and Planning (2014) forecast the spatial distribution of employment growth within the City of Melbourne varies significantly by suburb with the Melbourne Inner along with Southbank and Docklands capturing the majority of commercial growth. While surrounding areas of Parkville, Carlton, West Melbourne and Melbourne Remainder will capture the majority of institutional (education and health) employment growth which will be focused around existing major facilities (Figure 4). Conversely retail and entertainment will be spread across all suburbs largely in line with existing levels (SGS Economics and Planning, 2014).

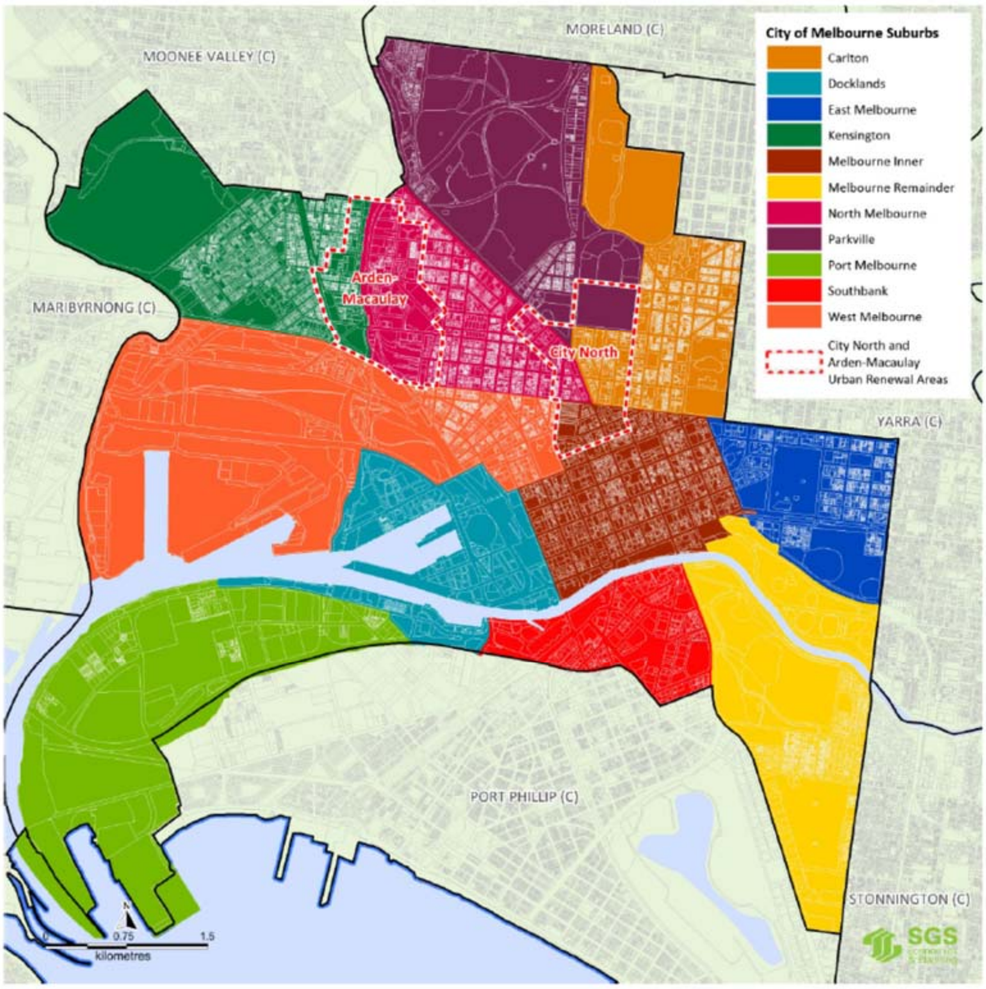

Figure 4: City of Melbourne suburbs (SGS Economics and Planning, 2014 p2)

The increase in employment by region is shown in Table 1.

Suburb	2002	2012	2021	2031	2012-2031
Carlton	15689	16963	21933	25731	8768
Docklands	6902	38198	44241	19888	11690
East Melbourne	19809	22378	28042	38029	15651
Kensington	3360	6981	8232	9587	2606
Melbourne Inner	175917	220109	275444	328313	108204
Melbourne Remainder	16863	25706	32498	42850	17144
North Melbourne	7311	9589	14876	30489	20900
Parkville	19080	25538	34360	41306	15768
Port Melbourne	11369	13984	13557	14442	458
Southbank	31751	42768	50281	58583	15815
West Melbourne	11679	16579	17951	21632	5053
City of Melbourne	**319730**	**438793**	**541415**	**660851**	**222058**

Table 1: City of Melbourne Employment by Suburb (SGS Economics and Planning, 2014 p18)

For the purposes of this case study, the area being examined will be restricted to Melbourne Inner with a projected increase from 220,109 to 328,313 jobs which is an increase of 108,204 jobs from 2012 to 2031. This would represent a 49% increase in employment and a 49% increase in job density. Using the Graham's economy wide elasticity of 0.119 (Graham, 2007) a 100% increase in density would result in an increase in productivity due to agglomeration economies of 11.9%. A 49% increase in density would lead to a 5.7% increase in productivity. Other studies have suggested an economy wide elasticity of 0.05 (Ciccone, 2002). The average of the two being 4.1% for a 49% increase in density. However, such increases in productivity due to agglomeration economies assume these jobs are accessible. Given the transport constraints currently faced in Metropolitan Melbourne (Kelly and Donegan, 2015) such a large increase in employment in a central area, an important question is whether people would be able get to these new jobs given the current state of transportation provision. If they are unable to access these jobs what are the ramifications for employment and productivity?

5.2. Transport in Melbourne

The current transport mode share to the CBD area of Melbourne is shown in Table 2. Due to the greater concentration of public transport options and extensive links Melbourne Inner has a much higher percentage of public transport usage than the rest of Melbourne:

Mode	Mode Share
Public transport	63.8%
Car + motorbike	25.5%
Bicycle	3.3%
Walk	5.8%
Worked from home	1.5%
Other	0.1%

Table 2: Melbourne Inner Transport Journey to Work Mode Share 2011 (DEDJTR, 2015)

The substantial forecast in employment requires a commensurate increase in transport provision. Several different scenarios present themselves in order to meet this challenge.

5.2.1. No Change in Mode Share

No change in mode share with increasing jobs would result in a corresponding increase in congestion. Rail appears to be near capacity at peak times already; however, the Melbourne Metro link has begun planning and presumably will be built even with a change in government, especially as the Federal Government has recently changed its policy with respect to funding commuter rail. Unchanged mode share for journeys to work in 2031 are shown in Table 3.

	%	2012 jobs	Journeys to work	2031 jobs	Journeys to work	Absolute Increase
Public Transport	63.8%	220109	140430	328313	209464	69034
Car + motorbike	25.5%		56128		83720	27592
Bicycle	3.3%		7264		10834	3571
Walk	5.8%		12766		19042	6276
worked from home	1.5%		3082		4925	1623
Other	0.1%		220		328	108

Table 3: Journeys to Work 2012 & 2031 by mode (ABS, 2011)

The Melbourne Metro Rail Project is forecast to carry an additional 20,000 passengers per hour during the peak period (MMR, 2015). To maintain its mode share, public transport would have to provide nearly 70,000 extra journeys to work percentage. This figure suggests a 3.5 hour peak period with the additional infrastructure planned.

For car and motorbikes journeys to work to maintain their mode share, over 27,500 extra trips would need to be catered for, in addition to parking spaces to accommodate these vehicles. For bicycles to maintain their mode share there would need to be an additional 3500 commuter trips.

Of the additional trips required to maintain the current mode share, it is feasible the rail investment planned with the Melbourne Metro project may provide sufficient capacity. For bicycle journeys to work an additional 3500 trips over a 20 year period for bicycle commuting would require an additional 175 extra daily trips per annum, which could conceivably be accommodated by current infrastructure. The same logic applies to pedestrian journeys to work where an additional 81 trips per year would be required.

However, the increase in motorised vehicle journeys to work presents a considerable challenge. With a 49% increase in car and motorbike journeys to work required for the forecast jobs and for this mode to maintain its share, the level of congestion would increase substantially as well as the travel time and resource usage associated with it. The Bureau of Transport Economics (now the Bureau of Transport and Regional Economics) forecast the social costs of congestion in Melbourne will rise to $6.1 billion by 2020 per year (2007 dollars) in additional travel time and resource usage. Due to this increase in congestion, it is conceivable the forecast jobs may not materialise, or perhaps may be located elsewhere, and the productivity gains associated with increasing density would also not eventuate which would have a deleterious effect on the economy and Melbourne's competitiveness as a whole.

Alternatively, investments could be made to accommodate the increase in jobs in the Melbourne Inner area. Listed below are different potential scenarios for Melbourne to accommodate this job growth. However, as discussed above, agglomeration economies are not simply about journeys to work, but rather easier interactions and mobility as part of a business's operations and interactions with customers and suppliers.

5.2.2. Potential scenarios

Three potential scenarios are examined below, one with a different emphasis; public transport, road transport and bicycle transport.

Mode	2012 trips	2031 trips	2031 mode share	Absolute increase	% increase
Public Transport	140430	229819	70.0%	89389	64%
Car + motorbike	56128	63364	19.3%	7236	13%
Bicycle	7264	10834	3.3%	3570	49%
Walk	12766	19042	5.8%	6276	49%
worked from home	3082	4925	1.5%	1843	60%
other	220	328	0.1%	108	49%

Table 4: Public Transport Scenario

Mode	2012 trips	2031 trips	2031 mode share	Absolute increase	% increase
Public Transport	140430	178602	54.4%	38172	27%
Car + motorbike	56128	114910	35.0%	58782	104%
Bicycle	7264	10834	3.3%	3570	49%
Walk	12766	19042	5.8%	6276	49%
worked from home	3082	4596	1.4%	1514	49%
Other	220	328	0.1%	108	49%

Table 5: Car Scenario

Mode	2012	2031	2013 mode share	Absolute increase	% increase
Public transport	140430	196988	60.0%	56558	40%
Car + motorbike	56128	58111	17.7%	1983	4%
Bicycle	7264	49247	15.0%	41983	578%
Walk	12766	19042	5.8%	6276	49%
Worked from home	3082	4596	1.4%	1514	49%
Other	220	328	0.1%	108	49%

Table 6: Bicycle Scenario

As can be seen in Table 4, Table 5 and Table 6, all scenarios include an increase in absolute numbers of trips if the job growth is to occur. However, the different emphases lead to very different outcomes. For public transport to have a 70% mode share of journeys to work, this requires an increase of nearly 90,000 (64%) journeys to work over the current level. Even with the Melbourne Metro project this seems problematic. A large increase in journeys by bus would appear to be the only way to accommodate this number by public transport. This could conceivably maintain public transport's mode share but in order to increase it in the public transport scenario then more radical ideas would need to be implemented such as massive investment in bus transport and prioritisation such as has occurred Curitiba, Brazil (Lindau et al., 2010). However, public transport provision does increase agglomeration economies through improved sharing, matching and learning.

For car based travel to accommodate a greater mode share of 35%, this would require an increase in nearly 59,000 trips, which represents an increase in that mode of 104%, i.e. more than doubling the current number of journeys to work by that mode. In addition, approximately the same number of car parks would need to be built to accommodate these journeys to work due to the low occupancy rate of private motor vehicles during peak hours (Austroads, 2011). This would require enormous levels of road and car park building. In addition, car based transport does not add to agglomeration economies in the same way as public transport or bicycle based transport due to the diseconomies of congestion.

For the bicycle scenario to eventuate, an increase of nearly 42,000 trips would need to be made by bicycle. This represents an almost six fold increase from the 2012 figure, however, this figure is generated off a low base and overall bicycle journeys to work would still be less than car journeys to work. In addition, the increase in public transport journeys to work may conceivably be accommodated by the Melbourne Metro project, while the car and motorbike journeys only increase by an absolute total of less than 2000, thereby adding tittle to infrastructure requirements and congestion.

5.2.3. Productivity Increases in each Scenario

The different percentages of journey to work for the different scenarios have implications for productivity as those who taking different transport options. Those who cycle and walk to work can be assumed to benefit from the productivity gains identified due to exercising as well as the productivity gains due to agglomeration economies and the increase in effective job density. These gains are independent of one another and hence are multiplicative.

Table 7 below shows how the range of productivity increases for the and includes the combined values for those engaging in active transport.

Active transport productivity increase		Agglomeration productivity due to 49% increase in job density		Combined productivity increase	
Low	High	Low	High	Low	High
4%	15%	2.5%	5.7$	6.6%	21.6%

Table 7: Agglomeration and Active Transport Productivity Increases

As Table 7 shows, the high range value leads to an increase in productivity due to combined job density and active transport of an extremely high figure of 21.6%. When these productivity gains are factored into the different scenarios, only the increased percentage of those engaging in active transport are considered to benefit from the productivity gains with the resulting productivity increases shown in Table 8.

Scenario	Productivity Increase	
	Low	High
No change in mode share	2.5%	5.7%
Car Scenario	2.5%	5.7%
Public Transport Scenario	2.5%	5.7%
Bicycle Scenario	3.22%	8.47%
Bicycle Scenario increase relative to other scenarios	0.72%	2.77%

Table 8: Productivity Increases in Different Scenarios

Table 8 shows that the bicycle scenario improves productivity across the study area by between 0.72% and 2.77% over the other scenarios. This extremely large difference occurs with only 15% of the journeys to work being undertaken by bicycle and a constant level of walking. Obviously a higher percentage of journeys to work by bicycle would result in an even greater productivity increase.

6. Discussion

The productivity and cost implications of the different investment emphases are considerable. Rail and road infrastructure are very expensive whereas bicycle infrastructure is relatively inexpensive. Capital costs and entry costs are low due to the lower level of engineering requirements and the cost of a bicycle vehicle being an order of magnitude less than a private vehicle. The agglomeration economies benefits of bicycle and public transport are also much greater than car based transport; however, bicycle transport has additional productivity benefits not available to public transport or private motor vehicle transport.

By accommodating job growth through increased transport provision through a focus on bicycle infrastructure, productivity improvements are significantly higher (0.72% to 2.77%) than if transport improvements were focussed on car or public transport. With a bicycle infrastructure focussed scenario these figures would range from 3.22% – 8.47% due to the increased general productivity, increased alertness, reduced sick days, better decision making and fewer task errors. In addition to this would be the savings from public health benefits.

6.1. Further Research

6.1.1. Cycling and Gender

Numerous studies suggest female participation in cycling is more dependent on their level of risk aversion and alternative household roles and responsibilities than men. Observed behaviour studies (Garrard et al., 2008) as well as stated preference studies (Emond et al. 2009) identified an increased adversity to risk from women compared to men, which included avoiding major roads, taking longer detours along quiet paths, or avoiding riding all together. Safety concerns and a lack of confidence were found to affect a far greater proportion of females than males (Garrard et al. 2006), with concerns about cycling in traffic and aggressive behaviour from motorists identified as the most significant deterrents to cycling for women (Heesch et al. 2012, Winters et al. 2011).

This is corroborated by a recent study examining cycling to work in Brisbane and gender disparity (2012). Results from this study indicate the perceptions of comfort and safety while cycling on roads is a function of both traffic volume and the degree of separation between cyclists and motorists, though traffic volume was found to be a more significant consideration for riders than the presence or absence of bicycle infrastructure on the road, (anecdotal evidence suggests the same is true in Melbourne with high levels of female cycling in Napier St Fitzroy which has no specific bicycle infrastructure as such but very low traffic volumes and speed). Examining routes such as Napier St with the recently developed Level of Service Tool (Bicycle Network, 2016) would provide the possibility to quantify how gender shares and quality of bicycle infrastructure are related. Lower cycling use by females due to poor quality infrastructure would have potential negative impacts for agglomeration effects as if the infrastructure is not of a sufficient quality, then this would effectively preclude half of the population from participating. This is an area than requires further examination and documentation.

7. Conclusion

Agglomeration economies are increasingly important in large cities and their future growth and development. If the productivity improvements and the gains from increased job density are to eventuate, then it is clear additional transport infrastructure is necessary in Melbourne. The question then becomes what type of transport infrastructure is best for Melbourne.

While agglomeration economies suggest the forecast increase in job density in Melbourne would lead to a 2.5%-5.7% increase in productivity, this is a less than certain outcome. Transport constraints could conceivable reduce this increase in job creation and even if it were to result, the increasing levels of private motor vehicle congestion would prevent any agglomeration productivity increases occurring. Public transport provision has been shown to increase agglomeration economies but bicycle infrastructure leads to increased agglomeration economies as well as productivity improvements in the range from 3.22% – 8.47% due to the increased general productivity, increased alertness, reduced sick days, better decision making and fewer task errors as well as generate savings from public health benefits. When these benefits are included in transport investment analysis as well as the health benefit implications, it becomes clear that bicycle infrastructure provision should be a high priority for cities and especially Melbourne in the coming decades.

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