Evaluating the Economic Benefits of Density and Land Use around Railway Stations through the Assessment of Travel Behaviour

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Abstract

With estimates predicting Perth's population will reach 3.5 million by the year 2050 major Government resources have been committed to accommodate this population into the existing transport network. A key part of this is optimizing the public transport system to increase the attractiveness of alternatives to car use by creating transit oriented communities which are compact, vibrant, lifestyle precincts with a dense concentration of residential, leisure and business land-use conveniently centred around a railway station. This report investigates two major components of transit oriented development (TOD) policy, population and employment density, examining the effect on travel behaviour as it pertains to embracing public and active transport whilst reducing car use. Using a four step model and Bayswater station as a test case the benefits of such TOD policy were reaffirmed. In addition, an economic appraisal was developed and used to objectively compare economic benefits of such change by analysing the marginal benefits(and costs) of factors such as decongestion, pollution reduction and health improvements to further comprehend the advantages of TOD policy.

1. Introduction

Whilst investigations of this relationship have been going on for some time, the major focus of this study is extending that correlation to devising a method to appraise the economic benefits of such policy. This will have use for government bodies such as the Department of Transport and the Department of Planning in providing a preliminary understanding of a precinct's viability for development, and whether or not to proceed to an expensive business case or cost benefit assessment.

For this project, Bayswater Station will be used as the focus of the study. According to the Bayswater Town Centre Structure Plan, planners envision the *eventual evolution of the Bayswater Town Centre into a mixed use centre based around the Bayswater Train Station and the established retail areas, with increased residential densities within a walkable catchment to enhance the viability and vitality of local businesses* (City of Bayswater 2017). This is an example of contemporary TOD motivated policy, making Bayswater an ideal case study.

1.1 Current State of the Art

Household surveys and elasticity analysis are the most common methods by which the relationship between density/land-use and travel behaviour has been investigated in the current literature. The results of such analyses fall in line with the current understanding of planning and development. That is, if localised around a station, population density is negatively related to vehicle use as is the diversity and quality of land-use. This refers to the range of facilities, amenities, jobs and services available in the precinct. These studies investigate the one-to-one relation between some variable (density, land-use) and vehicle usage. However for the purposes of appraisal we wish to understand how a policy variable (density, land-use) affects all transport modes at once. More specifically we wish to obtain the *mode share diversion rates* of a policy scenario. Diversion rates are quantitative estimates of the changes in mode shares between the Base case and the Project case. The relevance of diversion rates and how they will be used in this study will be detailed in the following sections.

2. Methodology

2.1 Diversion Rates and STEM

Diversion rates for this study were determined using the Department of Transport's Strategic Transport Evaluation Model (STEM), a four step transport model purpose built for Perth. A four step model divides a city into numerous zones from which trips originate and terminate based on the demographic and land-use characteristics of each zone. The more zones the more accurately the model can depict the spatial makeup of the city's population and employment. The four steps themselves are trip generation (1), trip distribution (2), route assignment (3) and mode choice (4). Running the model executes these four steps until convergence outputting the simulated daily traffic numbers. STEM outputs the number of trips departing and arriving each zone each classified by type (work, education, shopping etc.) as well as by transport mode. Comparing the transport mode shares before and after some policy change reveals mode share diversion rates which are critical for the appraisal.

The DoT STEM model divides Perth into 472 zones. Through land use data supplied to the Department, each zone has its own unique population and employment breakdown stored within Excel input files. Employment is broken into 15 categories whilst population variables are also in various categories including dwellings, total population, labour force and children. Adjustments in these inputs can be made to mirror densification or land-use policy in a zone or number of zones. In this case, the zones representing the Bayswater precinct were adjusted to simulate population and employment densification.

2.2 Application to Bayswater

Given the typical size of a railway precinct being defined as that which is enclosed by a radius of ~1.6km (~8km^2), a number of STEM zones of roughly equal area can be used in the model simulation. The area surrounding Bayswater station that can be described as its *precinct* is contained in the four zones 201, 202, 204 and 205 (Figure 1). From STEM, the total area is ~8.8 km^2 slightly larger than a typical precinct. More importantly, the centroid distances are all less than or equal to 1 kilometre. Zone centroids are where the model assumes all the population and employment contained within the zone to exist. They are located at the zone's geographic centre and as shown below, all Bayswater's zone centroids are less than 1km from the station which is ideal for the precinct model.

Zone	Area (km^2)	Centroid distance (km)	Total population	Total employment
201	2.17	0.84	4018	514
202	2.09	0.64	5882	906
204	2.68	0.89	3694	1292
205	1.90	0.99	4369	635

Table 1 STEM zone characteristics for the Bayswater precinct

Figure 1 STEM interrelation of Bayswater Station shown from Google Maps. Four zones (201, 202, 204, 205) covering an area of ~ 8.8km^2.

2.3 Policy Scenarios

To investigate the travel behaviour response of Bayswater to density and employment changes, seven principal scenarios will be tested. The seven scenarios include combinations of 20% and 50% increases in total population and total employment as well as the 2021 base scenario population and employment. These values (20%, 50%) were chosen in conjunction with DoT stakeholders, as they represent reasonable future targets achievable within the next 10 years and as part of the *Perth @ 3.5 Million* plan which details strategic land use and planning measures which aim to accommodate a population of 3.5 million in Perth by 2050. Each simulation can take up to five hours to reach convergence; this was also a consideration when deciding how many cases to test. Below are the seven principal scenarios that were run on STEM.

Scenario	Description	Label
0	No change in population or employment (2021)	2021 Base
1	20% increase in total population and total employment	PE20
2	**20% increase in total population only**	**P20**
3	**20% increase in total employment only**	**E20**
4	50% increase in total population and total employment	PE50
5	50% increase in total population only	P50
6	50% increase in total employment only	E50

Table 2 Policy scenarios tested using STEM.

2.4 Adjusted Centroid Scenarios

TODs are best served when commuters and employment exist within walking distance of transit facilities. As presently constructed, STEM uses the default centroid lengths for each of the zones in question. Default lengths being the geometric centre of the zone. However, these distances can be altered on STEM to simulate the movement of people and employment closer to the railway facility. To investigate how such proximities affect travel behaviour, two variations of the initial principal scenarios will be tested. The first will be to halve the existing centroid lengths and the second will be to reduce them all to 100m. The second one is rather extreme and less practical in reality but will be used as an exaggerated test case.

2.5 Appraisal

Understanding the relationship between population/employment and travel behaviour is the first objective of this study. Cost and benefit appraisal takes this a step further and *quantifies* the benefits in economic terms. This involves assigning *resource costs* to measures of marginal utility and disutility, for example, externality costs can be attached to pollution and congestion. Individual costs for parking, vehicle maintenance and accident costs can also be allocated on a per trip or per kilometre basis. Similarly, individual *benefits* can be attached to active transport trips such as walking and cycling, an example being health benefits. Once these resource costs have been identified the appraisal process is quite intuitive. Benefits accumulate through net benefits received from the new transport mode being adopted. Benefits also accrue if costs are avoided by changing from one mode to another. For example savings in petrol, parking and vehicle maintenance when switching from car use to public transport are considered benefits. The key to this process is knowing how people are switching between transport modes which is why diversion rates are of such interest. As a client deliverable, an *appraisal tool* was constructed on Excel to streamline this calculation to be used on a range of policy scenarios. The standardised inputs for resource costs were sourced from secondary analysis of data tailored to Australia and New Zealand.

Typically an appraisal will analyse both benefits and costs, however there is significant uncertainty in estimating the costs of TOD policy. The administrative and planning costs of densification are difficult to quantify and vary significantly depending upon policy settings, Government priorities, the physical environment, the local population, stakeholder groups and project parameters. To avoid diluting the results that can be developed this project limits its analysis to the benefit side of the appraisal. This will serve as a useful rapid appraisal for government when deciding whether to proceed to an expensive in-depth business case and/or cost benefit assessment.

3. Results and Discussion

The STEM analysis delivered some pertinent findings with possible implications for planning policy. The most logical way to cover the results is to separately discuss the effect of population and employment. The best data sets to do this are P20 and E20 which were 20% increases in population and employment respectively. The effect of population change is concerned with trips departing Bayswater or *origin* trips, whilst the employment scenarios primarily affect trips arriving in Bayswater or *destination* trips. The results will also include the average yearly benefit (discounted at 5% over 10 years).

3.1 Population

P20		Car (driver)	Car (passenger)	Public transport	Active transport	Discounted yearly benefit
Increase in vehicles	Standard	-0.151 %	-0.032 %	0.000%	0.194 %	$105,182
	½ distance	-0.975 %	-0.193 %	0.460 %	0.708 %	$1,006,303
	100m	-1.944 %	-0.454 %	0.941 %	1. 457%	$2,113,112
No increase in vehicles	Standard	-0.398 %	0.867 %	0.161 %	0.000 %	$59,550
	½ distance	-1.391 %	0.647 %	0.748 %	0.000 %	$1,091,443
	100m	-2.198 %	0.404 %	1.128 %	0.667 %	$1,819,484

Table 3 Results from two approaches to the P20 scenario

The table above documents the results of two approaches to the P20 (20% increase in population) scenario. The first section pertains to an increase in population *and* an increase in vehicles. The second represents an increase in population and no increase in vehicles. These two poles represent two situations; one where the new residents move in with little intention of switching to public transport and the other where they move in primarily to take advantage of public transport access. Both are two extremes of what occurs in reality therefore it should be acknowledged that the true travel and appraisal effect lies somewhere in-between the quoted results. Predictably, the first scenario (vehicle increase) is less productive in decreasing car use and increasing public transport however this improves as the population moves closer to the station. The second scenario (no vehicle increase) shows a very sharp decline in car use and increase in public transport even at the furthest distances from the station. As a result of no vehicle increase, carpooling (car passenger use) rises partially offsetting the gains in reduced individual car use. This scenario also indicated minor negative diversion rates for active transport for the standard and ½ centroid distance simulation. This is likely a model convergence issue and as such the rate is normalised to zero. For the 100m distance scenario the impact on active transport is large enough to be non-zero verifying the assertion that as densification occurs closer to the station active transport diversion is positive. Economic benefit fluctuates between the scenarios with active transport and public transport growth being the determining factors. From an appraisal perspective the two variations of densification are almost equally beneficial. The conclusion from this is that economic benefit can be driven by favourable mode shifts to either public or active transport. From a policy perspective, vehicle inclusive densification (first scenario) appears preferable as it gives a better average increase in both public and active transport, whilst still reducing car use. To summarise, moving closer to the station increases public and active transport accessibility thus making it more attractive. If vehicle accessibility is constrained this shift to public transport is exacerbated however slightly countered by some carpooling.

3.2 Employment

E20	Car (driver)	Car (passenger)	Public transport	Active transport	Discounted yearly benefit
Standard	0.596 %	-0.404 %	0.050 %	-0.242 %	- $67, 443
½ distance	0.003 %	-0.683 %	0.329 %	0.351 %	$295, 139
100m	-0.616 %	-0.976 %	0.507 %	1.085 %	$723, 638

Table 4 Results from E20 scenario

The analysis for employment is focussed on the mode share diversion rates for trips arriving in Bayswater. From the results, increasing employment has a strong impact on trip attraction, with model outputs indicating a 20% increase in employment creates a 20% increase in incoming trips. However as the table above shows these new incoming trips are likely to be via car given the distance between employment and the station. Carpooling does decrease for the first scenario but net change in car use is still positive. This is reflected in the appraisal as the yearly benefit is actually a loss as car use increases and active transport declines heavily. Looking at the two scenarios where the employment is brought closer to the station a noticeably favourable increase in public transport is observed. This reflects the accessibility improvement on the destination side. However individual car use only decreases by the extreme 100m case. This shows that despite the increased accessibility on the destination side, accessibility to a station from wherever these trips originate still dictates the shift in travel behaviour. Active transport also becomes more viable as employment draws closer to the station which is also reflected in the appraisal benefits which become larger as a result.

4. Conclusion and Future Work

The overall implication from the results described above is that population growth nearby a station assists with diverting mode share towards public transport. The effect of this greatly depends on how much the inflow of residents embrace the transit oriented development lifestyle. Employment attracts more trips to the region, whether they arrive via private or public transport is a function of railway accessibility on both ends of the trip. Although local accessibility can be improved the impact on mode share diversion is constrained by the accessibility of the trip origin. From the appraisals of both scenarios, the most total benefits coincide with reduced car use and increases active transport. Future work includes processing the results and appraising the results of the remaining scenarios and potentially running the same analysis on another station.

5. References

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