The evaluation and rating of travel energy efficiency and emissions of Offices for development assessment purposes: Adelaide City Centre and Technology Park compared

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Abstract: This paper discusses the value of a star based rating system for assessing the transport impact of urban development projects and how such a scheme could be introduced. A scheme of this nature would be based on empirically derived performance standards related to the energy efficiency and CO_2 emissions generated by travel activity for a particular development in particular type of location. A survey of two case studies within metropolitan Adelaide, the Adelaide City Centre and a suburban office park, Technology Park at Mawson Lakes was conducted in November 2006 to provide the necessary data base underpinning the derivation of the star ratings for three types of urban settings that are typical of Australian and western cities: (1) C.B.D. or major metropolitan regional locations; (2) suburban transit interchange nodes; and (3) suburban settings.

The use of a travel energy development rating tool for commercial office developments to postulate new development standards allows planners to theoretically justify planning decisions that reject developments with poor accessibility from an energy efficiency perspective whilst encouraging developments that have high accessibility to non-energy intensive travel modes such as walking and cycling.

Introduction

Australia as a developed and wealthy nation with an educated populace, whilst small in population, it has the natural resources and human capital to be in the vanguard of the global community of nations in establishing environmentally sustainable practices. To date, however, because of access to cheap energy, an abundance of land and a resource driven national economy, environmental efficiency has not been the key underlying principle in developing Australian cities, the Australian economy or in influencing Australians' travel choices. The sprawling low density nature of Australian cities with their concomitant reliance on fossil fuelled powered motor vehicles for mobility (Newman and Kenworthy, 1989), underlines the extent of the challenge faced in reorienting them towards a more environmentally sustainable activity and development regime.

According to the South Australian Greenhouse Gas Inventory prepared in 2004, South Australia has made significant progress since 1990 in documenting reducing its carbon dioxide emissions (an 8% decrease during the period 1990-2004), but transport has consistently accounted for approximately 18-20% of total carbon dioxide emissions (Australian Greenhouse Office, 2007). Auditing of greenhouse gas emissions at the national and state value has been generally well documented, although detailed data at smaller spatial units is largely unavailable and requires specialised research methodologies to obtain.

A preliminary step in achieving an environmentally sustainable activity and development regime in Australian cities is to have detailed auditing of how people use energy and produce emissions which contribute to the greenhouse effect. Auditing provides planners with empirical evidence regarding the selection of activity and development paradigms in our cities that are most likely to achieve the goal of environmentally sustainable development. This empirical evidence can then be used create a star rating scheme that assesses travel energy efficiency for proposed urban development projects. Once enshrined in legislation as a critical component of the development assessment process, a star rating scheme could then be used to compel developers to choose locations that have optimal transport efficiency characteristics or compel developers to upgrade the transport characteristics of a proposed development where these fall short of the required standard. There is already a long standing precedent for this approach reflected in the current star energy rating standards that have been introduced for a wide range of consumer appliances (including motor vehicles) (AGO, 2007) and residential building standards (governed by software programs such as Accurate, BERS Pro and FirstRate 5) (Planning SA, 2007)

In recognising the shortcomings in existing travel data, the project discussed in this paper attempted to accurately quantify the energy and carbon emissions characteristics of all trips to and from a workplace location, for two locations, Adelaide's city centre (offices located on the west end of Adelaide's North Terrace) and a suburban office park (Technology Park, Mawson Lakes, 13km north of Adelaide's city

centre). An Excel based spreadsheet model in connection with the survey instrument allowed the energy consumed for work related trips to be estimated. The data and survey methodology developed out of this project provides a preliminary basis for the creation of an energy and emissions rating schema that could be applied in the development assessment process for future developments.

Previous Work

In the Australian context, the most significant attempt to comprehensively assess the travel related energy consumption of urban areas was Newman and Kenworthy's (1991) landmark publication entitled "Cities and Automobile Dependency: An International Sourcebook". This publication was a study in the relationship between metropolitan urban form, transport and energy use in 32 world cities and it produced a 5 category typology of cities based on their transport energy consumption, correlating this to urban aesthetics, urban densities and modal choices. This study relied heavily on secondary quantitative indicators (i.e. government statistics), together with the authors' own ratings of various cities to determine a typology of cities. The approach had significant analytical power at the metropolitan scale, however, it had limited application at the micro urban scale of the suburb, neighbourhood or particular urban developments.

Other rating approaches have tended to be aggregate model modal based schema, such as the "Friends of Oregon" LUTRAQ project (1000 Friends of Oregon Project, 1997) that concentrated on factors that facilitated pedestrian activity across the Portland metropolitan area in the United States. The LUTRAQ project provided useful ratings down to the level of neighbourhood precincts with GIS derived mapping, but not of individual developments, although the nature of their analysis is that it provided a reasonable indication of pedestrian oriented locations in the Portland area. The Portland (US) developed INDEX software (Allen, 2001) for generating and analysing Community Indicators has been applied widely in cities across the US, typically to determine areas of US cities that are conducive to pedestrian and cycling modes or increased public transit activity. The authors of the decision making tool can have the discretion in applying a rating schema or the raw data can be derived from community surveys.

Much of the fieldwork, largely US based, has used subjective surveys of residential neighbourhood environments to produce either an aggregated score or a set of measures which are used to rate the performance of a neighbourhood that is conducive to pedestrian activity (Kockleman and Cevero, 1997; Kitamura et al. 1997; Replogle, 1988; Pikora et al. 2002).

There has been other work by Cevero and Gorham (1995) in the US which conducted matched pair analysis of transit and auto-oriented neighbourhoods using the similarity of income of residents, however, such simple binary classification schemes can mask important differences and are of limited value in quantifying the nature of travel oriented energy consumption even at the neighbourhood level.

Recent empirically based work by Soltani in Soltani and Allan (2006) used survey research of residents in four Adelaide suburbs who were asked to apply ratings to various characteristics of their local area which was subsequently analysed to explore the relationship between urban form and travel behaviour. Although this research did produce GIS based mapping of the four case study suburbs for Pedestrian and Cycling Environment factors, the aggregated nature of the outputs meant that the performance of specific development sites could not be ascertained.

The Australian development industry through the auspices of the 'The Green Building Council of Australia' (GBCA, 2006) has made some effort to develop an all encompassing energy rating scheme for new development projects. Their rating scheme includes management practices, indoor air quality, energy, transport, water, materials, land use and ecology, emissions and innovation. On close scrutiny, these ratings are vaguely defined, potentially compromised by some double counting and they require subjective judgement on the part of the analyst in their derivation. Transport only accounts for a maximum of 8.2% of the maximum energy rating score available, which compares to 17.9% for building energy usage. This is somewhat inconsistent with other government transport statistics that suggests that transport accounts for around 18% of urban energy usage (AGO, 2007; ABARE, 2007).

The GBCA rating scheme is a useful step in the right direction, nevertheless, its arrangement lacks a methodology that has a quantitative, rather than a qualitative basis for evaluating the travel energy efficiency of a development. Travel energy efficiency for a development refers to the total amount of

energy expended by the occupants and visitors travelling to and from the subject development by whatever mode of transport. While the tool is currently being applied widely in Australia, what is communicated to the public in its assessments is simply the star rating for the building, without quantification of what the star rating actually means in terms of kilojoules of energy per square metre of building or per building occupant. The major failing of this approach, is that it is neither theoretically robust in nor does it have a sufficiently sound foundation of empirically based evidence employing the scientific method to support its ratings.

The Research Concept and Methodology
There are two possible approaches for a creating a travel energy and emissions development rating tool. One option is a location based approach where empirical evidence (such as that which was developed in this research) is obtained for five basic categories of office development locations (i.e. city centre; suburban transit node; inner suburban; middle suburban; and outer suburban). The ratings for these five location types could then be modified according to their actual development orientation to various transport modes. Another option, is a commuter behavior and land use pattern approach which would model likely commuter travel behaviour profiles and take into account the travel modal split based on the nature of residential densities surrounding it, parking provision and the nature of pedestrian, bicycle, road, bus transit and rail transit networks serving the development. However, developing empirically based models on the latter approach is complex and statistically unreliable, particularly with regard to modeling potential commuter travel behaviour profiles unless very large data sets are used. Hence, for the purposes of this project, the location based approach was adopted.

There were two elements to the research concept adopted in this research. Firstly, the empirical evidence produced from the surveys of commuter travel behaviour would yield a representative profile of the average energy consumed and carbon emissions produced for each of the surveyed locations. Because the locations were homogenous in character, with regard to the nature of urban development and accessibility, it was assumed that the data would be representative of development for offices in those types of locations (i.e. either a suburban node or city centre office location). Secondly, these findings, while admittedly limited in scope, could then provide a basis for calibrating a star based rating system for assessing future office development locations. Rating schemes are simple in conceptualisation, in that they are basic tiered classification schemes which aim to describe performance values from poor to excellent using a number of distinct points or 'stars'. These tiered classification schemes can be subjective in character (akin to using a Likert rating scale) (Vogt, 1993), or employ quantitative values with each 'star' representing a category that describes a range of quantitative values that is usually of a similar scaling to most of the other categories in the rating scheme, with the possible exception of the star ratings at either end which can be open ended. The advantage of star rating schemes is that for the lay person, a judgment on the relative merits of the item being measured is already provided, thereby obviating the need to interpret unfamiliar facts or figures or establish useful reference points for meaningful comparisons about what constitutes good or bad. The disadvantages of star rating schemes are that they can be based on flawed logic or analyses and over time, they may fail to prompt improvements if the top rating becomes too easily achievable.

An online travel behaviour survey with approximately 600 responses was completed in Adelaide in November 2006 at two locations: a city centre office location (with approximately 90% of responses); and a suburban office park (Technology Park at Mawson Lakes with 10% of responses), 13 km to the north of Adelaide's city centre. The response rate for the survey was approximately 15% overall. The purpose of the survey was to collect the necessary data to demonstrate the application of the travel energy and carbon emissions development rating tool. The estimation of commuter travel energy and carbon emissions component of the project was partnered between the University of South Australia and Adelaide City Council.

The survey instrument consisted of an online questionnaire survey that was designed to capture information about the exact means by which people travelled to and from their work place for commuting, work related and personal trips. The timing of trips, trip distance, the trip modal characteristics and the nature of the trip were also gleaned from the respondents. The majority of respondents at Technology Park worked in private sector firms (59%), whereas for the three city centre office buildings, the majority of respondents (70%) were employed in public sector organisations. Because the bulk of commuter trips in Adelaide are by motor vehicle, the survey was perhaps different from many previous surveys in attempting

to obtain detailed trip modal information specific to the use of personal motorised transport such as the vehicle make, vehicle size and type, engine capacity, engine energy source (i.e. fuel type or hybrid) and vehicle occupancy ratio. The survey also asked respondents to indicate subjectively the level of traffic congestion experienced for the main legs of their trips.

The most complicated aspect of the survey structure was that it also captured information on up to four trip legs on the commuting trips and multiple work related and personal trips made between the trips. This required a logic loop in the software which may have deterred some respondents with complicated travel patterns from completing the survey.

From the survey data procured, the data regarding travel behaviour allowed the average travel energy consumed and carbon emissions produced per commuter to be estimated for each of the two survey locations. SPSS and Microsoft Excel software was utilised to analyse and process the survey data. When the survey data is aggregated, the rating tool allows an indication of total energy to be determined for a particular development. The advantage of this tool is that the data can also be used to produce a rating measure from the individual commuter up to and including large aggregated spatial units such as a suburb, metropolitan area or region.

The structure of the analysis in deriving the amount of fuel consumed and the greenhouse gas emissions per respondent was determined by applying a set of simple algorithmic operations using Microsoft's Excel spreadsheet program based on the respondent's estimate of their vehicle kilometres covered and the probable fuel consumption characteristics according to the vehicle type driven. For buses and taxis, standardised fuel consumption values were adopted using national commercial fleet data from the Australian Greenhouse Office (2006). Published per capita estimates of energy consumption and greenhouse gas emissions for trains and trams were adopted.

All online survey respondents were asked to identify where their workplace and homes were located, thereby allowing an estimate of a particular development's travel energy consumption and greenhouse gas emissions to be generated.

Figure 1: Technology Park Office Park, Mawson Lakes (left) and offices on North Terrace, Adelaide CBD
Source: A.Allan, 2006

The Key Research Findings
Adelaide's metropolitan area stretches in a coastal plain approximately 80km from north to south and spans a distance of between 8 and 20km between the Gulf of St Vincent to the west and the 700m high escarpment of the Mount Lofty Ranges to the east. The city has a highly centralised commercial core with about 25% of metropolitan Adelaide's total employment and although the South Australian State Government through its metropolitan Planning Strategy does have a strong centres' policy for Adelaide's suburbs, to date these have largely been dominated by retail activity. Nevertheless, these centres (e.g. Port Adelaide, Mawson Lakes, Tea Tree Plaza, Elizabeth, Marion and Noarlunga) incorporate significant transport interchanges and connect the major trunk public transit routes serving Adelaide's metropolitan area. The average commuting distance could be hypothetically inferred from gravity modelling which for a city such as Adelaide with its clear hierarchy of centres, generally flat terrain and uniformity of residential development densities (predominantly separate family dwellings), would produce a representative

estimate. From the survey results, the average commuting distance for Mawson Lakes was found to be 12.0km (52 respondents) compared with 11.6km for Adelaide city centre (453 respondents). These findings are consistent with previous Australian Bureau of Statistics population and housing Census surveys where average commuting distances across the whole of metropolitan Adelaide are around 12-14km (ABS, 2001; ABS, 1996). Considering that the two survey locations were 13km apart, the closeness of this value is remarkable. Although this research was only based on two case studies, it suggests the possibility that within a defined metropolitan area (at least for a city of around 1 million people with relatively uniform, residential densities of around 20 persons/Ha), commuters may travel a similar distance to their workplace regardless of whether their workplace is in a centralised location or out in the suburbs. This finding suggests that in a metropolitan area such as Adelaide, the adoption of average commuting distances can be a suitable proxy for approximating per capita travel energy consumption and emissions. Since the location type of a workplace in a metropolitan setting such as Adelaide with largely homogenous urban densities may not be significant in varying commuter trip length, it suggests that trip mode becomes a critical variable in influencing transport related energy consumption and carbon emissions.

Commuters at Technology Park did demonstrate some diversity in travel choices, with respondents walking (2%), cycling (6%), driving a private car (79%), driving a company car (6%), as a car passenger (2%), using the bus (2%) or a motorbike (4%). Interestingly, most respondents (85%) travelled directly from their home to the workplace, indicating that commuters' trips were not particularly complex, which may reflect the heavy reliance on private cars. The overwhelming orientation to car usage is somewhat surprising given that Technology Park is accessible to the recently completed Mawson Lakes transport interchange facility (which became operational in early 2006) via a regular feeder bus service.

As might be expected, commuters travelling to offices in the Adelaide C.B.D. made much greater use of public transit (34.7%), cycling (9.4%) and walking (6.5%), although many still travelled by car (46%) or by motorcycle (3.5%). The high usage of public transit usage in this part of Adelaide city centre is impressive, (although unremarkable by world standards), because on a per capita basis, Adelaide's city centre has a very high rate of provision of private parking for cars (in excess of 40,000 spaces for CBD casual and long stay commuting parking serving shoppers and a workforce population of around 96,000 employees) (Adelaide City Council, 2004). Moreover, long stay commuter parking is available within 500m of the survey sites for as little as $7.50 per day. Overall, the average daily travel energy consumed by respondents for all types of trips (i.e. commuting, work trips and personal work trips), was found to be 151.6 MJ/commuter at Technology Park and 82.7 MJ/commuter in the Adelaide city centre. The average daily CO_2 emissions were 9.8kg/commuter for employees at Technology Park compared with 5.4kg/commuter for employees working in Adelaide's city centre. Hence, office employees working at a city centre office location as opposed to a suburban office location would consume 49% less energy and 45% less CO_2 emissions in relation to their travel activities connected to their workplace. Given that the average commuting trip distances between the CBD and suburban locations were virtually identical, the key reasons to emerge from the survey results as to why the CBD office location performed better than its suburban counterpart at Mawson Lakes is that firstly, the modal choice for CBD workers was more oriented to public transport usage and secondly, although CBD employees made more personal errand and work related trips to and from the workplace during the course of their workday, most of these were as pedestrians whereas for Technology Park employees, these types of trips were exclusively car based.

Journey from Home to Work energy and CO_2 emissions
For the complete commuting trip (see table 1 for daily results), commuters working in Adelaide City Centre produced 25.6 % less CO_2 emissions (2.52kg/commuting trip versus 3.4kg/commuting trip) and consumed 25.9% less travel energy (38.3 MJ/commuting trip versus 51.5 MJ/commuting trip) than did their suburban counterparts commuting to work at Technology Park. Given that the bulk of urban travel tasks in metropolitan Adelaide, whether it is by car or public transit buses, burn fossil fuels in their operation, the potential reduction by up to 25% of fossil fuel usage and CO_2 emissions for commuting trips, presents a powerful argument for locating employment in a centralised location rather than in a decentralised suburban location, particularly since it appears that in a metropolitan context such as Adelaide, average commuting distances to employment are similar, in both a CBD and a suburban location. For both city centre and suburban office locations, the majority of travel energy consumption (94.8% for the city and 70.3% for Technology Park) and emissions (94.4% for the city and 85.7% for Technology Park) are

generated by commuting trips to and from the place of employment rather than by personal or work related trips originating and terminating at the workplace.

Table 1: Daily Journey to Work Energy Consumption and CO_2 Emissions Compared For Technology Park and Adelaide City Centre

TRIP TYPE	TECHNOLOGY PARK		ADELAIDE CITY CENTRE	
	Average energy MegaJoules/trip/ commuter/day	Average kg of CO_2 emissions/trip/commuter/day	Average energy MegaJoules/trip/ commuter/day	Average kg of CO_2 emissions/trip/commuter/day
Journey from home to work commuting	51.5	3.4	38.3	2.5
Journey from work to home commuting	55.1	5.0	40.1	2.6
Work related trips	25.9	1.34	3.9	0.3
Personal Trips from the workplace	19.2	0.1	0.4	0.03
All daily trips	151.6	9.8	82.7	5.4

NOTE: For Technology Park, n=52 ; for Adelaide City, n=458 *Statistics taken as an average in each case for all respondents.*

These findings suggest that policymakers can achieve the greatest impact in maximising travel energy and emissions reductions by concentrating policy on improving the nature of commuting trips between the home and workplace. However, this research has excluded ex-urban, rural or interstate trips in making these estimates hence the actual energy and emissions values for all employees may actually be higher in practice.

Towards a New Development Assessment Rating Tool Paradigm
There are several challenges in developing a rating tool. This research examined employee travel behaviour patterns for existing office developments in a central urban and suburban location, whereas a rating tool for proposed office development would need to make various assumptions about modelling future travel behaviour for a particular development or extrapolate existing data to provide an estimate of likely energy consumption and greenhouse gas emissions for a proposed development. The findings from this research suggest that for the two case studies in metropolitan Adelaide, the average commuting distance of commuters was approximately 12km. Moreover, survey findings such as these, together with data about travel modal split, tend to be remarkably consistent across urban locations with similar characteristics in a relatively homogenous metropolitan areas such as Adelaide.

The most logical way to proceed in developing a rating tool that could be used in the development assessment process is to use empirically derived standards about likely performance levels for suburban versus city centre/centralised locations that would be updated every 3 years. For a particular development project, a two step process would be applied in estimating the travel energy and emissions for the development's employees. The first step would be to select a standard, using an empirically derived energy and emissions profile for the project's proposed location according to whether it is a CBD, suburban transit interchange, inner suburban, middle suburban or outer suburban location. The definition of whether a suburban location is inner, middle or outer would correlate with the extent of the metropolitan area that a development is located within. Because commuter parking provision for a development encourages employees to travel to work in their car, it can be assumed that any long stay commuter parking within walking distance of a development or as part of that development will result in that parking capacity being utilised by the future employees of the proposed development. Hence, the predetermined standards (according to the five main location types), would assume a certain level of existing parking provision, and hence, default star ratings (i.e. 4 stars for a city centre/major regional location; 3 stars for an inner suburban location, 2 stars for a suburban transit interchange, 1 star for a middle suburban location and 0 stars for an outer suburban location). However, if the developer can demonstrate that their proposed development actually reduces the long stay commuter parking demands that would normally be expected to arise from their development proposal by reducing the usual rate of onsite parking provision

for that particular location type and by not contributing to local parking capacity within a 1km radius of the development, then the proposed development's energy profile can be estimated on the basis of the revised level of parking provision.

For example, if a proposed development catering to 100 employees is located by a suburban transit interchange, and the standard parking provision according to parking regulations is 100 parking spaces, the 2 star rating would apply for travel energy (151.6 MJ/commuter/day) and CO_2 emissions (9.8 kg.CO_2/commuter/day) as detailed in tables 2 and 3. Hence the default travel energy and emission values that would be expected from this development would be 15.2 GJ/day and 980 kg.CO_2/day respectively. If however, the developer can demonstrate that the long stay commuter parking provision for the proposed development can be reduced by 25 parking spaces and replaced by cycling commuters (i.e. with on-site bicycle storage facilities for 25 cyclists), then the travel energy and emissions profile could be modelled on the development having only 75 employees commuting by car, resulting in an average travel energy consumption of 113.7 MJ/commuter/day and CO_2 emissions of 7.3 kg.CO_2/commuter/day both of which would equate to a 3 star travel energy and CO_2 emissions rating respectively. Energy and emissions concessions would also be applied for employees who commute by public transit provided that onsite or offsite commuter parking is not available for these commuters. The level of the concession requires more detailed empirical evidence for this particular example, however, the limited data available for the Technology Park case study indicated that the energy and emissions concession for public transit users could be discounted as much as 145 MJ/commuter/day and 9.4 kg.CO_2/commuter/day. The advantage of this approach in rating a proposed development for its travel energy and emissions profile is that if the developer wants to achieve a higher star rating than the default settings for the location concerned, then the onus falls back on the developer to reduce the level of parking provision below what existing planning rules permit without compromising their commercial viability.

The main policy challenge in developing a rating tool is in determining a range of values that the tool attempts to identify as bad or good practice. In order to be easily understood, the tool should have a simple categorisation which usually takes the form of a five point 'star' rating scale. It is assumed that each of the categorisations is based on interval data of equal increments. However, star ratings can be problematical when the underlying analysis is based on almost purely subjective judgements and when the range between good and bad is very narrowly defined. For example, 'green' vehicle efficiency rating guides for UK vehicles are inadequate in analysing vehicles in the North American and Australian automotive contexts because the bulk of the private motor vehicle fleet in the UK has engine sizes of 1-2 litres compared with 2-6 litres in the North American and Australian private motor vehicle fleets.

For policy makers pondering what an energy and emissions rating tool needs to do, they are faced with a two pronged dilemma of whether it should simply highlight what can be achieved to minimise energy consumption and emissions given existing transport, building and communications technology, land use development practices and planning regulations, or alternatively, should it aim to push the regulatory envelope significantly beyond current capabilities? Levine and Inam's (2004) research in the US determined that developers believed that local government regulations were the biggest hurdle to achieving more environmentally sustainable and innovative urban development.

The current safety ratings for motor vehicles such as the Australian New Car Assessment Program (ANCAP, 2007) highlights the weaknesses in using regulatory envelopes defined by existing performance levels because several models of motor vehicles are being given the maximum star rating and yet traffic accident statistics would confirm that even the safest motor vehicles have a less than perfect safety record. Moreover, the defined safety limits are relatively restricted compared to the actual operational speeds of vehicles, risk and hazard profiles on public roads. At the very least, a rating tool needs to identify with its worst rating (i.e. 1 or no stars), its worst performer, but award no more than 4 out of a possible 5 stars to the best possible performer given current technology, practices and regulations. In the application of many star rating schemes, for example with ratings for 'green' buildings by the GBCA, many new building projects now have the capability to comply with 5 star ratings which means that in the absence of introducing a higher star rating, progress to further energy efficiency and emissions reductions may become curtailed particularly if a rating scheme is unable to recognise a significant improvement beyond the top star rating. One approach around this dilemma (apart from the ad hoc adding of stars which becomes confusing beyond 5 stars), would be to index the 5 point star rating at regular time intervals (i.e. every 3 years), together with an indication of what the calibration values are for that given point in time. Indeed, the energy rating authority that is responsible for rating appliances in Australia, the

Australian Greenhouse Office does in fact change the formula from time to time and has also moved from a 5 star to a 6 star rating scheme, together with providing an annual power consumption quantity in kilowatt hours when applied to electrical appliances.

If the findings of this research were to contribute towards a benchmarking exercise (once bolstered with further case studies), the Adelaide City Centre case study could be used to represent performance at the higher end of the scale, whilst the Technology Park case study represents the lower end of the scale. The work of Newman and Kenworthy (1991, 1995), however, highlights that Australian cities are not exemplars of environmentally sustainable travel behaviour when compared with other world cities. To reliably establish a 5 point scale, several calibration points are required, thereby necessitating further case studies. Because within the context of Australian city scapes and the fact that the case studies were selected from perhaps the area with the highest level of public transport services in the Adelaide metropolitan area, the city of Adelaide case study was nominated in the midrange of the 4 star rating band. Technology Park was positioned within the midrange of the 2 star rating band because although it is in a suburban location, it is connected with a feeder bus to the Mawson Lakes bus-rail interchange and it is accessible by pedestrians and on-road dedicated cycle lanes in an area with residential dwelling densities approximately double the metropolitan Adelaide norm. Tables 2 and 3 detail the derivation of these proposed star ratings using the key findings from the case studies and the preceding discussion.

Table 2: Derivation of a Commuter Travel Energy Star Rating

Star rating	Calibration Points	Range of energy values in MJ/commuter/day	Midpoint value of star rating in MJ/commuter/day
0		>203.5	
1 star		169.1-203.5	186.3
2 stars	Technology Park 151.6 MJ/commuter/day	134.6-169	151.6
3 stars		100.1-134.5	117.3
4 stars	Adelaide City 82.7 MJ/commuter/day	65.5-100	82.7
5 stars		65.5<	32.75

Note: 0 stars=poor performance; 5 stars=highest performance

Table 3: Derivation of a CO_2 emissions Commuter Star Rating

Star rating	Calibration Points	Range of CO_2 emission values in kg.CO_2/commuter/day	Midpoint value of star rating in kg.CO_2/commuter/day
0		>13.1	
1 star		11.0-13.1	12.0
2 stars	Technology Park 9.8 kg of CO_2/commuter/day	8.8-10.9	9.8
3 stars		6.6-8.7	7.6
4 stars	Adelaide City 5.4 kg of CO_2/commuter/day	4.3-6.5	5.4
5 stars		4.3<	3.2

Note: 0 stars=poor performance; 5 stars=highest performance

For a rating scheme to work at a political level, a consistent set of performance standards would need to apply at the state level to avoid local governments playing one off against the other in competing for developers to locate within their jurisdiction. In other words, regulations are most effective if they are uniform in nature and applied universally. Whilst it can be argued that competition amongst local governments could be a spur to further improvements to environmental standards, there may still be cases of recalcitrant developers that will actively seek out development locations such as in the outer suburbs that permit a high reliance on cars for their employees.

Directions for further research
Before the community, relevant professions, politicians and legislators can have confidence in a rating scheme for development, it would need to have solid empirical evidence to demonstrate the reliability of the assessments. Ideally, a national approach would be needed which would imply that a rating scheme would need to be capable of taking into account the full diversity of Australian urban environments. The relative lack of diversity in the style of Adelaide's commercial office development compared to Sydney and Melbourne provides considerable scope for further case studies to underpin the development of a star rating scheme.

Whilst rating schemes imply that only future development projects need to be evaluated, the next logical step towards having all commercial office development achieve more environmentally sustainable commuter travel behaviours would be to compel all existing commercial office developments to obtain a star rating for their commuter travel characteristics. When developers or property owners sell their property, there could be a statutory requirement that a travel energy and carbon emissions star rating be provided by an accredited authority. Such an approach already applies in the Australian Capital Territory for residential sales. The creation of a carbon trading scheme that applies to commercial office development could also be introduced which would encourage existing property owners who do not intend placing their property on the market to pursue an optimal star rating and possibly derive commercial benefit by selling on their carbon credits. Carbon credits would be granted to property owners where their star rating is in excess of the minimum legally mandated star rating requirement either generically or for that particular location or location type or zone. The survey auditing tool discussed in this research would be an auditing mechanism that is particularly well suited to evaluating existing development because it attempts to ascertain quantitative estimates rather than being heavily reliant on subjective assessments.

Conclusions

The empirical findings indicated preliminary evidence that for office developments, central CBD locations are more energy efficient and produce less CO_2 emissions than a suburban location, even when commuter distances are of a similar magnitude. In the case of Adelaide, this is most probably due to the high density of public transit routes serving the wider metropolitan area being focused on the city centre whereas offices in suburban locations rarely enjoy this advantage. Even if an office is located on a transport interchange, it is likely that this will only have one or two major cross metropolitan routes. Employees' commuting travel patterns from the two case studies in Adelaide appear to be relatively simple and do not involve many modal transfers beyond two trip legs. A further crucial finding is that employees in a city centre location tend to walk or cycle to undertake personal or work related trips between their commuting trips. The survey confirmed that Adelaide is very much part of the carbon economy when it comes to urban commuter travel with the majority of employees using a fossil fuel powered motor vehicle to travel to and from work. Notwithstanding this, city centre commuters utlised public transit to a significantly greater extent than did their suburban counterparts at Technology Park. This research utilised the key research findings from the two case studies to provide an abbreviated and approximated calibrated star rating standard for work related trips regarding the amount of travel energy consumed and the CO_2 emissions produced. However, before such a star rating standard is adopted, further case studies would be required to confirm the veracity and reliability of these star ratings, particularly if this were to be applied at either a metropolitan, state wide or national level. The basis for a scheme was also proposed that outlined the main variables required to estimate the travel energy and CO_2 emissions produced for a development proposal. It was suggested that the auditing survey tool developed in this research project would have useful application in underpinning a carbon trading scheme and requiring property owners to demonstrate their property's environmentally sustainable commuting performance at the point of sale.

The use of a travel energy development rating tool for commercial office developments to develop new development standards allows planners to theoretically justify planning decisions that reject developments with poor accessibility from an energy efficiency perspective whilst encouraging developments that have high accessibility to non-energy intensive travel modes such as pedestrians and cycling. The successful implementation and community acceptance of energy rating schemes applying to residential building standards and home appliances suggests that a travel energy rating and carbon emissions rating scheme is feasible and a logical extension of issues that development assessment should apply to.

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