

Wheels still in spin?: urban social structure and technological change in Brisbane's private motor vehicle fleet.

Jago Dodson, Urban Research Program, Griffith University, Australia.
j.dodson@griffith.edu.au

c/- Urban Research Program, Griffith University, Nathan, QLD 4111.

Terry Li, Urban Research Program, Griffith University, Australia.

Neil Sipe, Griffith School of Environment, Griffith University, Australia.

Keywords

Urban transport, vehicle fleet, socio-spatial patterns, technology, equity

Abstract:

This paper examines the capacity of suburban households to respond to a changing global energy context by changing their motor vehicle technology. Transforming transport systems will comprise a crucial element in policy and planning responses to energy and climate challenges. Government policy appears focused on a transition to more efficient vehicle types or alternative fuel and engine types. Yet such policies have failed to account for the considerable social differences in household exposure to the costs of transport energy constrain and the adaptability of households in altering their use of modes and vehicle types. Nor do such policies recognise how urban social structure, household social status and automobile types intersect spatially within Australian cities. This paper examines the links between urban social structure and the composition of the motor vehicle fleet to test whether the households that are most reliant on motor vehicles for transport have the financial capacity to rapidly alter their vehicle technology in response to changing energy price and supply conditions. The paper uses ABS Census data and motor vehicle registration data at the postcode level to compare socio-economic status with the age, fuel consumption and value of the suburban vehicle fleet for Brisbane and the Gold Coast. This spatial deployment of Census and vehicle registration data is novel in the Australian context. The paper argues that policies that focus on vehicle technology alone face a number of social equity hurdles as measures to overcome urban transport fuel security problems.

Introduction

It is now clear that the world faces a major change in the type and rate of energy consumption. Between 2004 and 2009 the pattern of world oil prices changed dramatically. Petroleum prices became highly variable, racing from low, reasonably static, levels to levels not witnessed for almost three decades. The price of oil in early-2004 was around US\$25 per barrel but by mid-2008 exceeded US\$140 per barrel. Higher oil prices translated into much higher fuel costs and caused

considerable anxiety among many economically advanced nations with widespread concern about the impacts of high oil costs on economic activity. The increase in oil prices has also stirred assessments of future petroleum supply scenarios. An increasing body of opinion now anticipates much higher future oil prices, perhaps even within a few years, as global oil production systems prove incapable of meeting growing demand. Particular anxiety and uncertainty surrounds the probability that global petroleum will peak as depleting reserves prove incapable of meeting demand.

Accompanying the pending stresses facing the global petroleum supply system is a new and heightened awareness of the impacts of human carbon emissions on the global climate system. The acceptance that a reduction in climate emissions is established policy among the governments of developed nations. Debate is now centred on measures to reduce global greenhouse gas levels. Measures under consideration include a mix of pricing mechanisms accompanied by various forms of regulation and rationing, with an array of incentives for technological transformations of high-emissions economic sectors. The Australian government is seeking to institute a greenhouse gas emissions trading system to reduce national emission levels but is also pursuing a range of industry support measures to encourage use of low emission production and consumption practices.

The automotive transport sector faces a considerable transformation if it is to respond to the challenges of petroleum depletion and climate mitigation. There is evidence that the sector in its current form is poorly positioned to respond to the changing strategic energy environment. Technological innovation has been identified by commentators and policy makers as a central component of this task (Romm 2006). Around the world research into energy efficient vehicle types is accelerating rapidly. The Australian government is spending AU\$1.3 billion on a 'green car fund' which aims to reduce fuel consumption and greenhouse gas emissions of the passenger vehicle fleet (Carr and Rudd 2008).

The race for a green car has largely been expressed in technological terms. Most discussion centres on discovering and supplying a new technology and fuel combination that can deliver current patterns of mobility at comparable levels of affordability. Almost no discussion has questioned whether the achievement and implantation of a low-carbon or low-petroleum vehicle fleet is socially achievable. There has been almost no assessment of the differential socio-economic demand capacity of individuals and households for new vehicle-fuel types. Furthermore there has been little consideration of the spatial patterns of automobile ownership and use and their intersection with urban spatial socio-economic patterns. How long will it take for new vehicles to filter down to the point that they are affordable to lower income groups? Might some socio-spatial groups be trapped with old fuel inefficient vehicles while more affluent households take advantage of new technology? Can policies that rely on new vehicle technology meet greenhouse and energy objectives in a timely, socially equitable way?

This paper examines the links between urban social structure and the composition of the motor vehicle fleet to examine the social implications of transport policies that rely on vehicle and fuel innovation. The remainder of the paper is structured around four key objectives. First the paper sets out the urban transport policy challenges associated with greenhouse abatement and energy security. Second, the paper considers the role of urban socio-spatial structuring in allocating household exposure

to both higher fuel prices and vehicle renewal costs. Third the paper presents insights into these issues via the results of spatial analysis of Brisbane's motor vehicle fleet. Finally the paper concludes by arguing that the capacity of policies based on vehicle and fuel innovation to ensure social and spatial equity in meeting greenhouse and petroleum challenges is likely to be strongly constrained by urban socio-spatial structure. A particular methodological contribution of the paper is the use of Queensland Transport motor vehicle registration data for the Brisbane motor vehicle fleet in combination with spatial data derived from the ABS census.

Energy Challenges

The world is facing major energy challenges (Moriarty and Honnery 2009), in particular managing greenhouse emissions and the depletion of petroleum resources. The sharp increase in oil prices during the 2004-2008 period drew increasing attention to the problems facing global petroleum supplies. The 2004-2008 oil shock was the result of a number of factors, including strong global growth and petroleum demand, production facility capacity constraints, declining production in some major fields, geopolitical uncertainty, speculative investment and anxieties about future petroleum supply. The rapid growth of China and India, for example, received considerable attention from both scholars and policy makers for adding further demand to existing global petroleum consumption (IEA 2007; Yi-chong 2007). Some commentary has considered the capacity of present production facilities while other analysis has noted major production constraints due to ageing plant and weak investment in future facilities (Simmons 2005). The growing awareness of global energy challenges has been accompanied by geopolitical uncertainty and indications that major oil consuming nations are repositioning their strategic outlook for an era of greater international competition for petroleum reserves and resources (Kleveman 2003; Klare 2008).

A further set of fears surrounds the long-run sustainability of petroleum supplies. A large body of literature has developed in the past decade which suggests that global petroleum production may soon hit a peak of maximum production followed by a decline. The notion of 'peak oil' has been used to describe a scenario in which declining petroleum production is unable to satisfy global petroleum demand leading to increasing prices for petroleum fuels (Campbell and Laherrere 1998; Deffeyes 2001; Campbell 2005; Deffeyes 2005). The probable timing of peak oil is the subject of considerable uncertainty, with a range of periods from the mid-2000s to the 2040s posited as the point at which peak oil might occur. There are recent indications an emerging official consensus on the timing of peak oil which is settling the late-2010s. A US Government Accountability Office concluded that peak oil was a significant strategic threat to the country. In 2007 an Australian Senate inquiry concluded that peak oil could be expected by 2030 (Australian Senate 2007). A Queensland Government report into the state's oil vulnerability suggested 2013 \pm 7 years as a likely period in which peak oil would occur (Queensland Government 2007). Infrastructure Australia has speculated that 2012 will be the likely point of peak oil (Infrastructure Australia 2008). The International Energy Agency's head of economic forecasting, which is the world's foremost authority on energy questions, a guarded suggestion that a peak in global oil production by 2020 is not inconceivable (Biol, quoted in Monbiot 2008):

In terms of the global picture, assuming that Opec will invest in a timely manner, global conventional oil can still continue, but we still expect that it will come around 2020 to a plateau as well, which is, of course, not good news from a global-oil-supply point of view.

If a peak in global petroleum production were to occur by 2020 it would likely bring severe petroleum shortages within the world economy with a consequence of rapidly rising prices for petroleum fuels. Transport systems that are highly dependent on petroleum would potentially face severe and prolonged potential disruption without the widespread deployment of alternative fuel types and vehicle technology or forms of mobility that do not rely on petroleum. The Australia transport sector accounts for 36 per cent of national energy consumption from all sources (Syed et al. 2007) and is responsible for more than 70 per cent of national petroleum consumption (DRET 2008). Australia is becoming increasingly dependent on petroleum imports as a result of domestic petroleum production peaking in 2000. This is both an operational and economic problem for the nation. Australian petroleum imports now exceed exports by more than \$6 billion annually (ABARE 2008) and are a major contributor to the national current account deficit. Australia will need to import 54 per cent of its domestic petroleum and LPG consumption by 2030, in an era which is expected to see increasing energy insecurity (Figure 1).

[INSERT FIGURE 1 HERE]

In this context questions about the capacity of major economies and cities to transform their urban transport systems, including vehicle fleets, so that they are dramatically less reliant on petroleum take on a major public policy significance.

The petroleum energy security question intersects with extremely serious concerns about the condition and future prospects for the global climate. The reality of human-induced climate change is now accepted science and considerable policy and political effort is now being expended on developing measures to reduce emissions of greenhouse gases. Transport systems contribute approximately 13.1 per cent of global greenhouse emissions and about 23 per cent of emissions due to energy use (IPCC 2007). The IPCC (2007) anticipates light vehicles will produce 38 per cent of the additional 100 EJ of global transport emissions expected by 2050. In Australia transport emissions comprise 14 per cent of the national total with approximately 53 per cent of all Australian transport emissions are from private passenger vehicles (Garnaut 2008). Such vehicles thus contribute slightly more than 7 per cent of total Australian greenhouse gas emissions. The Garnaut Review expects that carbon emissions pricing will lead to pressures to reduce the fuel consumption of transport systems via alternative low-carbon fuel types and through improved vehicle technology. This expectation echoes that of the IPCC (2007) which suggested that a range of changes to vehicle design and fuel systems if the predicted growth in global private motor vehicle use is to be achieved while mitigating greenhouse emissions

Current automotive sector policy in Australia

Over 97 per cent of Australian transport is powered by petroleum fuels in the form of petrol, diesel, aviation gasoline or liquefied petroleum gas. Australian cities are

among the most petroleum dependent in the world outside North America. Road vehicles accounted for 75 per cent of Australian transport fuel consumption and passenger vehicles comprise 62 per cent of this total (Syed et al. 2007). The private passenger motor vehicle fleet is therefore a key contributor to Australia's petroleum energy dependence and to national greenhouse emissions. Reducing the energy and carbon intensity and the Australian transport system, especially the private motor vehicle fleet, is now a key objective for policy makers.

Current Australian government policy for reducing the energy dependence and greenhouse impact of private motor vehicle use focuses on two components. First is an intent to reduce private motor vehicle emissions by improving vehicle fuel efficiency via new drivetrain such as hybrid petrol electric or plug-in electric motors. At the Federal level this policy shift is signified by the Australian government's recently announced *Green Vehicle Plan* worth \$6.2 billion to encourage innovation within the domestic automotive sector (Carr and Rudd 2008). The scheme is motivated by a combination of '[g]lobal warming, the emergence of low-cost competitors, and rising fuel prices' (DIISR 2008). The two largest components of the plan are a \$3.4 billion automotive industry structural adjustment package and a \$1.3 billion *Green Car Innovation Fund* that will assist the sector to design and sell 'environmentally friendly' cars.

A second policy objective is to shift the composition of fuels consumed to renewable forms, such as biofuels and electricity. The main energy form that is being pursued by motor vehicle producers globally is battery-electric vehicles. The Australian government's automotive industry review anticipated an array of electric and hybrid petrol-electric vehicles coming to market in the 2010-2012 period (Bracks 2008). However the vehicles identified were expected to have very modest ranges per charge of around 64 kilometres. And fuel efficiency gains for the hybrids appear not to differ dramatically from current models. For example, the Chevrolet Volt is expected to have a fuel efficiency of 4.7 L/100 km (50 mpg) (Welch 2008) which is less than the 4.4 L/100 km achieved by the current Toyota Prius (Department of Infrastructure Transport Regional Development and Local Government 2009). While there are no mass production electric automobiles currently on sale in Australia, or likely to be for at least five years, there have been moves towards introducing electric vehicle infrastructure in anticipation of such vehicles entering widespread use (Andersen et al. 2009). The Better Place electric vehicle company anticipates a future in which battery electric vehicles will be able to charge and swap batteries at an array of stations situated throughout Brisbane, Sydney and Melbourne (Blackburn 2009). The company has been endorsed by the Victorian government and is seeking joint-venture partners to develop this infrastructure (Markoff 2008). Despite no fully electric plug-in vehicles currently on sale in Australia the company anticipates roll-out of its charging infrastructure will begin by 2012.

The futuristic excitement that often surrounds proposals for the mass conversion of the Australian vehicle fleet to hybrid or fully electric vehicles may need to be tempered by the historical experience of both improved vehicle fuel economy and the provision and uptake of such technology. Australia has a very modest record on vehicle fuel economy improvements with average fleet efficiency remaining effectively unchanged since the early-1960s at around 11.4 L/100 km (Figure 2). The reason for this almost static fuel economy appears to be due to increasing engine efficiency being offset by increasing vehicle mass and the introduction of various

electrical accessories such as air conditioning. This change is much weaker than that observed for cars in the USA which have seen fuel economy improve from approximately 17.6 L/100 km in 1973 to 10.5 L/100 km in 2006 (Sivak and Tsimhoni 2009).

[INSERT FIGURE 2 HERE]

These patterns imply that the advances in energy efficiency and improvements in greenhouse gas emissions heralded by electric vehicles may be more complex than proponents admit. But further problems afflict the proposition that electric vehicles can offer a comprehensive alternative to current vehicle technologies. Three problems are particularly notable. First, even if fully electric vehicles were able to be introduced by 2012 the limited anticipated distance per charge ranges and lack of supporting infrastructure would mitigate against widespread adoption. Second, petrol-electric vehicles currently sell at a premium relative to conventional vehicle types and are therefore unattractive to large segments of the vehicle market. For example, while the Toyota Prius currently retails for around \$37,500 in Australia the updated model anticipated for release in 2010 is expected to retail for \$39,000 (Pincott 2009). This positions the Prius far above basic models of key mainstream vehicles such as the 2009 Holden Commodore for which prices start at around \$31,000. The question of price will be crucial if hybrid or fully electric vehicles are to achieve widespread adoption in Australia, particularly within the timeframes necessary to meet accelerating energy security and climate change imperatives. At current prices the Toyota Prius is far from entering mass adoption, given the availability of much cheaper comparably low fuel economy vehicles such as the Toyota Yaris or Fiat 500. The question of price will be a key question, especially when considered in terms of social patterns in Australian cities.

Urban transport patterns and socio-spatial structure

The uncertain cost and complex rollout and of new vehicle technology will intersect with a further set of social and economic processes within Australian cities. These processes will further complicate the adoption of new vehicle technologies. Few proponents of new vehicle technology have thought to enquire as to the affordability and rate of uptake of such vehicles among the Australian urban population. Nor has there been significant broader discussion of the current social distribution of current vehicle types or the rate of vehicle turnover among differing socio-economic categories. A further set of questions surrounds the spatial distribution of the vehicle fleet and whether those who can afford new vehicle technology are likely to be the most vulnerable to the impacts of declining energy security and carbon emissions pricing. Will the most car dependent and socially vulnerable households be able to access the fuel economy advantages of new vehicles? While a technological change in the Australian motor vehicle fleet may appear increasingly feasible to policy makers questions remain about how such a change might integrate with existing transport patterns in Australian cities. The remainder of this section addresses such concerns beginning with an assessment of current transport behaviour and their intersection with wider socio-spatial patterns in Australian cities.

Dependence on automobiles is presently highly spatially differentiated in Australian cities. This pattern is demonstrated clearly in data from Sydney's ongoing household travel survey (Table 1). While Sydney is less car dependent overall than other major Australian cities the good quality data collected there depicts the spatial travel behaviour patterns found in Australian cities generally. Households that reside in the inner eastern and inner western areas of Sydney undertake approximately 57 per cent and 55 per cent of travel respectively by private motor vehicle, while residents of the city's northwest and southwest suburban zones use private motor vehicles for around 80 percent per cent of their travel (Department of Planning 2006). On average Sydney's outer suburban residents also travel greater distances each day relative to those in middle and inner suburbs. Average daily 'vehicle kilometres travelled' (VKT) of 27 km and 30 km were reported by households located in the outer northwest and outer southwest development zones, respectively, whereas inner eastern and inner western residents travel on average only 12 km and 13 km (Department of Planning 2006). Outer suburban households also exhibit higher rates of vehicle ownership with 1.78 and 1.78 vehicles per household reported by those in the north west and south west respectively compared to 1.24 and 1.16 cars per households in the inner west and inner east. Similar patterns are found in other Australian cities (Morris et al. 2002). These differences in household dependence on automobiles, distances travelled and motor vehicle ownership will be critical in an environment of energy constraint and carbon limits. In the absence of other mitigating factors the most car dependent households in Australian cities will be exposed to far greater fuel costs than those with low automobile dependence. This might be deemed acceptable on an austere 'user cost' or 'polluter pays' basis, but patterns of automobile dependence also intersect with important socio-spatial patterns which will confound policy attempts to deploy new vehicle technology as means of adapting to energy and carbon constraint, especially if conventional market processes are used as delivery mechanisms.

[INSERT TABLE 1 HERE]

Spatial patterns of vehicle ownership and use in Sydney also reflect the availability of public transport services and infrastructure. In general, public transport in Australian cities is of good quality near the historic commercial core and declines in quality, density and frequency with increasing distance from the CBD. With the exception of Melbourne's network and Adelaide's single Glenelg line Australia's cities largely replaced trams with buses in the 1950s and 1960s. Unfortunately these services have not been expanded to match urban growth. Buses in the newer more distant suburban zones are typically privately operated, undercapitalised, fragmented and poorly coordinated with state-owned rail systems. Middle and central zones where publicly managed bus services replaced the trams receive a much higher service quality. Sydney's woes cannot be tied to a lack of infrastructure as Mees notes:

Sydney, which has more electrified rail infrastructure, both track and rolling stock, than any other city of its size in the world, is plagued with an unreliable rail service and apparent capacity problems. (Mees 2000)

The result is a core and middle suburban area well-served by public transport surrounded by a poorly served outer suburban periphery that reflects the socially polarising 'splintered' patterns of contemporary urban infrastructure distribution

identified by Graham and Marvin (2001). Access to good quality public transport, therefore, is a crucial dimension of socio-economic opportunity and inclusion (Lucas 2004; Currie et al. 2007).

The differential transport patterns set out above are linked to socio-economic differences observed in the structure of Australian cities. Such differences unevenly allocate household exposure to higher travel costs due to higher petroleum prices. The spatial distribution of various socio-economic groups is heavily conditioned by spatial housing markets which intersect with transport systems. Dodson and Sipe (2007; 2008b; 2008a) have demonstrated that the intersection of housing markets and transport patterns is a key factor in shaping oil vulnerability in Australian cities. Most Australian urban housing is provided through private housing markets which are strongly centralised and display sharp 'bid-rent' curves focused around the central business districts (CBDs) (Dodson 2008). House prices tend to be high around the CBD and decline with increasing distance from the centre. For most, their spatial housing options are conditioned by their capacity to pay, which in turn is heavily determined by income. Very low income households are more likely to be found in fringe suburban areas where land and house prices are lower than the metropolitan average. In contrast, wealthier households are more likely to locate in middle or inner suburban areas proximate to the high-value inner urban employment. Households on lower incomes tend to locate in dispersed outer and fringe suburban areas where they are susceptible to becoming car dependent (Maher 1994; Burnley et al. 1997). In contrast, higher income households in Australian cities are more likely to locate in 'transit-rich' middle and inner urban zones where public transport services are of high quality and local streetscapes are more compact and 'walkable'. This effect means that Australian cities are highly regressive from an oil vulnerability perspective because the socio-economically weakest households are typically most exposed to the higher costs arising from declining energy security due to their location in highly car dependent areas.

[INSERT FIGURE 3 HERE]

These regressive urban structural effects are depicted in Dodson and Sipe's (2007) analysis of oil vulnerability in Australian cities which combines measures of household socio-economic status and car dependence. Dodson and Sipe's (2007) analysis for Sydney is presented below (Figure 3). Households in the inner and middle suburban zones, especially within the CBD and immediately adjacent areas to the east and the north exhibit low levels of exposure to declining energy security and rising fuel prices. Beyond these areas a wide zone of moderate oil vulnerability covers many of Sydney's middle suburban areas. In contrast, the areas of highest oil vulnerability are found among Sydney's western suburbs especially surrounding Liverpool and the urban growth corridors to the southwest and northwest and around Penrith.

Dodson and Sipe's (2007) analysis shows that oil vulnerability is a socially regressive condition – the relatively weaker socio-economic households in Sydney's outer western suburbs (and in comparable outer suburban zones in other Australian cities) are the most vulnerable to the adverse consequences of higher global petroleum prices due to declining energy security or carbon pricing. Importantly, such weaker socio-economic status will also impede their capacity to adapt to rising transport fuel

costs through purchase of an alternative energy vehicle. But the problems are more complex than this because vehicle ownership and household social status are not the only factors shaping household vehicle adaptability. Because private motor vehicles comprise a major expenditure item and sunk cost for households, the characteristics of the existing motor vehicle fleet will affect household adaptability. Lower income households may find themselves trapped owning old inefficient vehicles, yet unable to afford the costly new technology coming onstream. The remainder of the paper explores this problem via an analysis of spatial motor vehicle data for Brisbane.

Analysing Brisbane's private motor vehicle fleet

Social analyses of the composition of the private motor vehicle fleet are rare in Australia and uncommon elsewhere. The questions raised above suggest that understanding the age and size of private motor vehicles will be an important dimension of any improvements to the environmental efficiency urban transport systems based on changes in vehicular and fuel technology. Private motor vehicle registration can offer insights into these issues, especially when combined with social variables from other sources, such as the Census. The remainder of this paper presents the results of an analysis of Brisbane's motor vehicle fleet which we then link to social data to develop an improved understanding of the relationship between socio-spatial oil vulnerability and motor vehicle ownership. The analysis was guided by three questions. First, what differences can be observed in the spatial distribution of vehicle characteristics within Brisbane; second, what are the social implications of this vehicle distribution; and third, what implications do spatial patterns of vehicle distribution have for the achievement of improved resource and environmental efficiency in Brisbane?

For this analysis we obtained motor vehicle registration data collected by Queensland Transport which is structured spatially at the postcode (POA) level. We have used the dataset from the fourth quarter of 2008 which contained 441,930 vehicle records. We have analysed the data for Brisbane urban area expanded to accommodate post-codes following Dodson and Sipe (2007) who used urban areas for Australian cities as the spatial category for analysis of oil vulnerability, at the Census Collection District scale. This geographical arrangement enables comparison of vehicle fleet and social variables along a number of dimensions which are discussed below. The dimensions investigated include engine size, vehicle ownership and vehicle age.

Engine size

Engine size is an important determinant in vehicle fuel economy with the number of engine cylinders providing a basic ordinal indicator of relative fuel consumption. In Brisbane, the private car fleet is dominated by cars with four-cylinder engines (Figure 4). Of the 441,914 private motor cars registered in Brisbane in 2008, 62.0 per cent had four cylinder engines while 30.9 per cent sported six cylinder engines. Eight cylinder vehicles comprised only 5.0 per cent of the private car fleet. Vehicles with engine cylinder numbers other than these three major categories comprised just 2.1 per cent of the total car fleet and are attributable to antique, exotic or custom vehicles.

One feature of note is that 36.8 per cent of the private car fleet in Brisbane have engines with more than four cylinders. Given that six-cylinder cars are indicative of higher fuel consumption, this proportion of larger engine vehicles presents policy makers with a significant challenge in shifting vehicle composition towards higher fuel economy vehicles.

Vehicle age

The age structure of the Brisbane private car fleet shows a bimodal clustering with a long tail. The fleet is relatively old with a mean year of manufacture as late-1996, or 12.2 years old (Figure 5). Also of note in the distribution of vehicles by year of production is the sharp fall in vehicle registrations in the 2008-2009 period. This fall can be attributed to a combination of high fuel prices during 2008 combined with the economic fragility associated with the global financial crisis. Such a precipitous decline in the motor vehicle registration statistics is both positive and negative. A decline in motor vehicle registrations indicates a moderating of growth in the private car fleet meaning fewer cars in use. However from a technology transition perspective the drop in new car registrations suggests that a lag in the uptake of vehicles with improved fuel efficiency with implications for improvements of overall fleet fuel economy.

Vehicles per household

We have used Census data to assess the relative numbers of motor vehicles per household at the postcode level (Figure 6). A range of spatial patterns may be observed in this data. First, there appears to be a coarse spatial difference in proportions of cars per household across Brisbane postcodes. Households in the inner areas immediately surrounding the CBD and in the inner northern and inner south-eastern areas of the city exhibit relatively low levels of cars per household. Some outer eastern and far outer northern postcodes also have relatively moderate numbers of cars per household. By contrast postcodes with much higher relative levels of cars per household are located in Brisbane's north west, west, south west and south, especially in the Ipswich corridor running south west of the city centre. These results demonstrate that motor vehicle ownership is highly spatially differentiated.

[INSERT FIGURE 4 HERE]

[INSERT FIGURE 5 HERE]

[INSERT FIGURE 6 HERE]

Distribution of large cars

While relative number of cars per household in a postcode serves as a coarse indicator of the potential distribution of relative burden in any technological transformation of the Brisbane car fleet a better indicator is the proportion of large vehicles as a proportion of the fleet. This is because larger cars have generally higher emissions

and therefore are reasonable targets for priority removal from the fleet or conversion to a low-carbon fuel. The proportion of large engine cars per Brisbane postcodes is presented in Figure 7, using six cylinders or greater as the measure of 'large engine'.

A broad if uneven spatial distinction in the distribution of can be observed between postcodes in inner urban zones and those in middle and outer suburban areas of Brisbane. A cluster of postcodes with very low proportions of large engine cars is observable to the immediate west and south of the Brisbane CBD. This cluster is surrounded by a wider zone of postcodes with moderate rates of large cars in Brisbane's middle northern and middle southern suburbs. High rates of large cars per postcode are observed among postcodes in the north west, west, south west and south of Brisbane, particularly in postcodes beyond approximately ten kilometres from the CBD. For example, high proportions of large cars can be observed in the Ipswich sub-region, to the south-west of Brisbane.

Distribution of old vehicles

The relative age of the private cars fleet is another factor that could impede the mass introduction of new vehicle technology. In general second-hand cars tend to be cheaper in terms of up front purchase costs than new cars which means that they could compete with new fuel efficient vehicles. The distribution of older cars in Brisbane is highly uneven (Figure 8). Very low proportions of old cars are found within inner Brisbane postcodes, particularly those within ten kilometres of the CBD. In contrast much higher proportions of old cars per household are found in the middle and outer Brisbane postcodes, particularly those in the north, south west and south. These patterns mean that different areas of the city face varying adjustment burdens in relation to higher fuel prices and the rollout of new vehicle technology.

Car age and engine size

Older cars are likely to perform worse terms of fuel efficiency and carbon emissions than newer cars, given advances in technology over time while large engine cars typically have higher levels of fuel consumption compared to smaller cars of a similar age. Postcodes with higher proportions of large older cars will face a greater fleet adjustment task compared to those with much lower proportions of large old cars. We have mapped the proportion of old large cars for Brisbane postcodes. 'Old' cars are those more with a production year prior to 1996 while cars with six or more cylinders are deemed 'large' cars.

[INSERT FIGURE 8 HERE]

[INSERT FIGURE 9 HERE]

[INSERT FIGURE 10 HERE]

The distribution of old, large cars by postcode in Brisbane is highly uneven (Figure 9). In general inner urban areas immediately surrounding the Brisbane CBD and

extending to the west and east of the CBD have very low relative proportions of old large cars per household. This band is surrounded to the north and south by postcodes with relatively moderate proportions of old large cars. In contrast postcodes to the far north, south west, south and south east exhibited among the highest proportions of old large cars per household. In this analysis the best performing postcodes in terms of car age and size had proportions of old large cars that were around half the level of those which performed with the highest proportions of such vehicles.

Car fleet efficiency and socio-economic status.

Our analysis comprises two parts. First we have replicated the ‘VIPER’ oil vulnerability analysis method described and deployed by Dodson and Sipe (2007) to provide an assessment of the relative oil vulnerability of Brisbane postcodes (Figure 9). Two groups were constructed comprised of the best 20 postcodes and worst 20 postcodes respectively by VIPER score (see Appendix). The construction of these two groups thus permitted a comparison of various car fleet characteristics relative to levels of socio-economic oil vulnerability. The results of this analysis, provided in Table 2, provide insight into the relative adjustment task for highly oil vulnerable postcodes compared to postcodes with low oil vulnerability. The location of the postcodes comprising the high and low VIPER groups is presented in the appendix.

This analysis reveals some important differences in the composition of the vehicle fleet in low and high VIPER postcodes. The 20 least vulnerable postcodes performed better than the 20 most vulnerable postcodes on measures such as cars per household, car age, proportion of large engine cars, proportion of old cars, and proportion of old large engine cars. Some of these variables are particularly distinctive. Postcodes in the most vulnerable VIPER group had median proportions of old cars that were almost 16 percentage points greater than those in the least vulnerable VIPER group while there was a ten percentage point difference in favour of the least vulnerable VIPER group for the large car variable. A comparable difference of nine percentage points is observed for the least vulnerable VIPER postcodes and most vulnerable VIPER postcodes in terms of the proportion of old large cars.

The second part of our analysis tests the relationship between the VIPER score and the proportion of old large cars in a postcode (Figure 10) using linear regression. Such analysis reveals a very strong positive relationship between VIPER score and the proportion of old large cars in a postcode. Postcodes with low VIPER scores (and hence low exposure to the socio-economic risks of higher fuel prices) tended to have a much lower proportion of old large vehicles than postcodes with high VIPER scores. This relationship is very robust with an R^2 value of 0.638 and a T-value of 13.5. These results suggest that attempts to overcome the impacts of higher fuel prices through the use of market-based technological advances will be confounded by socio-spatial patterns in Australian cities.

[INSERT TABLE 2 HERE]

Conclusions

Australia faces considerable energy security and climate mitigation challenges in coming years and decades. Urban transport systems will be strongly affected by the shifting energy environment. Present policy settings assume that advances in motor vehicle technology combined with a shift to low-carbon fuel sources will enable a relatively smooth transition to an energy secure greenhouse neutral vehicle fleet. Such a policy is currently being pursued by the Australian government through its Green Vehicle Plan and associated schemes to re-orient the Australian automotive sector towards the design and production of 'environmentally friendly' vehicles. Such policies echo those found in other jurisdictions such as the USA where the government is undertaking a major restructuring of the domestic automotive manufacturing sector.

While new technology holds considerable appeal among politicians and policy makers there are a number of problems and risks associated with a reliance on technology as a salve for urban transport problems. The analysis of Brisbane's vehicle fleet presented in this paper illustrates these problems in three ways. First, the age structure of the Brisbane motor vehicle fleet is such that even if all new vehicles entering the market within a few years were electric or petrol-electric hybrids there would still be a long period of potentially of potentially a decade or more, given current vehicle age patterns before even half the vehicle fleet is comprised of such vehicles. New vehicle registrations in Brisbane in 2008 comprised less than 4 per cent of the total fleet. The recent plunge in motor vehicle sales poses a further setback for the take-up of new vehicle technology, given the stockpiles of existing new vehicles.

Second, the socio-spatial dimensions of the vehicle fleet means that the oldest and largest motor vehicles are likely to be found in areas where households have less capacity to afford vehicle upgrades. These zones are also likely to experience the greatest economic stress from the global financial crisis (Baum and Mitchell 2009). There is already evidence that the 2004-2008 oil price shock was a key contributing factor to the current recession in the USA (Hamilton 2009). While there has so far been only modest evidence advanced to support a similar relationship in Australia, the problem of high fuel prices and weak economic performance may limit household capacity to afford new vehicle types.

Third, the links between the relative weaker household capacities to afford motor vehicles intersects with the structure of transport and travel behaviour outlined previously. In combination these patterns will impede carbon pollution reduction objectives because the areas with the highest levels of dependence on cars for transport are also typically those with relatively modest socio-economic capacity to afford new vehicle types. Such lower socio-economic status households will therefore potentially continue to drive longer distances in old large cars than more prosperous households located more centrally. Outer suburban households may also be larger on average than inner-urban households, given socio-spatial patterns of family structure, leading to ownership of larger vehicles. The result is a distinct friction in any process of transforming the composition of the suburban vehicle fleet to target the oldest largest vehicles that are also used the most.

In conclusion efforts to reduce Australia's urban transport dependence on increasingly insecure petroleum and reduce the carbon intensity of urban transport through the

deployment of new vehicle technologies are unlikely to offer a comprehensive transformation of urban transport patterns. In the USA the 'Car Allowance Rebate System' has been as a vehicle trade-in rebate of up to \$4,500 for inefficient vehicles conditional on purchase of new efficient vehicle. Such a policy has been mooted for Australia. Such policies are likely to be attractive only to a limited sub-range of owners of inefficient vehicles who are able to afford the purchase costs of a new vehicle beyond the \$4,500 trade-in rebate and will likely only have modest impact on fleet composition, at \$1 billion fiscal cost.

A much wider strategic approach to coping with declining energy security and reducing carbon emissions will be needed in which technology takes a less prominent role and other methods, such as the rollout of improved public transport networks and associated coordinating institutions (see also Mees 2000; Dodson and Sipe 2008a) are given greater emphasis. While new private vehicle and fuel technologies will provide an element within Australia's urban transport future they will probably only be a component rather than a dominant mode. Policies that fail to recognise this wider context will be insufficient to offer Australian cities secure low-carbon transport. Such wider more nuanced policy thinking will be necessary if Australian cities are to keep their 'wheels still in spin' under declining petroleum security and increasing carbon restraint.

Further work is still to be done in this area of research and analysis. We are currently building a dataset that will link current vehicle fleets to vehicle fuel efficiency ratings and combine this with revealed travel data. This will provide a richer depiction, not only, of the urban vehicle fleet and the links to socio-spatial patterns but also of the relative levels of fuel and carbon consumption.

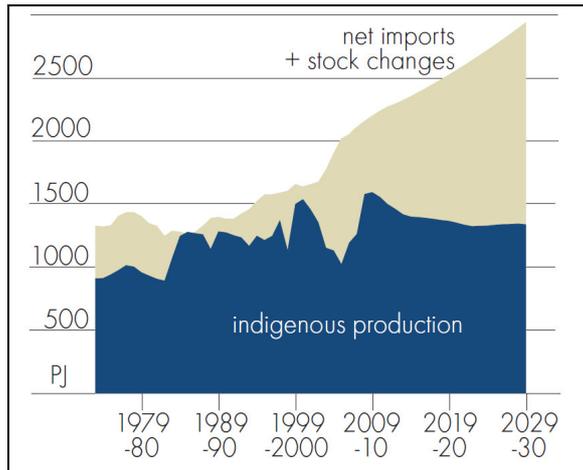
References

- Andersen, P. H., Matthews, J. A. and Rask, M. (2009). "Integrating private transport into renewable energy policy: The strategy of creating intelligent recharging grids for electric vehicles." *Energy Policy* **37**: 2481–2486.
- Australian Bureau of Agriculture and Regional Economics (ABARE) (2008). *Australian Commodity Statistics 2007 (Excel Spreadsheet)*. Canberra, ABARE.
- Australian Senate (2007). *Inquiry into Australia's future oil supply and alternative transport fuels: Final Report*. Canberra, Australian Senate.
- Baum, S. and Mitchell, W. (2009). *Red-Alert Suburbs: An employment vulnerability index for Australia's metropolitan regions*. Newcastle, Centre of Full Employment and Equity, University of Newcastle & Urban Research Program, Griffith University.
- Blackburn, R. (2009). "Battery stations to drive rise of electric car." *The Age*, 14 May: 9.
- Bracks, S. (2008). *Review of Australia's Automotive Industry*. Canberra, Australian Government.
- Burnley, I., Murphy, P. and Jenner, A. (1997). "Selecting Suburbia: Residential Relocation to Outer Sydney." *Urban Studies* **34**(7): 1109-1127.
- Campbell, C. (2005). *Oil Crisis*. London, Multi-Science Publishing.
- Campbell, C. and Laherrere, J. H. (1998). "The End of Cheap Oil." *Scientific American* **278**(3): 78-83.
- Carr, K. and Rudd, K. (2008). *A New Car Plan for a Greener Future*. Canberra, Joint Media Release by Prime Minister and Minister for Innovation, Industry, Science and Research, 10 November.
- Currie, G., Stanley, J. and Stanley, J., Eds. (2007). *No Way to Go: Transport and Social Disadvantage in Australian Communities*. Melbourne, Monash University ePress.
- Deffeyes, K. (2001). *Hubbert's Peak: The Impending World Oil Shortage*. New Jersey, Princeton University Press.

- Deffeyes, K. (2005). *Beyond Oil: The view from Hubbert's peak*. New York, Farrar, Strauss and Giroux.
- Department of Infrastructure Transport Regional Development and Local Government. (2009). "Green Vehicle Guide." Webpage, Retrieved 26 June, 2008., from <http://www.greenvehicleguide.gov.au>.
- Department of Innovation Industry Science and Research (2008). *A New Car Plan for a Greener Future*. Canberra, Australian Government.
- Department of Planning (2006). *Transport and Population Data Centre Statistics for the Subregional Planning Process*. Sydney, New South Wales Government.
- Department of Resources Energy and Tourism (DRET) (2008). *Energy in Australia 2008*. Canberra, DRET.
- Dodson, J. (2008). The wrong place at the wrong time: why the structure of housing markets means urban consolidation can't equitably solve our urban planning challenges. Third Australasian Housing Researchers Conference. Rydges Hotel, Carlton, 18-20 June, School of Global Studies, Social Science and Planning, RMIT University, Melbourne.
- Dodson, J. and Sipe, N. (2007). "Oil vulnerability in the Australian city: Assessing socio-economic risks from higher urban fuel prices." *Urban Studies* **44**(March): 37-62.
- Dodson, J. and Sipe, N. (2008a). *Shocking the Suburbs: Oil Vulnerability in the Australian City*. Sydney, UNSW Press.
- Dodson, J. and Sipe, N. (2008b). "Shocking the Suburbs: Urban Location, Homeownership and Oil Vulnerability in the Australian City." *Housing Studies* **23**(3): 377-401
- Garnaut Climate Change Review (2008). *Garnaut Climate Change Review - Final Report*. Melbourne, Garnaut Review of Climate Change.
- Graham, S. and Marvin, S. (2001). *Splintering Urbanism: Networked infrastructures, technological mobilities and the urban condition*. London and New York, Routledge.
- Hamilton, J. (2009). *Causes and Consequences of the Oil Shock of 2007-08*. Washington DC, Brookings Institution.
- Infrastructure Australia (2008). *A Report to the Council of Australian Governments*. Canberra, Infrastructure Australia, Australian Government.
- Intergovernmental Panel on Climate Change (IPCC) (2007). *Climate Change 2007 - Mitigation*. Cambridge, Cambridge University Press.
- International Energy Agency (IEA) (2007). *World Energy Outlook 2007: Focus on China and India*. Paris, International Energy Agency and Organisation for Economic Cooperation and Development.
- Klare, M. (2008). *Rising Powers, Shrinking Planet: The new geopolitics of energy*. New York, Metropolitan Books.
- Kleveman, L. (2003). *The New Great Game: Blood and Oil in Central Asia*. New York, Atlantic Monthly Press.
- Lucas, K., Ed. (2004). *Running on Empty: Transport social exclusion and environmental justice*. Bristol, The Policy Press.
- Maher, C. (1994). "Residential mobility, locational disadvantage and spatial inequality in Australian Cities." *Urban Policy and Research* **12**(3): 185-191.
- Markoff, J. (2008). "The next 'better place' is Australia." New York Times Webpage, from <http://bits.blogs.nytimes.com/2008/10/22/the-next-better-place-is-australia/>.
- Mees, P. (2000). *Rethinking Public Transport in Sydney; UFP Issues Paper 5*. Sydney, Urban Frontiers Program, University of Western Sydney.
- Mees, P. (2008). Presentation to Forum on Transport and the Built Environment, Garnaut Review of Climate Change, Perth, 19 February. Perth, Garnaut Review of Climate Change.
- Monbiot, G. (2008). "When will the oil run out?," *The Guardian*, 15 December.
- Moriarty, P. and Honnery, D. (2009). "What energy levels can the Earth sustain?" *Energy Policy* **37**: 2469-2474.
- Morris, J., Wang, F. and Berry, M. (2002). "Planning for Public Transport in the Future: Challenges of a Changing Metropolitan Melbourne." Proceedings of Australasian Transport Research Forum, Canberra, 2-4 October., Australian Bureau of Transport and Regional Economics.
- Pincott, K. (2009). "2010 Toyota Prius price announced." Webpage, Retrieved 23 June 2009, from http://carsguide.news.com.au/site/news-and-reviews/story/2010_toyota_prius_price_announced/.
- Queensland Government (2007). *Queensland's Vulnerability to Rising Oil Prices - Taskforce Report*. Brisbane, Queensland Government.
- Romm, J. (2006). "The car and fuel of the future." *Energy Policy* **34**(17): 2609-2614

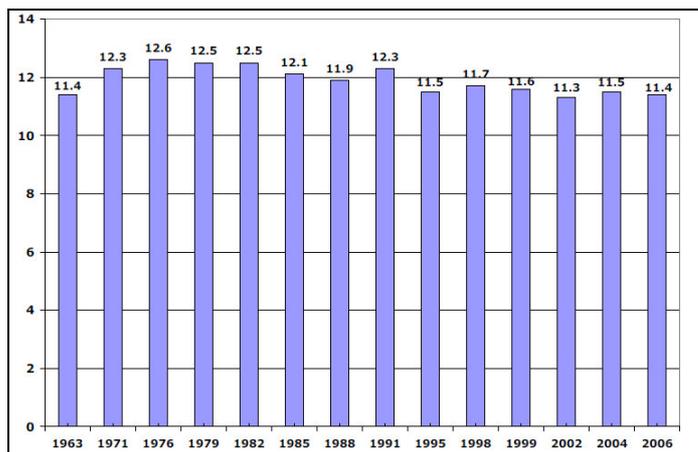
- Simmons, M. (2005). *Twilight in the Desert: The coming Saudi oil shock and the world economy*. New Jersey, John Wiley and Sons.
- Sivak, M. and Tsimhoni, O. (2009). "Fuel efficiency of vehicles on US roads: 1923-2006." *Energy Policy* **37**: 3168–3170.
- Syed, A., Wilson, R., Sandu, S., Cuevas-Cubria, C. and Clarke, A. (2007). *Australian Energy - National and State Projections to 2029-2030*. Canberra, Australian Bureau of Agriculture and Regional Economics (ABARE).
- Welch, D. (2008). "GM Charges Up the Electric Chevy Volt." *Business Week*, 18 September.
- Yi-chong, X. (2007). "China's Energy Security." *Energy Security in Asia*. Wesley, M. London and New York, Routledge.

[INSERT APPENDIX HERE]



Source: Syed et al (2007)

Figure 1: Projected Australian petroleum and LPG production and imports, 2005/2006 to 2029/2030.



Source: Mees (2008).

Figure 2: Fuel efficiency of the Australian passenger vehicle fleet, 1963-2006 (L/100 Km)

Table 1: Travel patterns for Sydney metropolitan sub-regions

	Sydney City	Inner West	Inner East	Inner North	Inner South	North North	North East	West Central	North West	South West	Central Coast	Sydney SD
Private Vehicle Mode Share (%)	31.8	55.3	56.9	60.0	67.6	73.5	71.8	72.2	79.0	79.3	76.5	69.5
PT Mode Share (%)	64.7	43.4	41.1	37.8	30.9	25.5	26.0	27.1	20.4	20.4	22.4	29.3
Avg Trip Length (km)	4.5	6.8	5.9	6.9	8.0	9.4	8.5	8.5	11.9	13.4	13.2	9.4
Avg VKT/person/	8.0	12.9	11.6	15.0	16.2	20.3	20.8	16.8	26.5	30.0	31.3	20.3

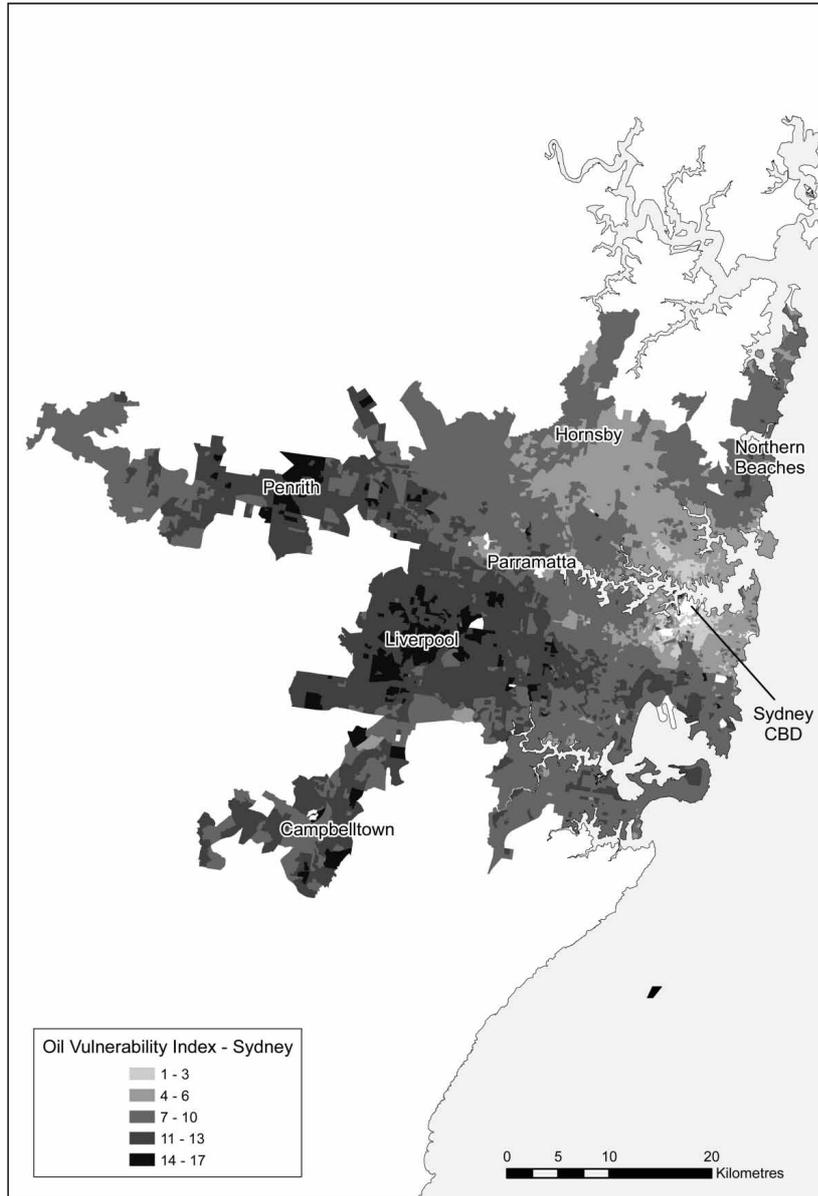
day (km)

Avg
number of
vehicle/
household

0.70	1.24	1.16	1.32	1.39	1.72	1.57	1.45	1.78	1.73	1.46	1.46
------	------	------	------	------	------	------	------	------	------	------	------

The location of Sydney sub-regions is provided in Figure 1

Source: Department of Planning (2006)



Source: Dodson and Sipe (2007)

Figure 3: The spatial distribution of relative household oil vulnerability in Sydney.

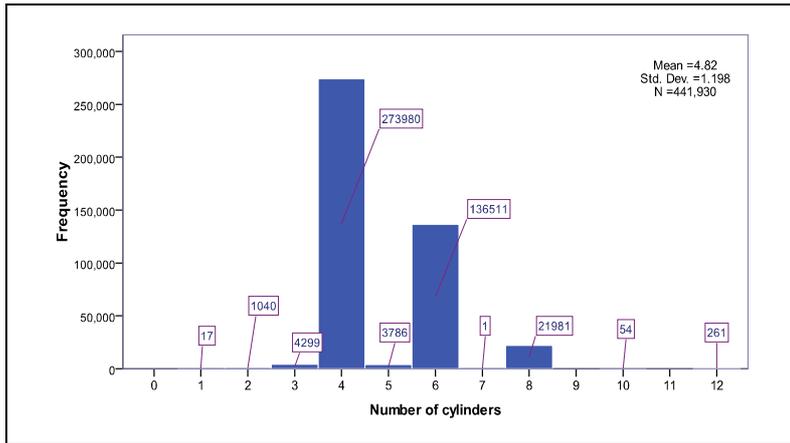


Figure 4: Distribution of engine size by cylinders within the Brisbane private car fleet.

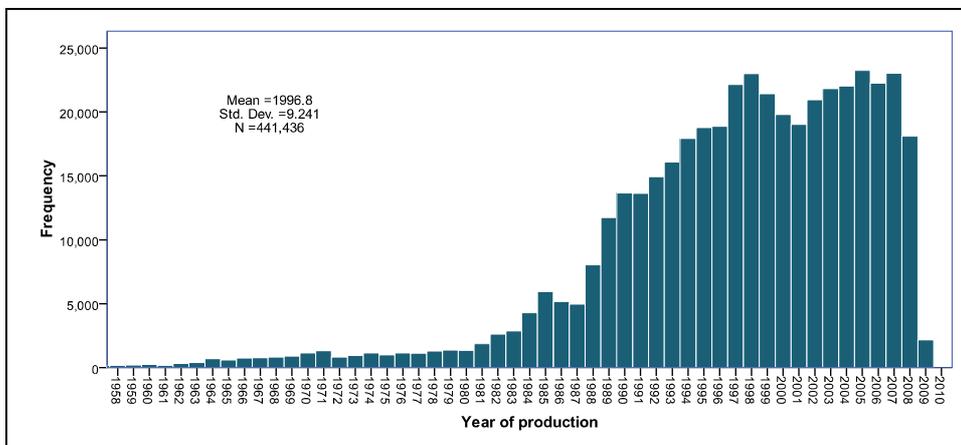


Figure 5: Frequency distribution of the Brisbane private car fleet by year of production.

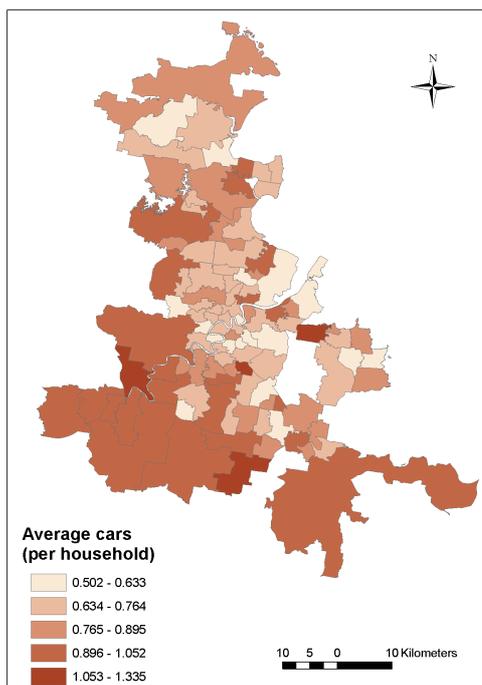


Figure 6: Vehicles per household in Brisbane (POA level)

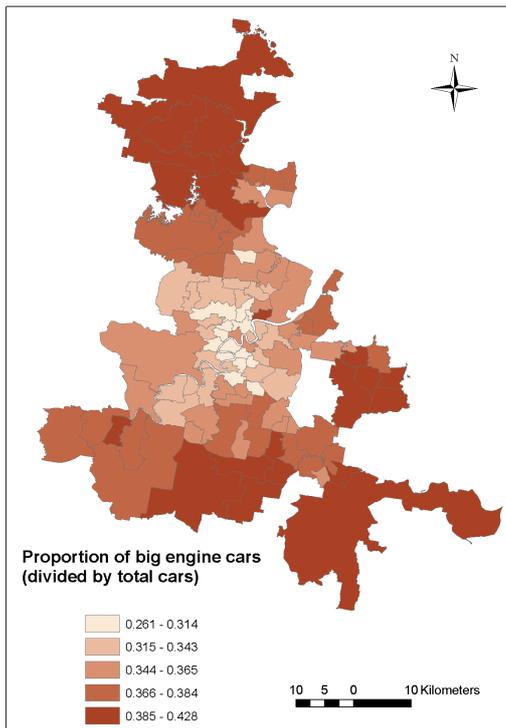


Figure 7: Proportion of car fleet comprising six cylinders or greater, for Brisbane postcodes

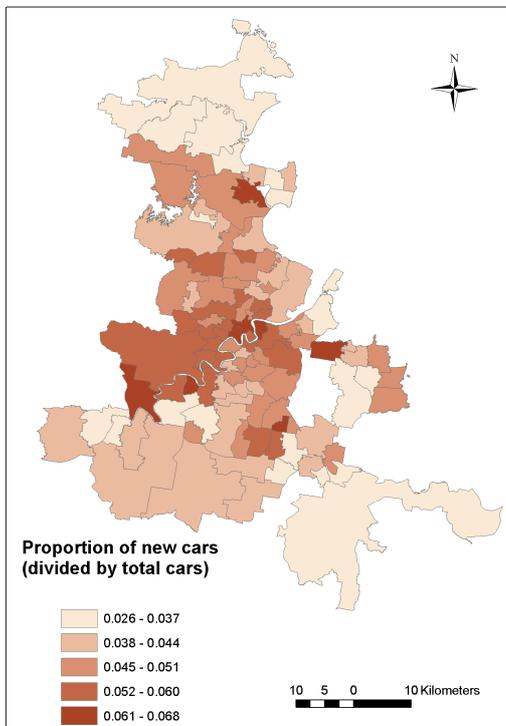


Figure 8: Proportion of car fleet less than 10 years old, for Brisbane postcodes

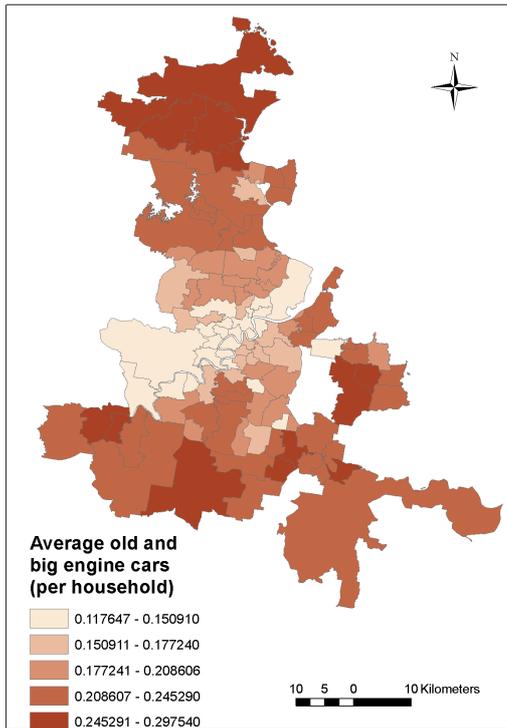


Figure 9: Number of old large cars per household for Brisbane postcodes.

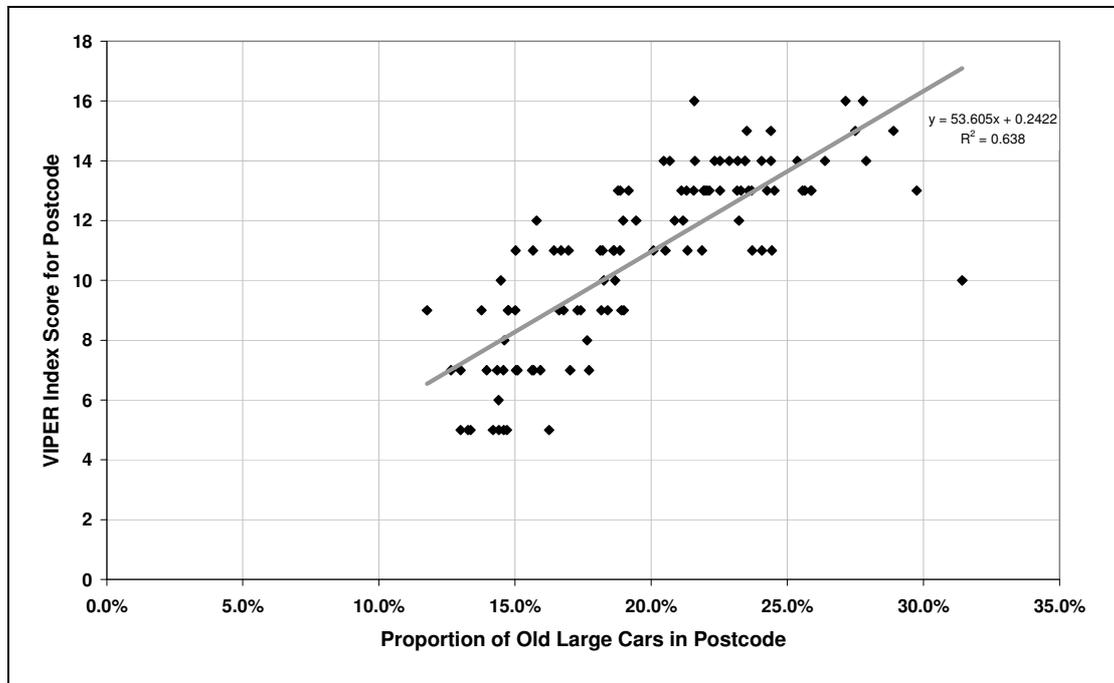
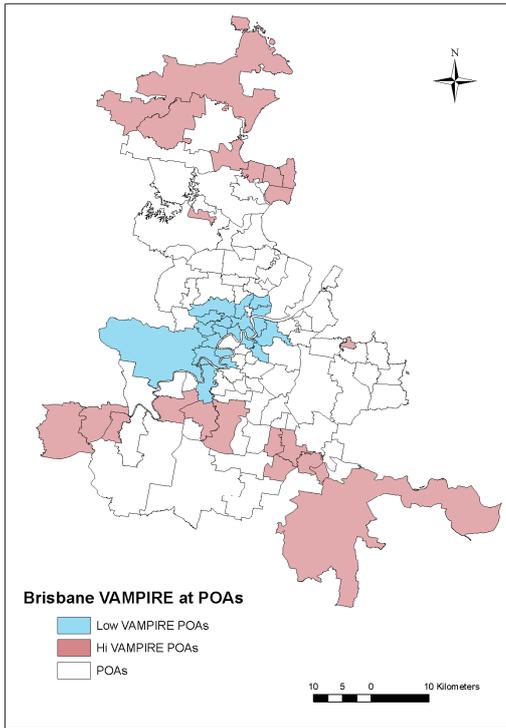


Figure 10: Proportion of old large cars versus VIPER score for Brisbane postcodes.

Table 2: Old large cars as a proportion of the car fleet for postcodes by VIPER score for the Brisbane Urban Area.

Variables	Statistics	LOW VIPER POAs	HIGH VIPER POAs
Proportion of total cars (per household)	Mean	0.725	0.814
	Maximum	0.972	1.006
	Minimum	0.502	0.571
	Standard deviation	0.107	0.133
	Median	0.712	0.802
Distribution of car age (years)	Mean	14.4	15.4
	Maximum	18	18
	Minimum	11	11
	Standard deviation	2.15	1.79
	Median	14	15
Proportion of big engine cars	Mean	0.240	0.311
	Maximum	0.362	0.388
	Minimum	0.172	0.227
	Standard deviation	0.047	0.049
	Median	0.226	0.325
Proportion of old cars	Mean	0.323	0.485
	Maximum	0.391	0.678
	Minimum	0.261	0.373
	Standard deviation	0.041	0.078
	Median	0.319	0.474
Proportion of old and big engine cars	Mean	0.147	0.024
	Maximum	0.177	0.289
	Minimum	0.126	0.204
	Standard deviation	0.001	0.024
	Median	0.145	0.235
Proportion of new cars	Mean	0.040	0.028
	Maximum	0.054	0.042
	Minimum	0.024	0.016
	Standard deviation	0.007	0.006
	Median	0.039	0.028
Proportion of new and big engine cars	Mean	0.011	0.005
	Maximum	0.019	0.010
	Minimum	0.006	0.003
	Standard deviation	0.003	0.002
	Median	0.011	0.005

Appendix



Constituent postcodes for low and high VIPER groups used in Table 2.