How can Improved Urban Land Use Reduce Vehicle Distance Travelled in the UK?

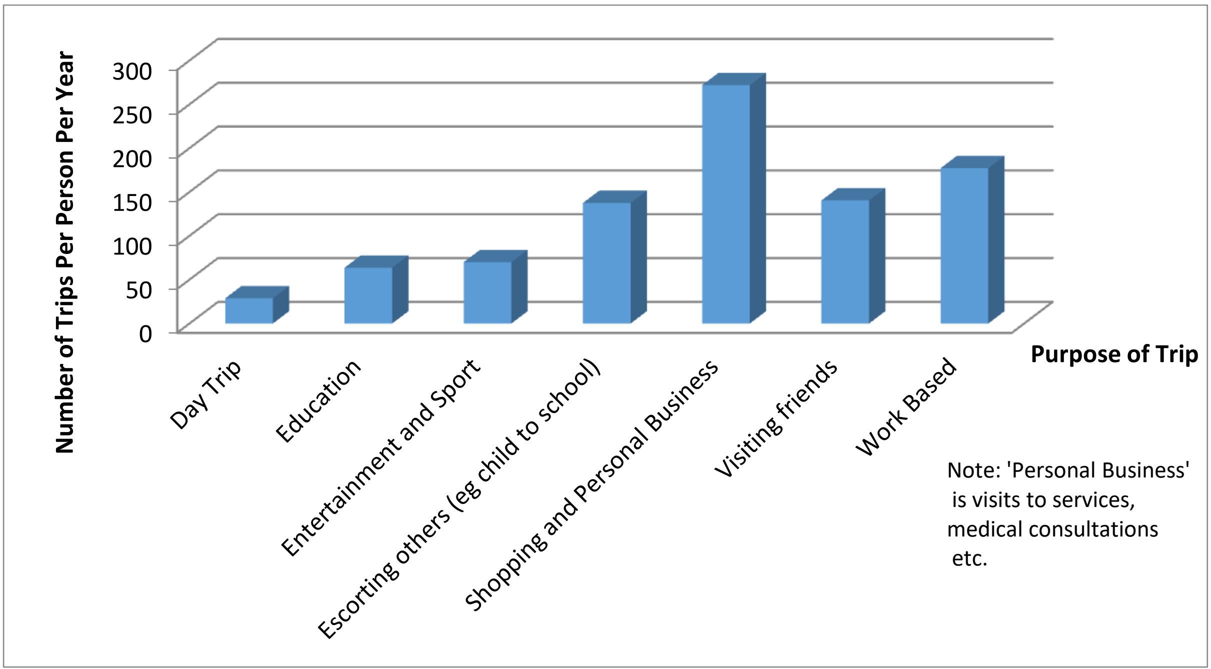
1 Introduction

A large proportion of the UK's energy demand and resultant emissions are for private vehicle (PV) use. In 2015, the transport sector contributed to 24% of the UK net domestic emissions, 58% of which were from PVs (Department for Transport, 2017). From this it can be calculated that the use of PVs alone contribute to 14% of UK emissions. Addressing ways of reducing PV use is therefore of great interest in reducing emissions.

Typical journey's made by people can generally be placed into a limited number of categories as shown in Figure 1. In order to reduce PV use, it must be possible to make necessary journeys by either non motorized transport or public transport.

Figure 1: The amount of trips taken per person in 2016 in the UK according to the purpose of the trip

Source: (Newman 2018, Based on Department for Transport, 2018)



Land Use That Encourages Non Motorized Transport

- It can be deduced that certain services, such as shops, schools, parks and places of work can fulfill a significant number of the journey purposes shown in Figure 1. Increasing the types of services in an area increases the land use mix. It logically follows that having a greater land use mix in a walkable area is likely to reduce PV journeys.
- If an area is more densely populated, buildings and therefore local services are likely to be closer. Also there is less space for PVs. Thus, more densely populated areas are thought to have less PV use per person.
- Streets can be developed to give walkers and cyclists greater accessibility and restrict PV use.

Public Transport

If a destination cannot be reached by walking or cycling then, in order to reduce PV use, public transport must be available, in both the origin and destination area.

The purpose of this essay is to determine the potential of these land use factors to reduce vehicle distance travelled (VDT) and therefore energy use in the UK, in line with learning objectives 1, 2, 5 and 6 of module EV7116. Section 2 will review relevant worldwide studies to evaluate the separate effects of these variables on VDT. Section 3 will examine how these variables can be combined to optimum effect. Section 4 will evaluate the potential of changing land use in the UK to reduce PV use.

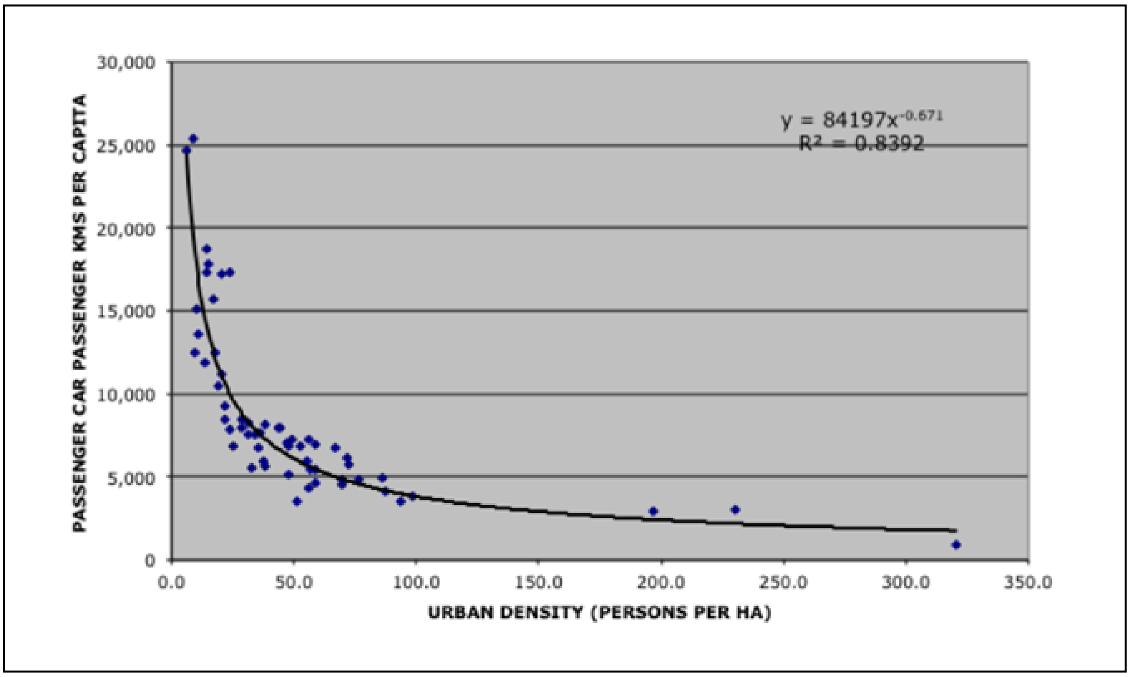
2 Effect of Land Use Variables on PV Use

In some cases this essay will refer to an ‘elasticity’ value which shows how much the percentage change in one variable effects the percentage change in another For example, an elasticity value of -0.5 means that for each 10% increase of the variable, the dependant value will decrease by 5%.

Out of the land use variables, the most commonly measured is density, which can be defined as the number of people, buildings or jobs within a particular area. It has long been accepted that increasing density in an area decreases PV use per person. Newman and Kenworthy (1989, cited in Holtzclaw *et al.*, 2002) used a sample of global cities to show a graph of annual car kilometers against density, which showed a logarithmic curve, with a strong negative correlation. An updated version of the graph is shown in Figure 2. The Authors concluded that increasing densification was the most effective way to reduce car use (Newman and Kenworthy, 1989, cited in Zhang, 2004).

Figure 2: Urban Density Versus Private Car Travel in 58 Higher Income Cities

Source: (Newman and Kenworthy, 2011)



This study was very influential although it was considered by many to be an over simplification that did not take into account a number of factors such as demographics and historical development in different countries (Zhang, 2004). Moreover, as a number of studies have suggested eg (Kockelman, 1997), when there are more people in an area, local amenities, such as public transport and shops are more viable and therefore tend to be better. The abundance of such amenities may themselves affect PV use (Ewing and Cervero, 2001). The data is at an aggregated regional level and so cannot account for the variations in density and other characteristics in district areas. It therefore cannot determine the effects of these characteristics, only the overall density. If these factors are considered, then the direct affect of density alone may not be as significant as the graph suggests. The effect of density separated from other factors is sometimes referred to as the *disaggregated density,* and the *aggregated density* when it includes them.

Holtzclaw (1994) studied 27 districts in California with a range of densities. Cervero and Kockelman (1997) built upon this principal, and measured various land use characteristics in 50 different districts of the San Francisco bay area and categorized them according to *density*, *diversity* and *design*, with diversity referring to mixed land use, and design referring to walking or cycling accessibility. Other factors such as demographics and public transport availability were measured as a control. Separating other factors from density enabled the effect of the disaggregated density on PV use to be calculated. The diversity of the districts was measured using the *entropy index*. This ranges from 0 to 1 with 0 meaning that all land use is the same and 1 meaning the area is distributed evenly among all of the land use categories. Another measure sometimes used is the jobs to population ratio, although it was not used in this study. The design of each district was measured using various indicators, the full list of which is shown in Table 1.

Table 1: Design Variables

Source: (Newman 2018, based on Cervero and Kockelman 1997)

Design Variable
Proportion of junctions that are four-way
Proportion of blocks with: pavements planting strips overhead lights flat terrain (< 5% slope) quadrilateral shape
Block face length (feet)
Pavement width (feet)
Distance between overhead lights (feet)
Proportion of commercial parcels with: paid parking side- or front-lot on-street parking

The framework used was influential on other studies, with density, diversity and design or the 3Ds becoming a recognized phrase to describe land use variables.

Ewing and Cervero (2010) conducted a meta analysis of various studies to calculate the weighted average elasticity of VDT with respect to the 3D variables. By this time, the distance of a dwelling to a transit stop and to the nearest urban centre (meaning the centre of a city or large town) were also commonly measured variables, and so were also included in the analysis. These variables are summarized in Table 2. The minimum and maximum elasticities from the original studies are also shown.

Table 2: VDT Elasticities With Respect to Land Use Variables

Source: (Newman 2018 based on Ewing and Cervero 2010)

3D category	Variable	Total Number of Studies	Minimum Elasticity Study Result	Maximum Elasticity Study Result	Weighted Average Elasticity presented by Ewing and Cervero (2010)
Density	Disaggregated Household/population density	9	0.00	−0.12	**-0.04**
Density	Disaggregated Job density	6	0.00	-0.06	**0.00**
Diversity	Land use mix (entropy index)	10	-0.02	-0.27	**-0.09**
Diversity	Jobs-housing balance	4	0.00	-0.06	**-0.02**
Design	Density of Junctions	6	0.00	-0.31	**-0.12**
Design	% of 4-way junctions	3	0.00	-0.15	**-0.12**
NA	Distance from dwelling to urban centre	3	-0.20	-0.27	**-0.22**
NA	Distance from dwelling to nearest transit stop	6	-0.01	-0.19	**-0.05**

These results show that the disaggregated elasticity of the density is relatively minor, with the distance to the nearest urban centre having by far the most significant effect.

The elasticity for the distance to the nearest transit point is not broken down into any other variables. However, Redman *et al.* (2013) shows that price, reliability, speed and frequency have a significant effect on patronage. It is also important to consider a possible difference between bus and rail. Some of the elasticities from the original studies used in the meta analysis by Ewing and Cervero (2010) indicate the type of transport. These are shown in Table 3.

Table 3: VDT Elasticities With Respect to Transit

Source: (Newman 2018, based on Ewing and Cervero 2010)

Study (Analyzed and Cited by Ewing and Cervero 2010)	Type of Transport	Elasticities
Frank & Engelke, 2005	Bus	-0.01
Frank et al., 2009	Bus	-0.04
Naess, 2005	Rail	-0.14
Zegras, 2007	Metro	-0.19

In these studies, the elasticities of rail are significantly greater those that of busses. Other studies show further evidence that rail services attract more patrons than busses, eg (Tal, Handy and Boarnet, 2013) and (Kenworthy and Laube, 1996). In some cases, this may be due to a higher capacity and a better service. However, even when service levels are similar, there is some evidence that people tend to use rail services more (Scherer, 2010).

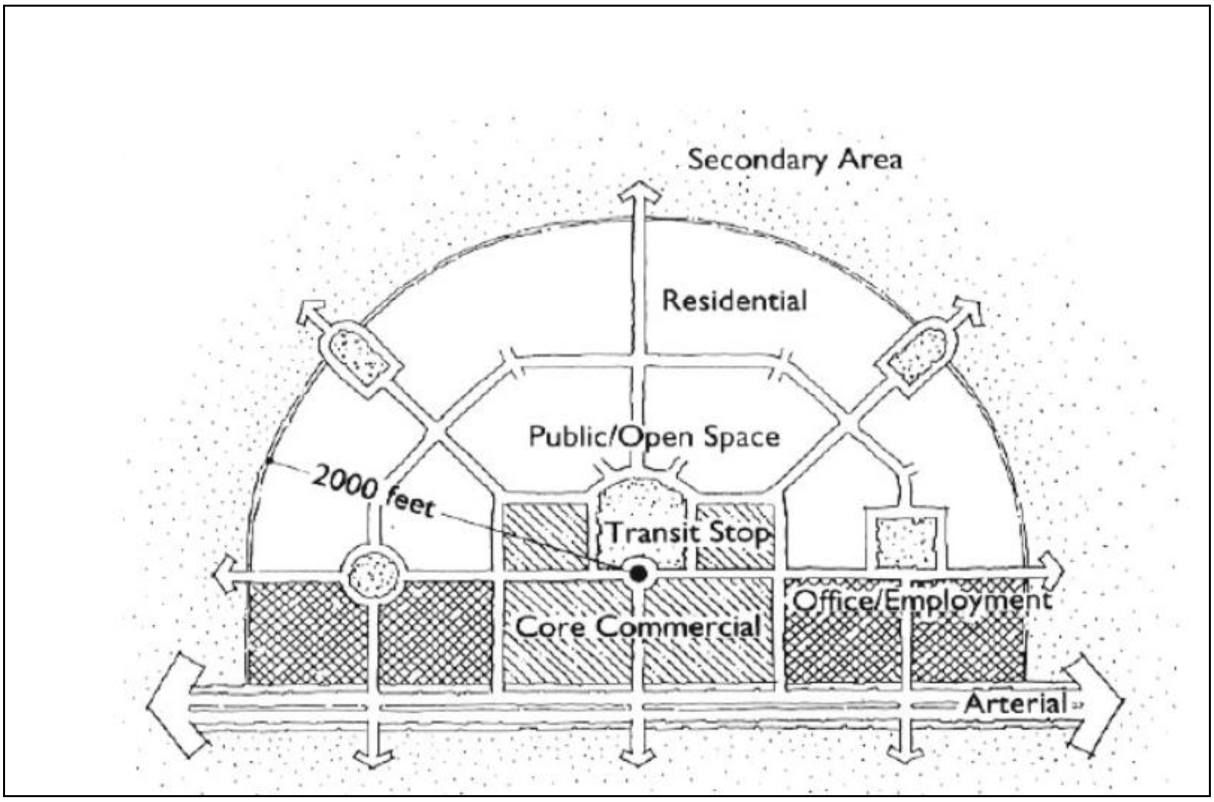
3 Urban Planning to Optimize PV Use Reduction

Transit Orientated Developments

As discussed previously, the VDT of residents near to a transit point is likely to be lower. It follows that planning developments next to such a point, with high density and good diversity and design, will have a combined effect on reducing VDT. A number of planners worldwide now follow this principal and construct developments with these characteristics. For clarity, this essay will refer to such developments using the phrase *Transit Orientated Development (TOD)*, based on an American planning policy first proposed by Calthorpe (1993). High density, mixed used buildings are based around transit points with good pedestrian access and within walking distance, often considered to be 800 metres (Barton, Horswell and Millar, 2012), as shown in Figure 3.

Figure 3: Calthorpe's Conceptual Model of a Walking-Scale TOD

Source: (Calthorpe, 1993, cited by Jeihani et al., 2013)



The previous section showed evidence that suggests a TOD based around a rail station would attract significantly more riders than one based around a bus station. Also the permanence of the rail structure may encourage greater confidence in a development that is based around it (Brown *et al.*, 2009). Gallivan *et al.* (2015) calculated that adding a rail station to a district is associated with a 9% increase in density. This essay therefore proposes that rail based TODs are likely to be more effective in reducing VDT and are generally more viable than bus based TODs.

The density of TODs in the USA vary from less than 60 to at least 300 dwellings per hectare (Arrington *et al.*, 2008). In Australia, the Queensland Government set out guidelines of TOD densities some of which are shown in Table 4.

Table 4: Recommended TOD densities in Queensland

Source: (Newman 2018, based on Kamruzzaman et al. 2014)

TOD Location	**Recommended Density Range (Dwellings per Hectare)**
City Centre	100 - 300
Town Centre	40 - 140
Suburb	30 - 80

VDT Reduction Case Studies

The effect of TODs on VDT is somewhat difficult to measure. One of the biggest challenges is that TOD residents may generally be attracted to transit use and so would be likely to travel in PVs less, even if they were not living at a TOD. Therefore comparing their VDT with non TOD residents may not give a true picture of the effect of the TOD. This principal is known as self selection (Handy, 2005). Some studies suggest that out of measured differences, around half can be considered independent of self selection eg (Zhou and Kockelman, 2008). In two case studies in Washington DC and Baltimore, with a degree of control for self selection, Jeihani *et al* (2013) calculated that in both areas, the VDT for TOD residents was around 20% less than for non TOD residents. In study of a number of TODs in four urban areas of America, Arrington *et al.* (2008) estimated that TOD residents on average make about half the amount of PV trips that non TOD residents do. In Stockholm, the VDT of residents in a suburb developed using TOD principals was also approximately half of those in similar non TOD suburbs of Stockholm (Cervero and Sullivan, 2011).

4 Application to the UK

Approximately 165,000 new dwellings in the UK are currently being built per year (GOV.UK, 2018). In theory, to reduce PV use, new developments in the UK could be built around TOD principals. By simply assuming the figure from Jeihani *et al* (2013) would apply in this context, it could be loosely suggested that each TOD residents' emissions would reduce by 20%. This essay will undertake an additional analysis below.

Newman and Kenworthy (1989, cited in Holtzclaw *et al.*, 2002) showed an elasticity of -0.25 for VDT with respect to aggregated density in UK cities. The effects of aggregated density on VDT can be thought of as a rough combination of the 3D's and public transport (Stead, Marshall and School, 2001). A TOD can be considered to be such a combination. In the UK the average density for new developments in 2015-2016 was 32 dwellings per hectare (Communities & Local Government, 2017). The increase from 32 to the TOD density recommended in Queensland can be used along with the elasticity to calculate the VDT reduction. The results are shown in Table 5.

Table 5: Elasticities of VDT with respect to densities.

Source: (Newman 2018, partly based on Kamruzzaman et al. 2014)

TOD Location	Recommended Density Range (Dwellings per Hectare)	Median (Dwellings per Hectare)	Increase from 32 (Dwellings per Hectare)	% Increase	% VDT Decrease using elasticity of -0.25
City Centre	100 - 300	200	168	525%	-131%
Town Centre	40 - 140	90	58	181%	-45%
Suburb	30 - 80	55	23	72%	-18%

The emissions decrease for city centre shows that the density increase has gone beyond the valid range for the elasticity. It does, nonetheless, suggest the emission reductions would be significant at high densities. This calculation depends upon assumptions that cannot be validated and so the other figures should be treated with caution, although they may have indicative value.

Approximately 165,000 new dwellings in the UK are currently being built per year (GOV.UK, 2018). The reductions suggested would only apply in the new dwellings, unless the TOD policy was applied to increase density of existing developments.

A major restriction in the UK is currently the lack of rail stations. Only a small amount of cities have a light rail service and a significant amount of towns do not even have a regional train station. In such towns, TODs could be based around bus stops, although the benefits are likely to be less.

Developments not near to public transport should optimize density diversity and design. The elasticities in Table 2 can be used as a predictor of VDT. It may be of interest to consider whether the elasticity of the design dimension would be the same in the UK as America. It may be more accepted to place restrictions on car use in districts, which could be another variable additional to those in Table 1.

With or without public transport, as shown in Table 2, further VDT reductions can be achieved by developing closer to urban centres.

5 Conclusions

Summary: Aggregated density measured in large areas has a strong correlation with VDT. It's effect can be thought of as due to a number of associated variables which can be measured separately in smaller areas. These variables can be categorized into disaggregated density, diversity, design and public transport availability. The elasticities of VDT with respect to these variables, as calculated by Ewing and Cervero (2010), are shown in Table 2. A TOD aims to optimize the reduction of VDT by planning high density developments within walking distance of a transit point. VDT is likely to be more significant if the transit point is a rail station. Some studies have shown that VDT for TOD residents appears to be 20% less and that they take approximately half the amount of vehicle trips. A proposed analysis in Table 5 suggests significant VDT reductions could be made by TODs, particularly in cities. The potential of TODs is currently limited by the lack of rail in the UK. If development near public transport is not possible, then density, diversity and design should be optimized. Developing nearer to urban centres can further reduce VDT.

Limitations: This essay examines the effect of land use variables on VDT. It does not consider the effect on any other aspects such as health, happiness or community cohesion. It also does not consider any social justice issues which may be relevant to TODs.

Implications: This study considers how developments with TOD characteristics could reduce VDT in the UK. It suggests another reason why rail services around the UK should be improved.

Further research: The effect of TODs on VDT is not yet completely understood. Further studies, where density diversity, design, distances from the transit point and quality of transit are clearly considered as factors are needed, with controls in place for self selection. A more standardized framework would help to further clarify this.

6 References

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