Can urban planning deliver sustainable outcomes: measuring the association between urban structure and form and sustainable household behaviour

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Abstract

Global commitments to make urban areas more sustainable coincide with debate over the type of urban structure and form to achieve it. This debate has caused confusion amongst planners and decision makers as to the correct planning position to take. In my PhD research, I re-examined previous research that measured the extent to which urban form induces sustainable outcomes and concluded that alternative methodologies were required for measuring and mapping urban structure and form, using Australia's largest metropolitan area, Sydney, as a case study. I argue that density is an inaccurate proxy for representing urban structure and form difference and recommend an urban structure and form typology approach to better represent differences. I also argue that only by understanding the behavioural choices of households can we compare the relative sustainability credentials of different urban structure and form contexts. The research findings have important implications for urban planners and policy makers. Future planning strategies should provide a clearer understanding of the actual direct influence different urban structure and form types can deliver from a sustainable behaviour perspective, rather than relying on the broad belief that density increases will deliver sustainable outcomes.
Keywords: sustainability, urban form, urban structure, density, household behaviour.

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1 Introduction

Previous research has shown that there are several urban structure and form elements that have the potential to influence a household's ability to behave sustainably (Ghosh and Vale [1]). These include new residential precincts designed to minimise impact on the surrounding environment (including innovative stormwater design, swales, bio retention systems; rain - gardens, rain water tanks and wetlands); on-site or centralised renewable energy systems; proximity to a public transport network; proximity to retail and community services; council waste reduction and recycling services; and ecologically sensitive housing design.

Although some researchers conclude that these enhancements help create sustainable urban areas (Blair *et al.* [2]), other research from North America, Australasia and Europe show that a wide variety of factors contribute to achieving sustainable outcomes (Barr [3]). These other factors relate to people's propensity to adopt sustainable behaviours. Such behaviours are influenced by socio-demographic characteristics, knowledge and experience, beliefs and attitudes, and a range of psychological variables.

When testing the level association that exists between selected environmental sustainability data (electricity consumption, water consumption, and car ownership) and urban structure and form, it was found that statistically significant associations exist between urban structure and form and these indicators. It was unclear, however, why such associations exist.

This article reports on the findings of research into why associations between urban structure and form and household sustainability behaviour might exist. It will begin by detailing the approach taken to representing urban structure and form and sustainable behaviour, measuring potential associations using data representing these variables, and surveying selected case study areas to interrogate why such associations might exist. The test results from the case study research are then analysed to assess the relative influence that urban structure and form has on several important household behaviours. The implications of these results from a policy and future research perspective are then discussed.

2 Background

Contemporary attempts to seek urban improvement has seen compact cities and urban consolidation promoted as the preferred urban planning model for achieving sustainable outcomes. This follows a tradition of urban designers and planners seeking utopian solutions to address the social and environmental problems of the day.

An urban consolidation policy position that supports more compact cities has been in place for some time now, particularly in Australia, yet there is still much debate as to whether more compact cities actually deliver the most sustainable outcomes; and whether urban form plays a role in delivering sustainable outcomes in the first place. Indeed, several researchers question the influence that urban form has on sustainable outcomes relative to socio-economic, behavioural and psychological factors.

A review of literature reveals methodological concerns with research that seeks to determine the extent of influence urban form plays in achieving sustainable outcomes. Several researchers [1, 4] choose to represent and compare differences in urban form by using density calculations even though these inaccurately represent urban form and urban structure difference. To address this deficiency, some researchers have developed urban form typologies unique to the metropolitan area being investigated.

Given the methodological questions raised, it is not surprising that some researchers conclude that there are too many complexities involved in determining which urban form type delivers the most sustainable outcomes. Although there has been a plentiful supply of research exploring the relationship between urban form and a variety of sustainability indicators, including transport use, energy use, water use, social participation and health outcomes, there is still no universal agreement as to the most desirable urban form.

Some commentators suggest that asking whether one urban form is more sustainable than another is the wrong question. Neuman [5] suggests it is only those that inhabit and behave in different urban form contexts that can be measured for sustainability. Following this lead, an alternative approach to measuring the relative sustainability of different urban form types is to measure household behaviours in different urban structure and form contexts.

Our research methodology consequently contained four distinct stages. The first stage identifies and maps Sydney's urban structure categories and dominant dwelling type areas. The second stage involves the collection of key environmental sustainability data, namely electricity consumption, water consumption and car ownership, so as the third stage can take place, which is comparing these three data sets across our urban structure categories to determine if any statistically significant differences are evident. The fourth stage involved collecting primary data from case study locations representing different urban structure and form types as a way of better understanding why some behaviour might differ across the Sydney metropolitan area.

3 Mapping Sydney's urban structure and form

Much of the urban form research that attempts to infer causality between urban form (represented by density calculations) and various sustainability variables relies on lineal regression testing. We will argue that not only is lineal regression problematic if the variables being tested contain inaccuracies, as density measures do when representing urban form difference, but that regression tests are not the only statistical step available to show relative levels of association between urban structure and form and various elements of sustainability.

An increasing number of researchers [1, 4, 6, 7] have begun using a typology approach to explain urban structure and form differentiation within large metropolitan areas. Such researchers tend to worry less about inter-city comparisons (as many researchers have done using density calculations) and more about developing typologies unique to the city or nation being investigated, based on variables such as residential type (using density as a guide rather than a proxy), public transport accessibility and land use mix.

Considering both urban structure and form, Ghosh and Vale [1] develop an urban taxonomy that encapsulates five data scales to map the level of urban structure and form differentiation that occurs in large metropolitan areas: metropolitan/regional scale; sub-metropolitan/city scale; community/neighbourhood scale; local/residential block scale; and house/micro scale. Theoretically, once a more spatially relevant urban structure and form typology is developed like this, it should enable a more accurate comparison of sustainability related characteristics across different urban structure and form types in the metropolitan area.

We developed six broad urban structure categories that we found differentiated parts of the Sydney metropolitan area and mapped these as accurately as possible with the assistance of GIS (Figure 1). We then placed every Census Collector District (the CCD is smallest statistical geography used by the Australian Bureau of Statistics – ABS) within the Sydney metropolitan area into an appropriate urban

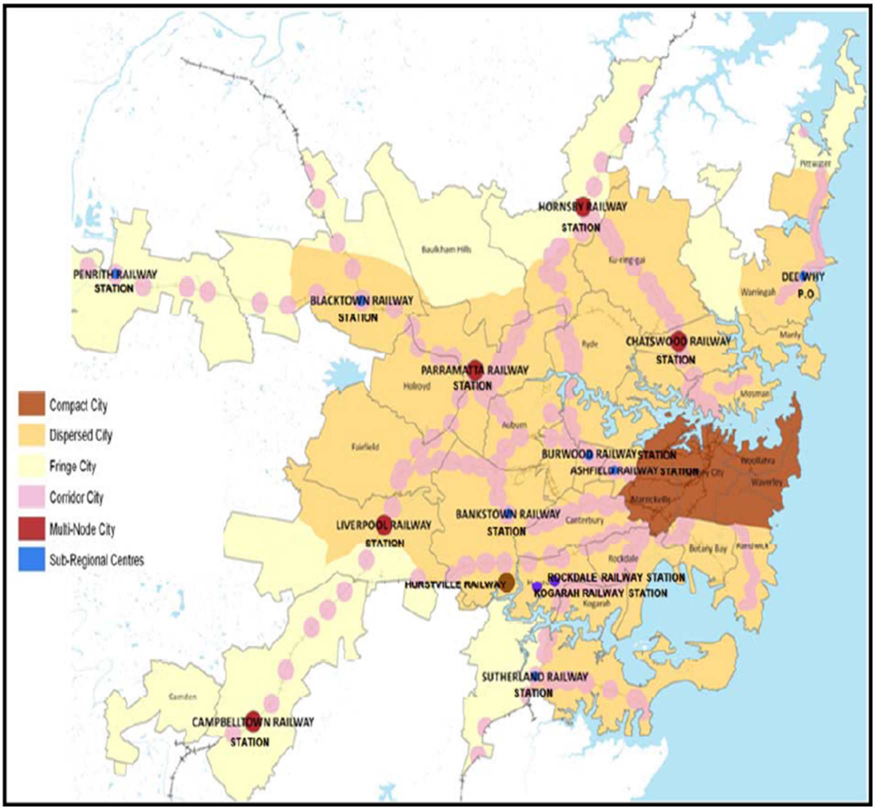

Figure 1: Sydney's urban structure layout.

structure category and highlighted those CCDs with a dominant housing type to enable a comparison of different combinations of urban structure and dwelling type (e.g. compact city four-storey and above with a predominance of apartments versus dispersed city with a predominance of detached dwellings). This approach to combining urban structure and dwelling type, which is broadly similar to the approach used in Ghosh and Vale's urban taxonomy, differs from other urban form research efforts which calculate residential densities and place them into high, medium or low density categories.

4 Secondary data collection, testing and analysis

Three indicators (energy, water and transport) are considered by some researchers [7] to comprise the key behaviours contributing to household related greenhouse gas emissions. Although these indicators, considered together, do not enable claims to be made about the overall sustainability credentials of each of the urban structure and form categories, they do enable us to test the level of relationship or association that may exist between urban structure and form and three key environmental behaviours.

One-way ANOVA tests were performed between the urban structure categories and each of the secondary sustainability indicators. Table 1 illustrates where the statistically significant differences between means occur at the 95% certainty level "sig." as 0.05 or below).

For electricity use, there are significant differences in the means between most urban structure categories except between the compact city and multi-node categories, the multi-node and corridor categories, and the multi-node and sub-regional categories. For water use, there is statistically significant difference in the means between compact city and every other category. For car ownership there is significant difference in means between most urban structure categories, except between the compact city and sub-regional and multi-node categories.

On the surface, the urban structure variable appears to have an influence on the three key sustainability indicators in different ways. Yet, can it be assumed that it is the urban structure category itself is responsible for generating statistically significant difference in the means for each of the indicators or are there other factors contributing to the results?

From the relevant literature it is apparent that two other potential influences on the three indicators are dwelling type (representing urban form difference in this research project) and socio-economic status [8, 9]. With regard to dwelling type, the different heating and cooling requirements of different building structure types, in particular, can have a marked impact on electricity use. Socioeconomic factors are also believed to be associated with energy consumption, with Randolph and Troy [8] showing in the Sydney context that higher income low density suburbs record much higher per capita electricity consumption than lower and moderate income low density suburbs. Water consumption rates are also affected by dwelling type, with those living in detached dwellings with backyards having a greater capacity to recycle and reduce the amount of water consumed [9]. Moreover, dwelling type and levels of home ownership may be more important

Table 1: One-way ANOVA results.

Electricity	Fringe	Dispersed	Corridor	SubRegional	MultiNode	Compact
Fringe						
Dispersed						
Corridor						
SubRegional						
MultiNode						
Compact						
Water	Fringe	Dispersed	Corridor	SubRegional	MultiNode	Compact
Fringe						
Dispersed						
Corridor						
SubRegional						
MultiNode						
Compact						
Car	Fringe	Dispersed	Corridor	SubRegional	MultiNode	Compact
Fringe						
Dispersed						
Corridor						
SubRegional						
MultiNode						
Compact						
<0.05	statistically significant difference					
>0.05	difference not statistically significant					

than socio-economic factors in influencing water consumption patterns [8]. With regard to car ownership, socio-economic factors and dwelling type may also have an influence on transport modal choice, although urban structure is identified as having a more significant influence on transport modal choice than these factors [10].

After considering the literature, it was decided to perform additional two-way ANOVA tests to quantify the extent of difference in the means that exists for the three indicators when different dwelling types (representing urban form difference) are considered and then when areas representing different socioeconomic contexts are considered.

Tables 2 and 3 illustrate the results of two-way ANOVA tests when the effect of urban structure is assessed for both the dwelling/urban form variable and socio-economic index variable (a ranking system considering many socioeconomic factors used by the ABS, with 10 being the highest socioeconomic ranking and 1 the lowest) respectively.

Table 2: Two-way ANOVA tests considering urban form (dwelling).

	Electricity		Water		Car Ownership	
Dwelling Variable	F value	Sig.	F value	Sig.	F value	Sig.
Detached Dwelling	17.885*	0.00	21.722*	0.00	33.793*	0.00
Semi or Terrace	0.399	0.67	0.138	0.94	2.125	0.10
WalkUps	0.551	0.70	2.839*	0.02	3.36*	0.01
FourStorey Above	1.938	0.10	7.827*	0.00	6.034*	0.00
Each F tests the simple effects of UrbanForm within each level combination of the other effects shown. These tests are based on the estimable linearly independent pairwise comparisons among the estimated marginal means.						

Table 3: Two-way ANOVA tests considering socioeconomic rankings (ABS).

	Electricity		Water		Car Ownership	
SEIFA Variable	F value	Sig.	F value	Sig.	F value	Sig.
Ranking 1	0.39	0.68	21.526*	0.00	32.241*	0.00
Ranking 2	1.52	0.21	2.334	0.04	13.936*	0.00
Ranking 3	21.532*	0.00	1.46	0.20	17.152*	0.00
Ranking 4	19.535*	0.00	1.171	0.32	28.606*	0.00
Ranking 5	0.50	0.73	1.826	0.10	45.07*	0.00
Ranking 6	1.39	0.24	3.902*	0.00	69.227*	0.00
Ranking 7	4.328*	0.00	4.472*	0.00	95.872*	0.00
Ranking 8	3.815*	0.00	6.192*	0.00	112.103*	0.00
Ranking 9	13.611*	0.00	3.97*	0.00	221.606*	0.00
Ranking 10	48.436*	0.00	9.355*	0.00	497.877*	0.00
Each F tests the simple effects of UrbanForm within each level combination of the other effects shown. These tests are based on the estimable linearly independent pairwise comparisons among the estimated marginal means.						

Table 2 shows that urban structure has a statistically significant influence on mean electricity consumption in detached dwellings, while mean electricity consumption does not vary significantly for the other dwelling types across different urban structure contexts. In other words, electricity consumption has the potential to vary significantly in detached dwellings when placed in different urban structure contexts.

Table 2 also shows that urban structure has a significant influence on water consumption in three of the four dwelling types, with the semi-detached and terrace dwelling type being the only exception. As well, urban structure influences car ownership for all dwelling types except semi-detached and terraces.

Table 3 shows that urban structure has a statistically significant influence on electricity usage and water usage across many of the socioeconomic index ranking categories, and for all socioeconomic rankings when it comes to car ownership. In fact, for every socioeconomic ranking above 7, urban structure has a statistically significant influence over electricity consumption, water consumption and car ownership.

Although we have not yet determined what it is about urban structure that results in significantly different household consumption patterns across certain dwelling/urban form types in the Sydney metropolitan areas, it is apparent that some urban structure types, like the compact city urban structure category, are associated with relatively low levels of electricity consumption and car ownership yet higher levels of water consumption. Therefore, to claim that one urban structure type is more sustainable than other is inaccurate. What can be claimed on the basis of the ANOVA testing is that some urban structure types have a statistically strong association with some environmental behaviours and not others.

Of course, we still have no clear understanding as to why this may be the case. It is clear we next need to compare urban structure and form's influence with other potential consumption behaviour influences, such as personal attitudes and beliefs, education levels and other specific socioeconomic variables.

5 Primary data collection, testing and analysis

Self-completion multiple-choice questionnaires were delivered to 11 selected case study areas representing different urban structure, dwelling (urban form) and socio-economic types across the Sydney metropolitan area. A 23% overall return rate enabled us to collect sufficient data to perform chi-square tests to compare potential associations that may exist between a number of categorical factors, including location and dwelling type (representing urban structure and form respectively); socio-economic index; values and belief; household characteristics; and education levels; with a range of sustainability behaviour responses related to waste recycling and composting ; non-journey to work travel behaviour; social and local community participation; access to and use of local services; and purchasing habits.

5.1 Results

The survey of case study areas representing different urban structure and form types generated responses that are defined as categorical for statistical purposes (i.e. they are not continuous or ordinal). Whereas t-tests or Analysis of the Variance of Means (ANOVA) is the most appropriate statistical test for determining the level of association between a categorical variable (urban structure, urban form and socioeconomic factors) and continuous or ordinal data (the secondary electricity, water and car ownership data), chi-square tests should be used when considering two categorical variables.

The collation of data from questionnaire returns enabled us to determine the level of association each case study location has with sustainability related household behaviours. Certain patterns emerged that suggest case study location has a significant association with some of sustainability behaviours, including transport modal choice; composting food and garden refuse; reusing and recycling household items often; and saving and reusing waste water. The chi-square results are particularly helpful in clarifying why associations between urban structure and water consumption; electricity consumption; and car ownership may or may not exist.

With regard to water consumption, two chi-square results are of relevance. Firstly, the dependent variable "reducing water consumption often" is found to have a statistically significant association with three independent variables: strong political support for the environment, belief that humans are responsible for climate change, and level of education. On the other hand, the dependent variable "reuse and recycle waste water often", a specific water saving technique, shows a strong statistical association with case study location and level of education. Yet, there is little statistical association between collecting and reusing waste water often and pro-environmental attitudes and belief in climate change, nor tenure and socioeconomic ranking variables. This suggests that case study location, in association with other influential factors such as level of education, may indeed have an influence on water consumption rates, at least with regard to a household's ability to reuse waste water as a specific water saving technique. As such, there may be a substantial difference between those saying they reduce water consumption often and actual water consumption rates based on the chi-square results. Whether this resolves the issue as to why compact city water consumption rates are higher than other urban structure and urban form combinations requires further investigation.

With regard to electricity consumption, the chi-square tests show that the dependent variable "reducing electricity consumption often" has a statistically significant association with three independent variables: political attitude towards the environment, belief in human-induced climate change, and level of education. This dependant variable also has a statistically significant association with the socioeconomic ranking, although not to the level of statistical significance as the other three independent variables. This shows that the independent variables representing pro-environmental attitudes; belief in climate change; and level of education are strongly associated with electricity consumption. The secondary data testing raised the prospect that these independent variables can have a unique geography and may somehow align to the urban structure categories that we have applied to the Sydney metropolitan area. The chi-square results suggest that the case study locations representing different urban structure and form categories may be statistically associated with other independent variables such as belief in human-induced climate change, level of education and a variety of socio-economic factors, which manifest as geo-political differences across large metropolitan areas. This then might explain differences in detached dwelling electricity consumption across the urban structure categories. The nexus between urban structure and form and the combination of political values, level of education and socio-economic factors is worth researching further.

With regard to transport modal choice and car ownership rates, the chi-square tests support the findings of the secondary data analysis. For both car ownership and modal choice, statistically strong associations not only occur with case study area location, but the household composition, tenure and socioeconomic ranking variables. The strongest of these are the associations with case study location, both for short and long trips, which supports the findings that urban structure is strongly associated with car ownership. Associations between car ownership/modal choice and political attitudes, beliefs and level of education are not statistically significant.

The other household behaviour found to have a strong statistical association with case study location was the "composting food and garden refuse often". Yet, pro-environmental attitudes and belief in human - induced climate change still provided a stronger statistical association.

6 Conclusion

This research project has shown that different urban structure and form types, which we classify using an urban typology, are associated with some sustainability behaviours and not others. There are strong statistical associations between urban structure and transport modal choice behaviours (in compact city, multi-node and subregional centre urban structure locations) and, in association with dwelling type (urban form), some environmental behaviours such as composting and collecting and reusing waste water (in fringe and dispersed urban structure locations). Urban structure and form, where it is dominated by certain dwelling types, is statistically associated with electricity consumption and water consumption levels, but there are other influential socio-economic, political attitudes and philosophical belief variables at play. Other household behaviours, such as recycling often and purchasing environmentally friendly products have been found to have little statistical association with urban structure and form, with political beliefs and attitudes and level of education having more of an influence.

These results show that the premise in many global urban planning strategies that the compact city will help achieve sustainable outcomes should come with qualifications. Firstly, if the compact city is defined as "high density" urban form, then we have an inaccurate proxy for representing urban form and the subsequent policy response of densifying the metropolitan area with an abundance of four-storey and above apartments is a misrepresentation of the different urban form types possible within a compact city. Secondly, we need to understand what is meant by a sustainable urban form. Sustainability is not a fixed measurable entity, rather a broad combination of measurable environmental, social and economic elements. We have recommended measuring the relative sustainability of different urban structure and form types by utilising sustainable household behaviour measures. Doing so will assist planners understand the impact that urban structure and form has on the households that inhabit them.

Finally, the sustainable outcomes associated with more compact cities, and other urban structure types such as the multi-node city, subregional centres, and to a lesser extent the corridor city, are primarily related to transport accessibility outcomes. These urban structure types have strong statistical associations with relatively high levels of public transport, walking and cycling use. Other sustainability behaviours such as electricity consumption, water consumption, and reusing and recycling have varying degrees of association with urban structure and form. In fact, with regard to water consumption, it is apparent that detached dwellings in fringe and dispersed urban structure locations may be associated with more sustainable water consumption practices, with the compact city being relatively unsustainable when it comes to this type of household behaviour. Future urban planning strategies should provide a clearer understanding of what the compact city can deliver from a sustainability perspective, particularly its impact on household behaviour, if it is to continue to be put forward as the preferred model for future urban development.

References

[1] Ghosh, S. & Vale, R. 2009. Typologies and Basic Descriptors of New Zealand Residential Urban Forms. Journal of Urban Design, 14, 507-536.

[2] Blair, J., *et al.* 2004. Affordability and sustainability outcomes: a triple bottom line assessment of traditional development and master planned communities - Volume 1. AHURI Final Report No. 63. Australian Housing and Urban Research Institute.

[3] Barr, S. 2003. Strategies for sustainability: citizens and responsible environmental behaviour. Area: Royal Geographic Society, 35, 227-240.

[4] Newton, P., *et al.* 2000. Housing Form, Energy Use and Greenhouse Gas Emissions. In: Katie Williams, E. B., Mike Jenks (ed.) Achieving Sustainable Urban Form. London E and F N Spon.

[5] Neuman, M. 2005. The Compact City Fallacy. Journal of Planning Education and Research, 25, 11-26.

[6] Jenks, M. & Jones, C. 2010. Dimensions of the Sustainable City. Future City Volume 2. Springer.

[7] Holden, E. & Norland, I. 2005. Three Challenges for the Compact City as a Sustainable Urban Form: Household Consumption of Energy and Transport in Eight Residential Areas in the Greater Oslo Region. Urban Studies, 42, 2145-2166.

[8] Randolph, B. & Troy, P. 2008. Attitudes to conservation and water consumption. Environmental Science and Policy, Volume 11, 441-455.

[9] Randolph, B. & Troy, P. 2007. Energy Consumption and the Built Environment: A Social and Behavioural Analysis. City Futures Research Centre Working Paper. Sydney: University of NSW.

[10] Mees, P. 2009. How Dense Are We? State of Australian Cities Conference. Perth; and Rickwood, P. & Glazebrook, G. 2009. Urban Structure and Commuting in Australian Cities. Urban Policy and Research, 27, 171-188.