# Assessing spatial distribution and variability of destinations in inner-city Sydney from travel diary and smartphone location data

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**Summary**

Relatively high densities and low car ownership levels in inner Sydney are associated with much lower levels of car use than other parts of Sydney's Metropolian Area but it is unknown how this affects the distribution nor the variability in destinations. Following processing of a dataset derived from a seven week travel diary and smartphone app, spatial density analysis is conducted on the destinations by variables including mode, purpose and day of the week. The results show substantial differences in choice of destinations depending on what mode is used and the purpose of the trip.

**KEYWORDS:** Spatial density, transport, destinations, trip purpose, smartphone tracking.

## 1 Introduction

The daily travel of residents in Sydney, Australia has generally been characterised by being largely car-based given the metropolitan area's relatively low population density (by global standards) and high car ownership levels (Greaves et al., 2014). However, the increasing affluance and density of inner-city suburbs coupled with an increasing push towards public transport and active travel by the City of Sydney council has resulted in a somewhat different mode share for travel in these areas (Bureau of Transport Statistics, 2013). Although this difference in market share has been well documented, it is not clear how this is related to the spatial distribution of trip destinations nor how this varies between individuals depending on what mode they use. With this in mind, this paper uses data on one week of travel of over 600 inner Sydney residents collected using a combination of an online travel diary and a location tracking smartphone app to analyse the spatial variability and distribution of trips with the aim of identifying the relationships between mode choice and destination choice.

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## 2 Background and Context

Sydney is a city with a relatively large area given its population and this means that many people travel considerable distances by car. Although the average daily travel distance is approximately 32km, this varies substantially with inner city areas seeing average daily travel distances of approximately 17km (10 miles) and some outer suburbs having average daily travel distances of over 60km (37 miles) (Bureau of Transport Statistics, 2013). This wide discrepency in the distance of trips is also evident in the choice of modes with trips by car ranging from 28 percent of trips to nearly 90 percent of trips. A large component of this variation between suburbs is associated with different levels of population density and car ownership levels throughout Sydney. In Figure 1 population density and vehicle ownership have been plotted on a map using a two dimensional colour gradient. Bright blue indicates areas with high population density (over and above 50,000/square kilometre) and low car ownership levels (cars per household). Bright red indicates areas with low population density and high car ownership levels. Dark colours indicate low values of both population density and car owernship levels and purple indicates medium values of both variables. As is clear from Figure 1, the higher concentration of areas with high population density and low car ownership is in and around Sydney's Central Business District (CBD).

The concentration of high density areas near the CBD coupled with an increasing focus on active travel by the City of Sydney council (albeit with relunctant support from the State government) means that the choice of destinations of residents and the modes used to access those destinations may also be changing (Pucher et al., 2010). Although these broad changes are slowly becoming apparent in aggregate statistics produced from census data and Sydney's continuous (one-day) household travel survey, it is not clear how destinations and modes vary within individuals as well as between them.

## 3 Data and methodology

A recent (and ongoing) multi-wave study designed to determine the effects of new bicycle infrastructure being built in Sydney on bicycle use in the inner city has resulted in the collection of both seven day travel diary data and corresponding location tracking data from smartphones for over 600 inner Sydney residents (Rissel et al., 2013). This dataset provides the opportunity to gain further insight into the travel patterns of residents in inner city areas and allows for the analysis of week long and repeated (over several years) travel data. The web-based travel diary used by respondents included questions common to many travel diary (including trip departure and arrival times, mode and purpose) as well as some intended to provide more detailed information on short and incidental trips, primarily short walking trips to and from public transport or local shops that are often forgotten by people completing travel diaries. In addition to this, some questions were asked to elicit further information about any reported bicycle trips that were largely focused on their use of separated bicycle infrastructure. The smartphone app was designed to complement (rather than replace) the travel diary and as such was designed simply to passively collect location data, primarily through WiFi location, approximately every five seconds and provide participants

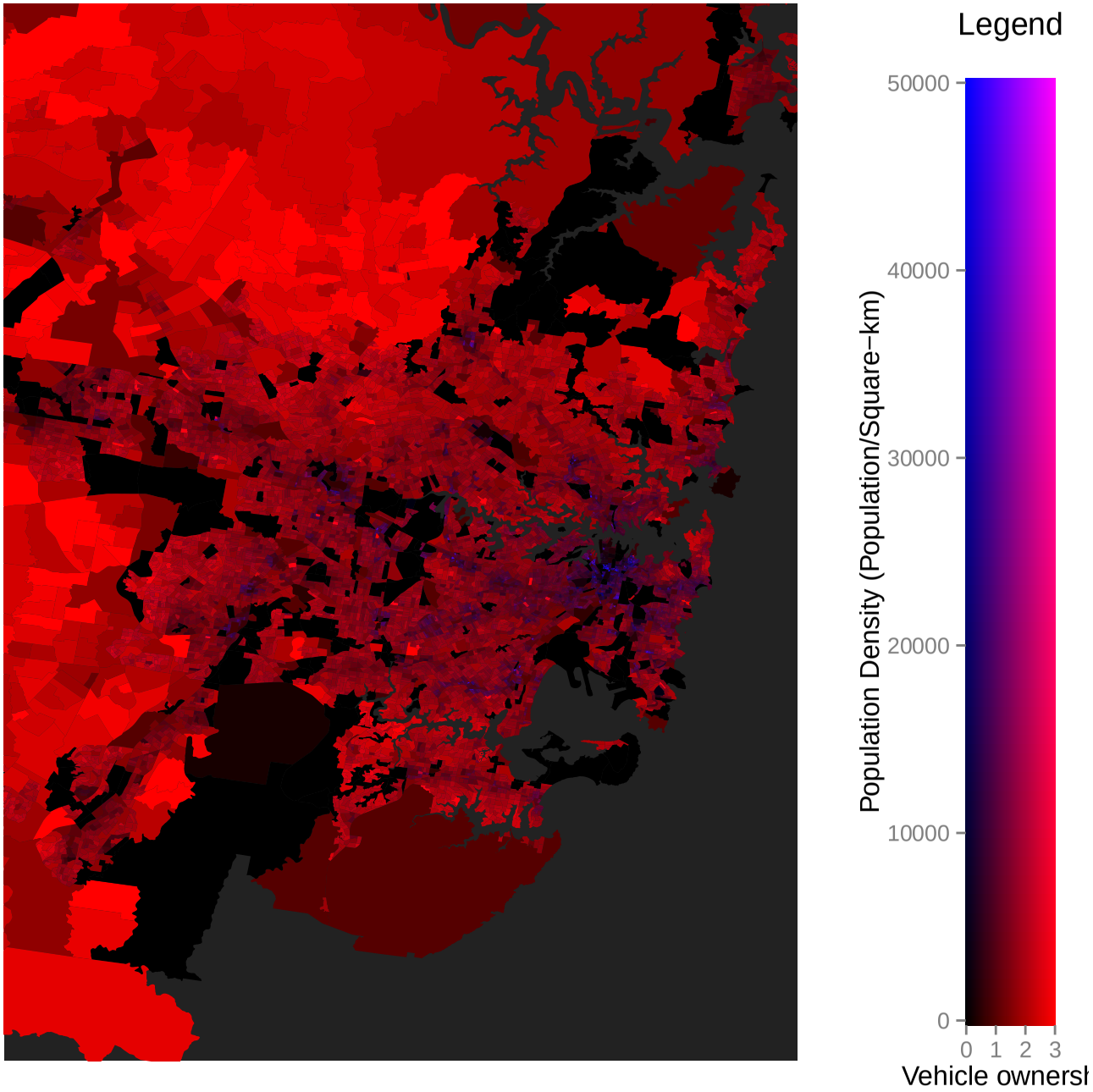


Figure 1: Population Density and Vehicle Ownership in Sydney Metropolitan Area

with the ability to view where they had travelled on a map (Greaves et al., 2014). Although the smartphone app was optional it was used by a significant proportion of participants with a total of approximately 54 million observations (so far).

The geocoded travel diary and smartphone datasets were combined into a single dataset recording all the trip destinations, purposes and mode as entered into the travel diary as well as intermediate stops calculated using the smartphone data. Additional destinations that were recorded by the smartphone tracking app but that respondents failed to record in their travel diary were also included. This combined dataset also included the calculation of other inferred trip variables including if the participant had travelled to work that day, the number of unique destinations in each trip tour[1] and the "main" mode for the trip. Using the combined dataset, a spatial density analysis was performed using several combinations of the trip variables included in the dataset. The spatial density analysis was used to assess the location and density of concentrations of destinations for a variety of different combinations of the trip variables. This was also conducted for different temporal classifications (e.g., weekdays and weekends, and morning, afternoon and evening) as a method of determining if the choice of destinations are associated with non-discretionary travel.

## 4 Results and Discussion

The results of the spatial density analysis on the combinations of trip purpose and travel mode show clear differences between the destinations of trips using each mode and for each purpose. However, there are also some similarities between modes/purposes with different modes having contours of similar shapes but different sizes suggesting a strong influence not only of the available destinations but also of the location of transport corridors and public transport services. Although conclusions from combinations of variables are perhaps most interesting, it is of use to look at mode and purpose separately before looking at the combination of the two variables.

For purpose alone, there are high concentrations of trip destinations for some purposes associated with specific land-use in Sydney (see Figure 2). This is most strongly evident (as can reasonably be expected) in destinations where the purpose is to attend university with destinations concentrated around the three main universities located in the area. Similarly, commuting trips are strongly concentrated in the city's CBD as well as the University of Sydney[2].

The spatial distribution of several of the other trip purposes are also reasonablly concentrated with most trips having destinations either close to home or in the CBD. Shopping trips appear to be particularly concentrated in a relatively narrow band stretching from the CBD to slightly further West than the suburbs included in this study. In contrast, trip purposes associated with recreational activities including sport, visiting friends and family, and religious activities cover a reasonably wide area.

The analysis of destinations by (main) mode suggest that there is also a difference in the density and distribution depending on the mode. Although this is to be expected to some extent given

[1] A series of trips starting and ending at home.

[2] One of the largest employers in inner Sydney is the University of Sydney.

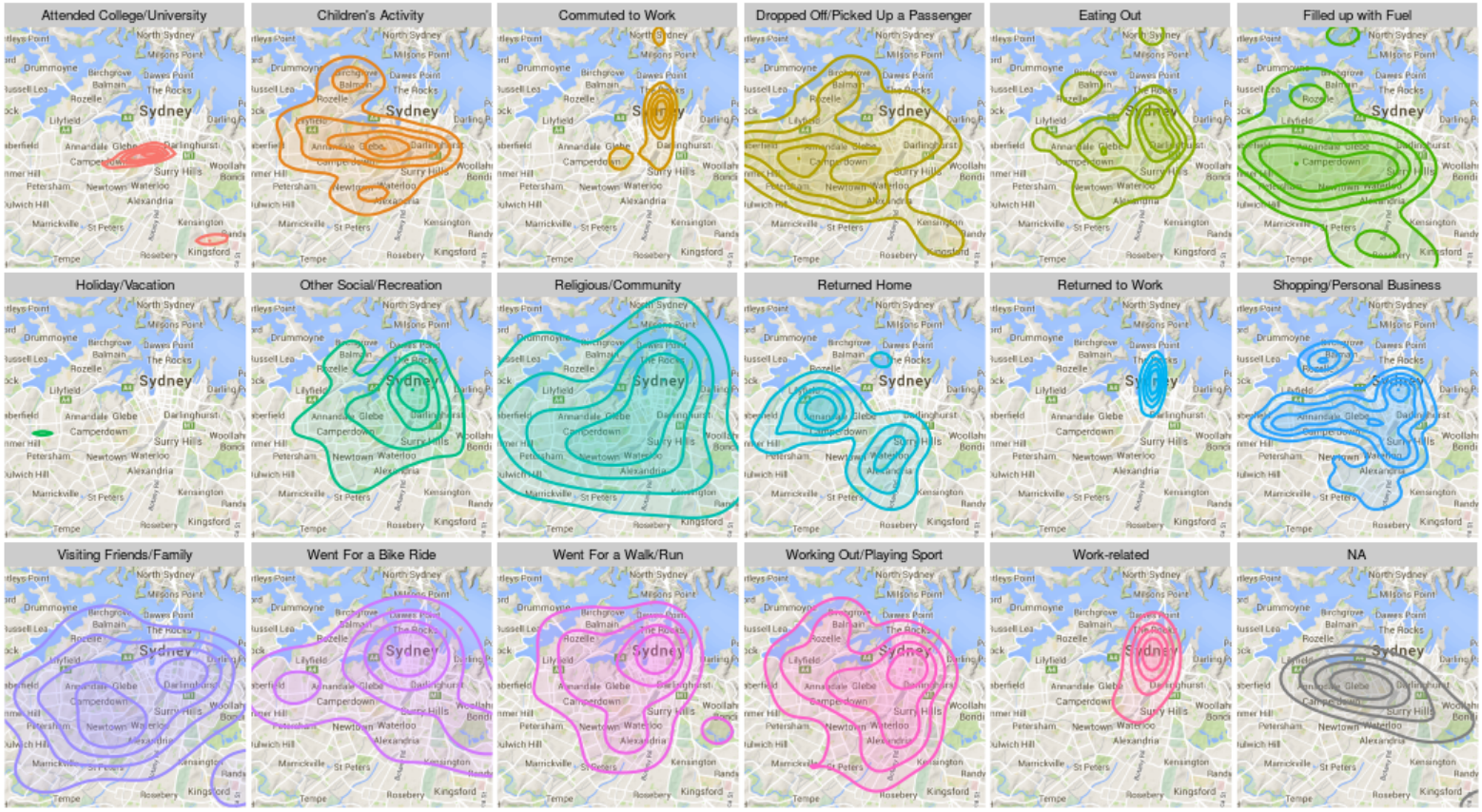


Figure 2: Spatial density plot of trip destinations by trip purpose

constraints limiting the use of some modes of transport to specfic corridors (train in particular), the differences are not as large as may have been expected. Furthermore, car trips are not significantly less concentrated than those of other modes. This is likely in part the result of the high availability of public transport in inner Sydney but may also be related to the large number of services available in the area that residents can reach by both cars and other modes.

When mode and purpose are assessed together, the differences between the modes become more apparent. This is particularly true of commuting trips (i.e., work/office destinations) in which the relatively small proportion of participants commuting by car travel to a wider geographic area but is also evident (to a smaller degree) with other purposes. One somewhat surprising result is that despite the flexibility of buses compared to trains, for many purposes destinations of bus trips are just as concentrated in (often similar) patterns to the train. This is despite Sydney's buses covering areas that are not very close to railway stations.

Analysis of some of the other trip variables also showed some differences in the distribution of trips. Although weekend destinations were rather less concentrated than weekday destinations, this varied substantially by purpose. Shopping and eating out were still relatively highly concentrated in similar areas during both weekdays and weekends with visiting friends and family being substantially less concentrated.

## 5 Conclusions

The analysis of the spatial distribution and variability of destinations by inner city residents of Sydney showed that the choice of destination is very much related to both the mode and purpose but also other trip characteristics (such as the day of the week). Furthermore, the high population density and low vehicle ownership of inner Sydney compared to the rest of the metropolitan areas has a clear relationship to the choice of destinations and the mode used to get there. In contrast to the travel of residents in outer areas of Sydney, destinations of inner Sydney residents is highly concentrated and characterised by repeated visits to several nearby areas for a variety of purposes.

## 6 Biographies

Richard B. Ellison is a Research Fellow at ITLS. His current research interests include modelling of freight transport and its environmental effects. He is also involved in several projects on cycling as well as broader research on the interaction between transport infrastructure investments and other wider benefits.

Adrian B. Ellison is a Research Fellow at the Institute of Transport and Logistics Studies (ITLS), The University of Sydney. Adrian's main research interests are in road safety, active travel and the use of GPS and smartphones to collect spatially aware data.

Stephen P. Greaves is a Professor of Transport Management at ITLS. Stephen's current research is focused around the health/environmental/safety impacts of transport, active travel including cycling, and innovative travel data collection methods using the latest technologies.

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