Spatial Analysis of Train Service Demand in Greater Melbourne

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1 Research Question and Topic

Our research question is to investigate **'How do population characteristics and location of non-residential properties impact the demand for train services?'** (non-residential buildings may include shopping centres or office buildings, they are places where the general population wishes to travel to.)

Topic: Urban Planning, Public Transport

2 Aim

The purpose of this research is to analyse the factors contributing to the demand for metro trains in Melbourne using spatial data analysis techniques, which builds towards a model to predict demand in locations that currently do not have train stations in an attempt to advise on the location of future constructions. Features that will be analysed include local population density and demographics (age, salary), and the existence of non-residential buildings. The relationship of elevation to the existing train lines will also be investigated to filter out locations where train line/station construction is infeasible from an engineering perspective.

3 Project Scope

- Geographical Scope: The boundary of our research is Greater Melbourne since train services beyond this region are sparse and scarce. Within the region, areas are aggregated according to ABS Statistical Area Level 2
- Temporal Scope: The scope for this project is present day. Data used in this project vary in timestamp between 2018 and 2023, but are considered sufficient proxies for the purposes of this project.
- Analysis Scope: The project will only investigate any features derived from the census, as well as the non-residential building types available in the data.

4 Literature Review

Metro Train is a vital service in the metropolitan area of Victoria. It provides connectivity across the region and has become one of the most popular travel options. According to the Department of Transport and Planning annual report, Victorian train services carried 173.8 million passengers from 2022-2023, and 90.39% are in the metropolitan region [2]. The accessibility for metro train services across Victoria is not uniform but varies significantly based on several factors. For example, a previous study in Melbourne based on public transport coverage has shown that areas with high population density have higher public transport accessibility [1]. Furthermore, an accessibility measure extending public transport accessibility levels (PTAL) and supply index (SI) is proposed, and it resulted in a similar conclusion [5].

While their approach analysed the frequency and availability of public transport service supplies, they did not incorporate the perspective of actual demand. There are two major factors that influence the demand for public transport: structural factors (such as travel time, distance, and level of transport supply) and external factors (including demographics, city-built environments, government policies, etc.) [4]. It implies that while population demographics and densities affect metro train usage, non-residential facilities are also important as there are more of them being developed in urban areas, such as shopping centres, schools and hospitals.

Many studies already exist for analysing correlation and predictive relationships between multiple factors in a spatial context. Amongst those commonly utilised are Geographically Weighted Regression (GWR) and Similarity GWR (SGWR). Multiscale GWR (MGWR) extend SGWR by removing its constraints on the local relationship within each model to vary at the same spatial scale [3].

Nonetheless, the actual placement of trains depends not solely on the population demand, but also on various environmental factors. For example, terrain elevation and hydrology also play critical roles in practical railway designs [6]. Therefore, it is necessary to address those aspects to provide a reliable recommendation for new train station locations.

5 Methodology

We propose to conduct our analysis in the following manner:

1. Conduct univariate point-data analysis (such as cluster and spatial-autocorrelation analysis) on:
    - Population characteristics data (from the census)
    - Location of non-residential buildings
    - Demand at each train station

    This analysis identifies geographic and demographic patterns by clustering population characteristics, locates key areas of activity using non-residential building data, and examines train station usage.
2. Perform multivariate point-data analysis and regression between the aforementioned factors and train station demand to determine their relationships. The result of this analysis shows how combinations of the above factors relate to train station demand, providing a quantitative basis for planning.
3. Analyse the station data in relation to the elevation data, to derive a threshold of slope change where building more train stations is not feasible
4. Propose locations for new stations based on the aforementioned findings by predicting demand at points that currently do not have train stations, and filtering proposals out by the DEM threshold.

6 Proposed Data Sources for project

6.1 Train Stop location data and Passenger Count data

Given the topic's focus, the Victorian train system dataset forms a cornerstone of our analysis. All subsets of this dataset are point data. Source: https://discover.data.vic.gov.au/dataset/train-service-passenger-counts

- Train stop location data gives the geographical location of each station.
- Train passenger count data is recorded from 2018.07 to 2023.07. The data records the number of boarding and disembarking passengers at each station for each service, which could be aggregated by time to be a proxy for the demand for trains at each station.

6.2 Census data

This is a polygon (point) from the Australian Bureau of Statistics (https://www.abs.gov.au/census/) containing the median values of various attributes of the residential population in each area.

6.3 Land Use datasets

We decide to use locations of hospitals, sports facilities, schools and shopping centres to model the region's land use. These are places that would contribute to the demand for trains, and cover the population's essential daily activities. The data sources are:

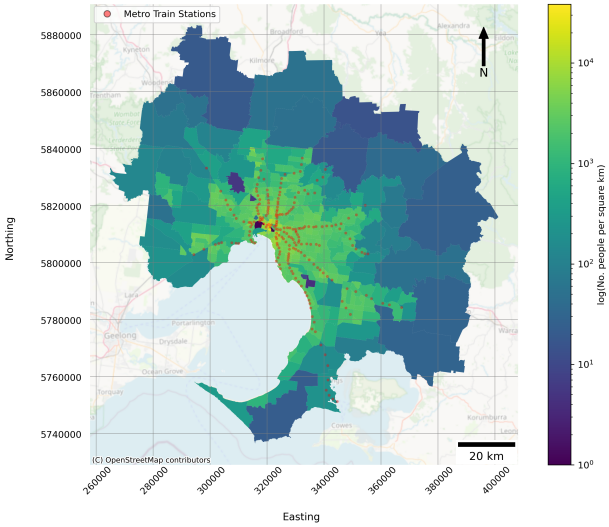
- Shopping Centres: https://www.australia-shoppings.com/malls-centres/victoria
- Hospitals: https://springernature.figshare.com
- Sports Facilities: https://discover.data.vic.gov.au/
- Schools: https://www.education.vic.gov.au

6.4 Digital Elevation data

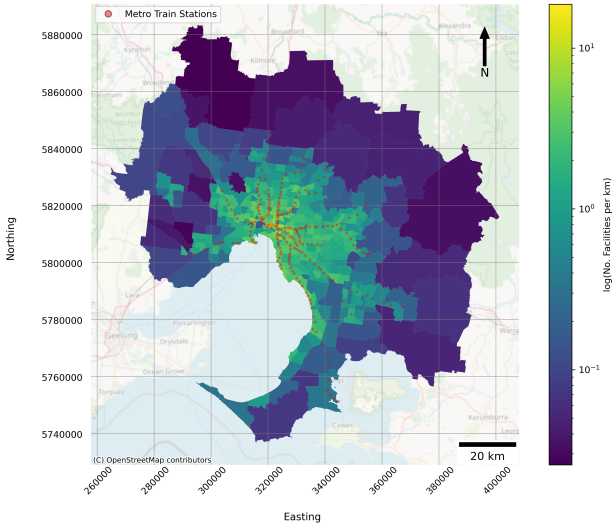
This is a raster dataset from DELWP DataShare (https://datashare.maps.vic.gov.au/search?q=DEM) that gives us the elevation at different points of Greater Melbourne.

7 Map

We present maps of density distributions of two of the features proposed for analysis. Each polygon represents a Statistical Area Level 2 region.



(a) Population Density of Greater Melbourne



(b) Non-residential Facilitiy Density of Greater Melbourne

8 Hypothesis

We hypothesise the existence of positive relationships between certain population density and certain population characteristics (i.e. age, income) which will impact demand for public transport. We also hypothesise the existence of building type shopping centre to have a significant positive relationship with demand. These should support the development of a model for predicting demand at other locations.

For elevation/train line analysis, we hypothesise high variability in elevation to have a negative relationship with station clusters.

References

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[4] Cihat Polat et al. "The demand determinants for urban public transport services: a review of the literature". In: (2016).

[5] Tayebeh Saghapour, Sara Moridpour, and Russell G. Thompson. "Public transport accessibility in metropolitan areas: A new approach incorporating population density". In: *Journal of Transport Geography* 54 (2016), pp. 273–285. ISSN: 0966-6923. DOI: https://doi.org/10.1016/j.jtrangeo.2016.06.019.

[6] Taoran Song et al. "GIS-based multi-criteria railway design with spatial environmental considerations". In: *Applied Geography* 131 (2021), p. 102449.