Leveraging GTFS to explore spatial patterns in transit supply with respect to social needs

James Reynolds[a,1], Yanda Qu[a,2], Graham Currie[a,3,*]

[a]*Public Transport Research Group (PTRG), Institute of Transport Studies, Department of Civil Engineering Engineering, Monash University, Clayton Campus, Melbourne, 3800, Victoria, Australia*

Abstract

This is the abstract.

It consists of two paragraphs.

Keywords: keyword1, keyword2

1. Introduction

The spatial distribution of transport disadvantage, gaps in transit supply and accessibility, and related issues have been the topics of much previous research. This has included studies of:

- geographic gaps in transport supply when accounting for social needs;
- transport disadvantage, well-being, social exclusion and equity with respect to accessibility;
- the use of Lorenz curves to explore how equitably transit speeds or accessibility is distributed; and various other similar approaches[4].

Much of this literature outlines approaches and methodologies for calculating the extent of transport need and transit supply, and then comparing the two across some geographic area. However, such methodologies do not appear to often be used again in further research to study other cases. In part this may be because there is not as much that is 'new' research knowledge that is created when applying the same methods to a different location. Instead, such efforts may be more likely to be done by practitioners than researchers. As well, presenting an approach or methodology in a research paper might only require an outline and presentation of some limited 'proof of concept' results for one geographic area.
Such results might be generated through bespoke, rather than generalised, methods given that there may

*Corresponding author

Email addresses: james.reynolds@monash.edu (James Reynolds), yanda.qu@monash.edu (Yanda Qu), graham.currie@monash.edu (Graham Currie)

[1]Research Fellow

[2]PhD Student

[3]Professor

[4]See for example Ricciardi et al. (2015) Currie et al. (2003); Currie (2010); Fransen et al. (2015); Guzman et al. (2017a); Jaramillo et al. (2012); Preston and Rajé (2007a); Delbosc and Currie (2011c); Delbosc and Currie (2011b); Engels and Liu (2011); Pavkova et al. (2016); Delbosc and Currie (2011a); Murray and Davis (2001); Currie and Delbosc (2010); Currie et al. (2007); Currie and Senbergs (2007); Yigitcanlar et al. (2007); Wu and Hine (2003); Currie and Delbosc (2013); Preston and Rajé (2007b); Hurni (2005); Mamun and Lownes (2011); El-geneidy et al. (2016); Kaplan et al. (2014); Martens et al. (2012); Lucas et al. (2016); Liu and Engels (2012); Lucas (2012); Lei and Church (2010); Mavoa et al. (2012); Delmelle and Casas (2012); Foth et al. (2013); Welch (2013); Bell and Currie (2007); Jaramillob and Grindlayc (2011); Guzman et al. (2017a); Wee and Geurs (2011); Currie (2004); Engels and Liu (2011); Litman (2002); Parolin and Rostami (2017); Xia et al. (2016); Welch and Mishra (2013); Jang et al. (2017).

be little need for the researchers in question to generate results for different places or again after some time has passed.

An example is provided by the Currie et al. (2003) Currie (2004), Currie and Senbergs (2007), Currie (2010) studies on spatial gaps between the social need for transport and the supplied transit levels. This work presented a transit Supply Index (SI) and compared it to measures of social need for transport in Melbourne, Hobart and elsewhere in Australia. However, it is unclear whether the problems relating to social needs and transit supply identified this previous research in the almost two decades since the original analysis. Nor is it clear whether the identified spatial patterns of transit need, supply and gap in these cities are generalizable to other places as the Currie (2010) approach does not appear to have been widely used since those studies. This is perhaps in part because at the time it was first published the transit Supply Index (SI) was not easy to calculate. The Currie (2010) analysis was based on combining multiple operator databases and service frequency data that had been manually extracted from transit agency websites.

Nowadays, however, the General Transit Feed Specification (GTFS) allows timetable data to be published in a standardized format, with more than 10,000 agencies releasing data this way (MobilityData, undated). Various tools for analysing GTFS data are now available, but there does not appear to have been many developed to allow the analysis of spatial gaps between the social need for transport and the amount of transit that is supplied.

While the previous literature provides a wealth of methodologies, the availability of tools that might be used by researchers, practitioners and advocates to easily use these approaches with GTFS data appears to be limited.

These gaps provide the motivation for the research reported in this paper, in which a new R package (gtfssupplyindex) specifically developed to calculate SI scores is presented. The paper also reports results for Greater Melbourne in 2016 and 2021, matching the most recent censuses and allowing comparison to the 2006 result reported in Currie (2010).

Comparisons are also made to other parts of Australia, so as to explore whether the findings about Greater Melbourne are generalizable.

The remainder of this paper is structured as follows: the next section outlines the background to this research, including the original formulation of the Transit Supply Index, and an explanation of the GTFS. Section 3 then describes the study methodology, followed by presentation of results in Section 4. Section 5 discusses the results and the limitations of this study, and outlines directions for future research. A brief conclusion is provided in Section 6.

2. Background

2.1. Transit metrics

Even a brief search reveals many metrics available for benchmarking transit services. Examples include: (1) those in the Transit Cooperative Research Program (TCRP) Report 88, which is an extensive guidebook on developing a performance-measurement system (Ryus et al., 2003); (2) online databases provided by the Florida Transit Information System (FTIS) (Florida Transit Information System, 2018) and International Association of Public Transport (UITP) (2015); (3) those used in the extensive benchmarking program undertaken yearly by the Transport Strategy Centre in the United Kingdom, (Imperial College London, undated); and (4) a recently developed methodology to calculate 'blank spots', beyond typical walking access distances to/from transit stops (Alamri et al., 2023). The Fielding Triangle (Fielding, 1987) provides a framework for combining indicators of service inputs, outputs and consumption to describe cost efficiency, cost effectiveness and service effectiveness. More broadly:

- Litman (2003) and Litman (2016) discuss some of the traffic, mobility, accessibility, social equity, strategic planning and other rational decision-making-based perspectives underling transport indicators;
- Reynolds et al. (2017) extends these into models of how institutionalism, incrementalism and other public policy analysis concepts might apply to decision-making processes relating to transit prioritization;

- Guzman et al. (2017b), developed a measure of accessibility in the context of policy development and social equity for Latin American Bus Rapid Transit (BRT) networks; and

- Creutzig et al. (2020) introduced street space allocation metrics based around 10 ethical principles

However, many of these, and other, transit metrics may be difficult to calculate and complex to explain or understand. It is also unclear how well suited transit metrics are to communication with those who are not planners, engineers or other technical specialists, especially political representatives and the general public. Where pre-calculated metrics are immediately available it may not be possible for practitioners, researchers or advocates to independently generate scores so as to test proposed system changes. Sometimes it is not even possible to know precisely how scores for the existing services levels are calculated.

Contrasting examples are provided by the metrics in the Transit Capacity and Quality of Service Manual (TCQSM) and the Transit Score metric, readily available on the Walk Score (2023) website, A Transit Score is available for locations with a published GTFS feed, eliminating the need for any calculations. The meaning of these Transit Scores also appears easy to explain, with the highest possible score of 100 representing what might be experienced in the center of New York. However, the Transit Score algorithm is unpublished, and effectively a black box. It does not appear that Transit Scores can be calculated independently or generated for proposed changes to networks. In contrast, the TCQSM provides a wide range of metrics for measuring different aspects of a transit system. The TCQSM scores themselves appear easy to understand or explain, ranging from A to F, although the number of metrics is very large and this might limit the practicality of using the TCQSM in practice for communicating with non-technical audiences. All of these can be calculated independently, given sufficient data, and Wong (2013) provides an example reporting various TCQSM metrics across 50 transit operators. This analysis by Wong (2013) is made possible by the availability of General Transit Feed Specification (GTFS) datasets for each of the transit systems

The GTFS is an open, text-based format, developed originally to allow transit to be included in the Google Maps navigation platform (MobilityData, undated). Figure @ref(fig:GTFS_ERD) shows an Entity Relationship Diagram (ERD) of the GTFS data structure, indicatating how GTFS data is stored as a series of tables (agency, routes, trips etc.) with primary and foreign keys (agency_id, route_id, trip_id etc.) providing links. While there are many software tools for analyzing, visualizing or otherwise manipulating GTFS data, one to calculate Transit Supply Index scores is not yet available.

2.2. The Transit Suppy Index

A generalized form of the SI equation, adapted from Currie (2010), is:

$$SI_{area,time} = \sum \frac{Area_{Bn}}{Area_{area}} * SL_{n,time}$$

where: (1) $SI_{area,time}$ is the Supply Index for the area of interest and a given period of time; (2) $Area_{Bn}$ is the buffer area for each stop (n) within the area of interest (in Currie (2010) this was based on a radius of 400 metres for bus and tram stops, and 800 metres for railway stations); (3) $Area_{area}$ is the area of the area of interest; and (4) $SL_{n,time}$ is the number of transit arrivals for each stop for a given time period.

Figure 2 shows a map of SI scores across Greater Melbourne in 2006, which was included in Currie (2010). The general pattern appears to be higher levels of transit supply closer to the Central Business District (CBD) and passenger railway lines, and large areas wth very low SI scores or no transit supply at all in outer areas.

2.3. Social need and needs gap

Currie (2010) also assessed the social need for transit across Greater Melbourne using: the Australian Bureaus of Statistics' Index of Related Socio-Economic Advantage/Disadvantage (IRSAD); a transport needs index derived by Currie (2010) from eight weighted indicators; and a combination of the two. The indicators used in the derived transport needs index were:

- Adults without cars (weight 0.19);

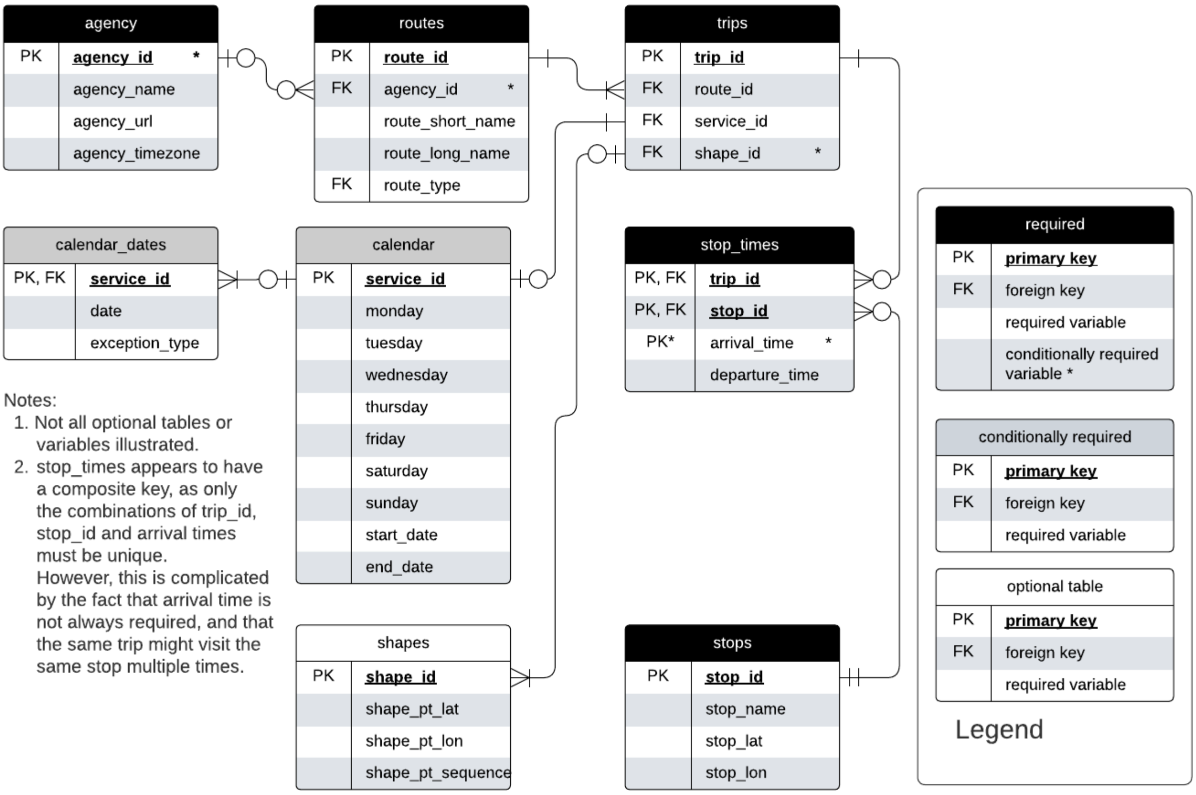

Figure 1: GTFS entity relationship diagram. Source: adapted by author from Alamri et al (2023) and the GTFS Schedule Reference (16/11/2023 revision).

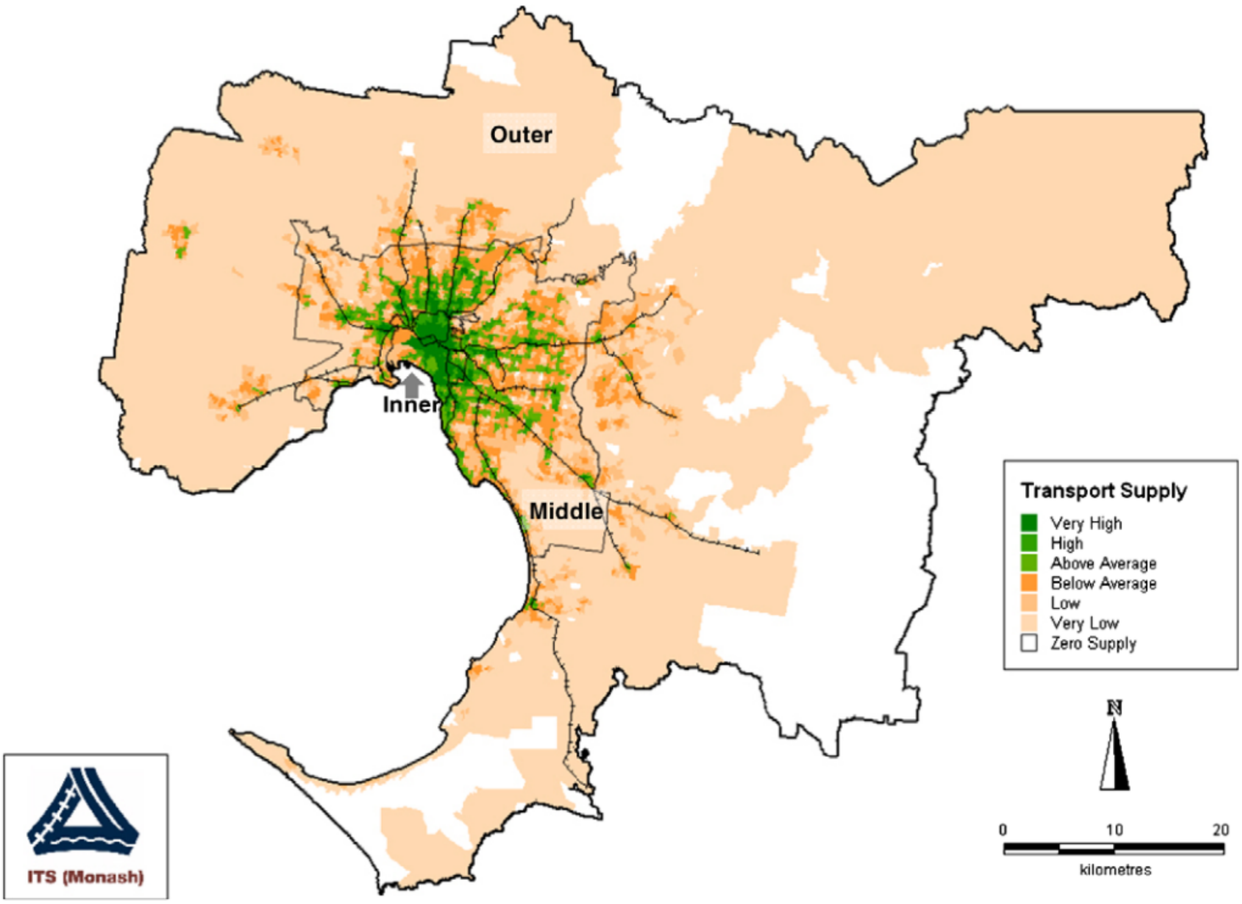

Figure 2: Distribution of supply measure scores – Metropolitan Melbourne (2006), Source: Currie (2010)

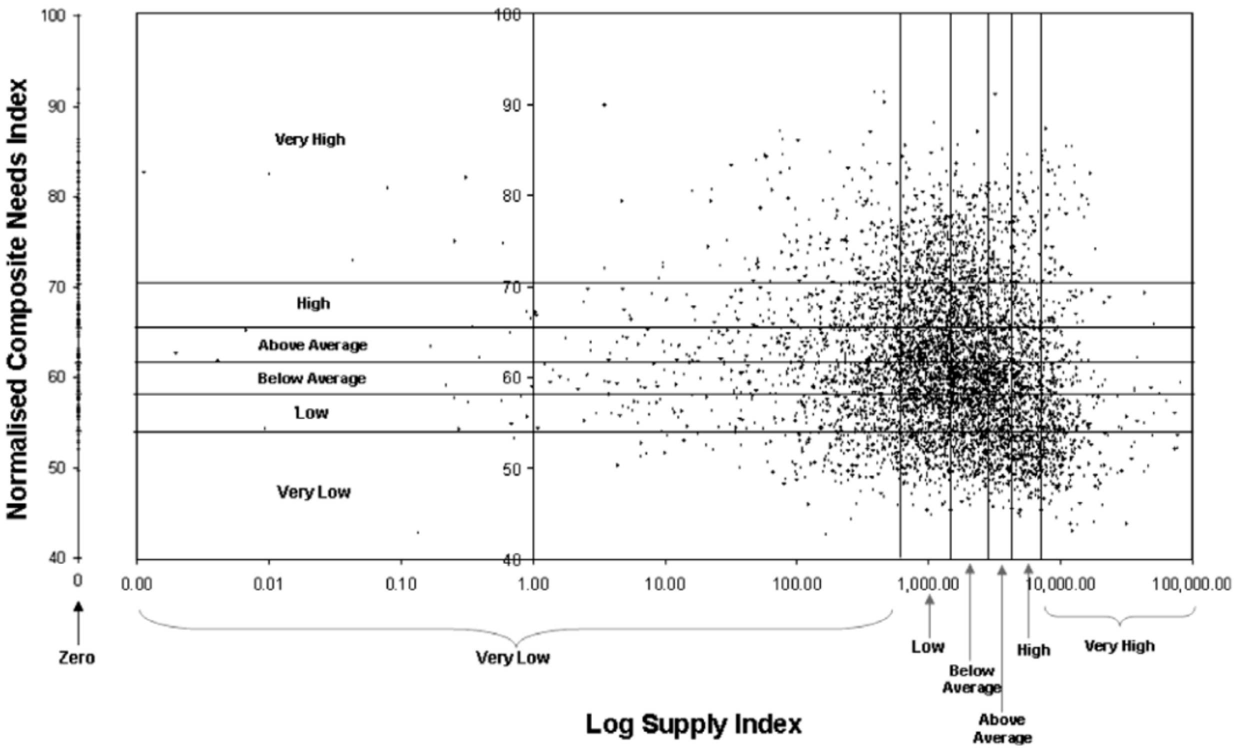

Figure 3: Log supply score and need index values – Melbourne needs-gap study, Source: Currie (2010)

- Accessibility, being the distance from the Melbourne CBD (weight 0.15);
- Persons aged over 60 years (0.14);
- Persons on a disability pension (0.12);
- Low income households (0.10);
- Adults not in the labour force (0.09);
- Students (0.09); and
- Persons 5-9 years old (0.12).

Data was sourced from census information, except for the accessibility variable and for the disability pension variable, which came from Centrelink, the federal government agency that manages income support payments. Figures 3 and 4 reproduce a chart comparing transport needs and transit supply, and a map of areas with very high social needs but zero or very low transit supply.

The results indicated that that there were service gaps of concern, especially in outer parts of Melbourne where low density development patterns make provision of transit more challenging. Currie (2010) found that "(o)verall, 8.2% of Melbourne residents have 'very high' needs but 'zero', 'low' or 'very low' public transport supply.", and suggested that this approach was "substantially more useful than the presentation of anecdotal evidence which is the most common means of identifying transport needs in local transport studies throughout the world."

However, it doesn't appear that this approach has been widely adopted in practice or academia.
Nor does it appear to have been applied to other places, except for related studies of Hobart and Adelaide that preceded Currie (2010). Our suspicion is that while the SI has a relatively simple formula and requires only geographic and timetable data, the lack of a software tool to perform these calculations may be part of the reason that it has not been more widely adopted and why formal needs-supply-gap analysis appear uncommon.
It is also unclear whether the patterns in Melbourne, where areas with very high transport needs but zero

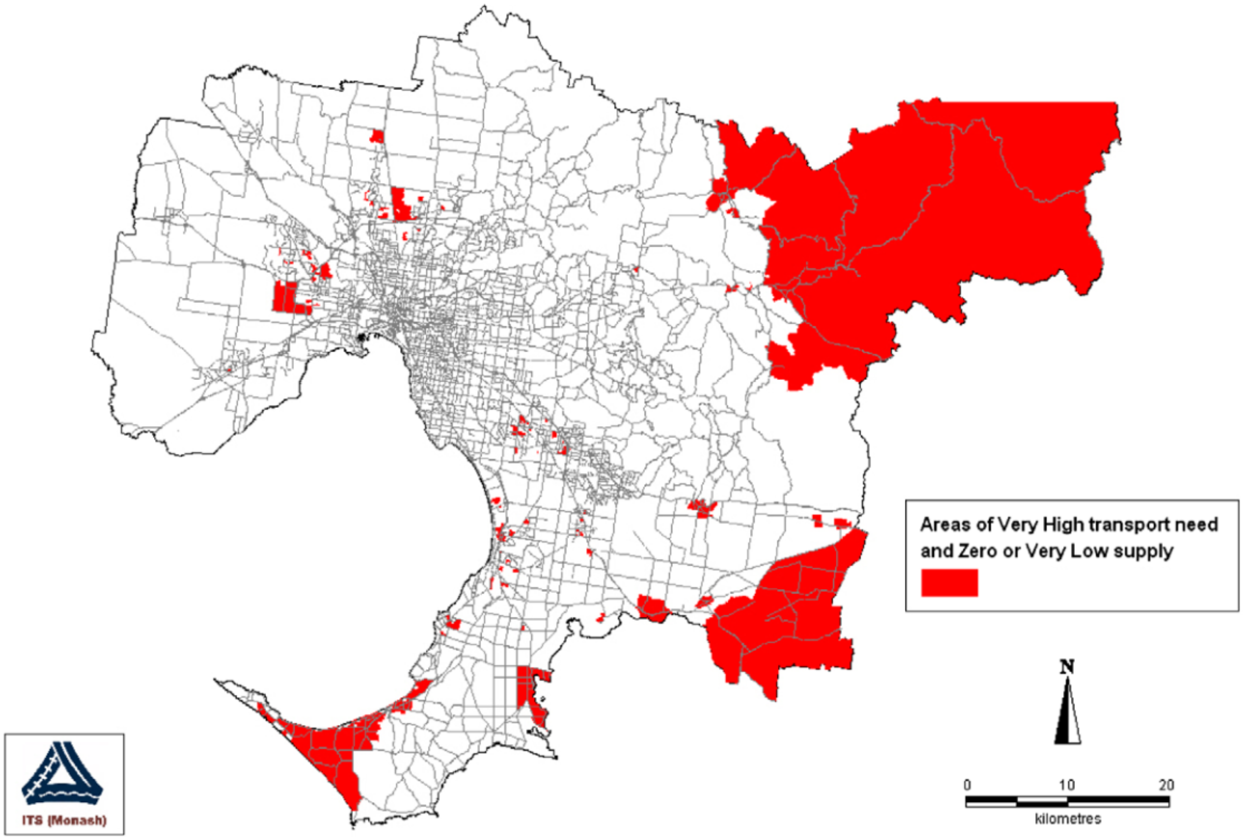

Figure 4: Melbourne needs-gap – very high transport need areas with zero or very low public transport supply, Source: Currie (2010)

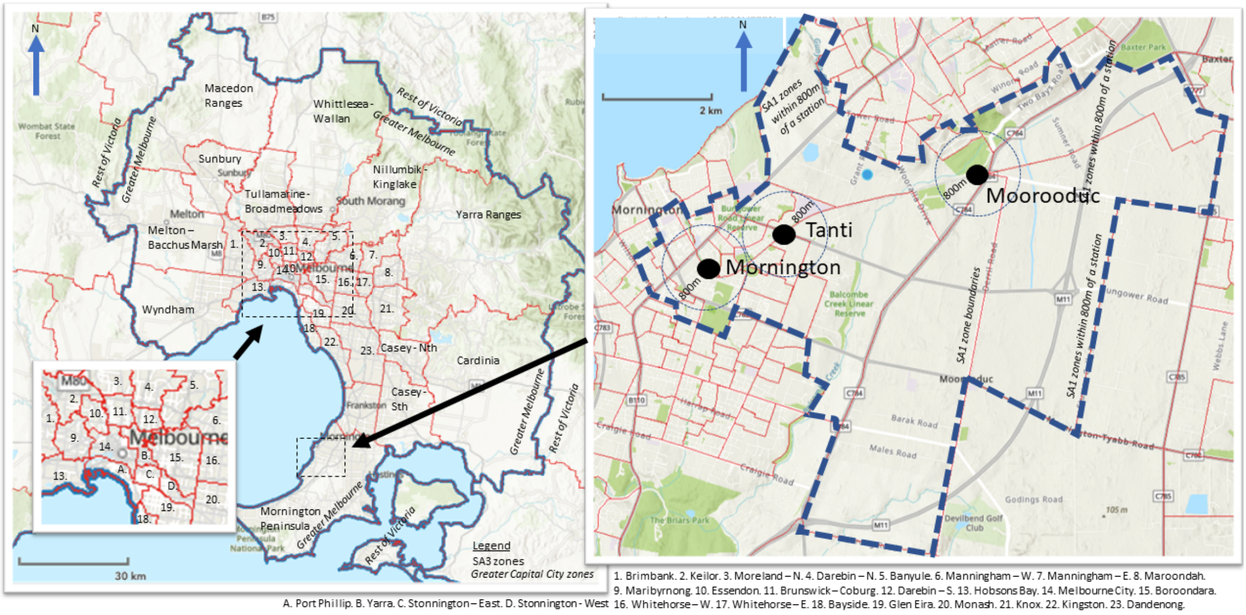

Figure 5: Areas of interest

or very low transit supply tend to be in outer areas of the city serviced by buses, are similar to patterns in other cities. Nor is it clear whether the patterns in Melbourne itself have changed since the 2006 analysis.

Developing a software tool, and then using it to comparing current conditions and other locations to the findings of Currie (2010), therefore, is the primary aim of this paper.

3. Methodology

This study developed a package with tools for calculating the SI from GTFS data. The R programming language (R Core Team, 2023) was adopted for code development. Package development setup and workflow as described by Wickham and Bryan (2023) was adopted. Various existing packages were relied upon including: the sf package (Pebesma, 2023) for geospatial analysis; the tidyverse (Wickham et al., 2019); gtfstools (Herszenhut et al., 2022); and tidytransit (Poletti et al., 2023). Some code was adapted from examples, vignettes and other documentation in the tidytransit, gtfstools and other packages.

Two cases were used during the code development and testing, such that results might be generated for real GTFS data: the Mornington Peninsula Tourist Railway GTFS feed and the Public Transport Victoria (PTV) GTFS feed, both in Victoria, Australia. Both were selected primarily for convenience, given that the authors are familiar with the typical service patterns and geography. The Mornington Peninsula Tourist Railway network, consisting of only three stations, also facilitated hand calculation of the SI as a cross-check of the results produced by the developed package.

Figure @ref(Melbourne_map)) shows the areas of interest relevant to the code development and testing, and selected railway stations. Statistical Area (SA) zones were adopted from the Australian Bureau of Statistics (Australian Bureau of Statistics, undated) as the areas of interest, and included SA3 zones across Greater Melbourne (main) and SA1 zones within 800 metres of the Mornington Penninsula railway (right). SA1 zones are the smallest geographical areas for which results are reported in the Australian census.
The census also reports results across the Greater Melbourne Greater Capital City (GCC) zone and SA3 zone boundaries, which are generally similar to Local Government Area (LGA) boundaries.

3.1. Mornington Penninsula Tourist Railway

The Morning Peninsula Tourist Railway is in the outer south-east of Melbourne, running on Sundays and Wednesdays between Mornington and Moorooduc, with an intermediate stop at Tanti Park (see https://transitfeeds.com/p/mornington-railway/806/latest/stops). A GTFS feed from 2018 was selected for the purposes of tests and demonstrating the code and output. Australian Bureau of Statistics (ABS) data was also used, sources via the strayr and absmapsdata packages (Mackey et al., 2023). The Mornington Peninsular Statistical Area 3 (SA3) zone and the Statistical Area 1 (SA1) zones contained within it were adopted as the areas of interest.

3.2. Public Transport Victoria (PTV)

The Victorian GTFS feed, published by Public Transport Victoria (PTV) and with historical feeds sourced via Transit Mobility Data, (2023), was used for analysis of Victoria. SI scores were obtained for the weeks starting on the day of the census in 2016 and 2021, which were on Tuesday 9th and 10th of August respectively.

3.3. Social disadvantage measurement approach

This paper adopts the same approach to social disadvantage measurement as in Currie (2010).

Continue from here»»»

4. Results

4.1. Code structure and functionality

Developed code is available and documented on github (Reynolds, 2024). The structure of the package, functions developed, and data tables are shown in Figure @ref(fig:SI_ERD). This shows
how the package takes input from three files: a gtfs feed (gtfs.zip); a sf object describing the geometry of the areas for which the SI is to be calculated; and a csv file (included in the package) defining the buffer zone distances for each route type. The ultimate output is a si_by_area_and_hour table (bottom-right), which reports the SI score for each hour of the day across dates specified by the user.

Various functions and their output are explained in the following, using the Mornington Peninsula GTFS for December 30th, 2018, and SA1 zone boundaries as a worked example. Individual steps are:

(1) loading the gtfs.zip file: the gtfs_by_route_type function loads the gtfs data and splits it into a list (by route_type) of tidygtfs objects, using the filter_by_route_type function from the gtfstools package (Herszenhut et al., undated).
(2) loading geometry information about the areas of interest: geographical data about the areas of interest are loaded by the load_areas_of_interest.R function into an sf object, using the sf package (Pebesma, 2023). The resultant areas_of_interest table contains each area_id and its associated geometry. Data about buffer zones, specifically the walking distance threshold assigned to each route_type (mode) is then loaded, again through a function (load_buffer_zone.R).
(3) calculating which stops are within the catchment walking distance of which areas: using the stops_in_walk_dist function. Figure @ref(fig:calculate_stop_in_or_near_areas_verbose)) shows how this function identified SA1 areas within the 800 metre catchment of the three Mornington stations.

(4) Calculating SI scores for a given time period: The si_calc.R function calculates the number of arrivals in a given time period, using code adapted from an article included in the tidytransit package (Poletti, undated), and combines this with the calculated area components. The si_total.R and hourly.R functions provided aggregation, giving the results mapped in Figure @ref(fig:SI_mornington_20181230_output).

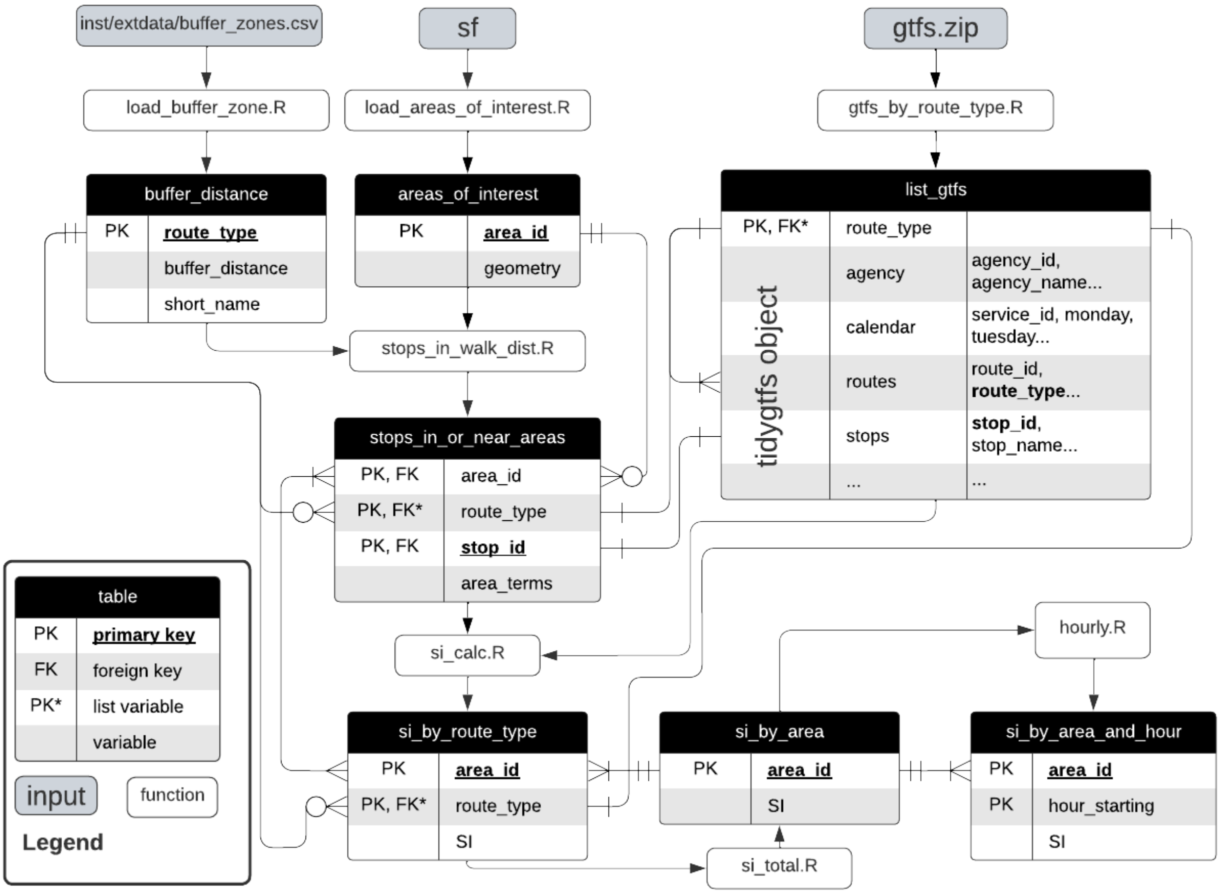

Figure 6: Entity Relationship Diagram (ERD) showing the data structure and functions related to the gtfssupplyindex package

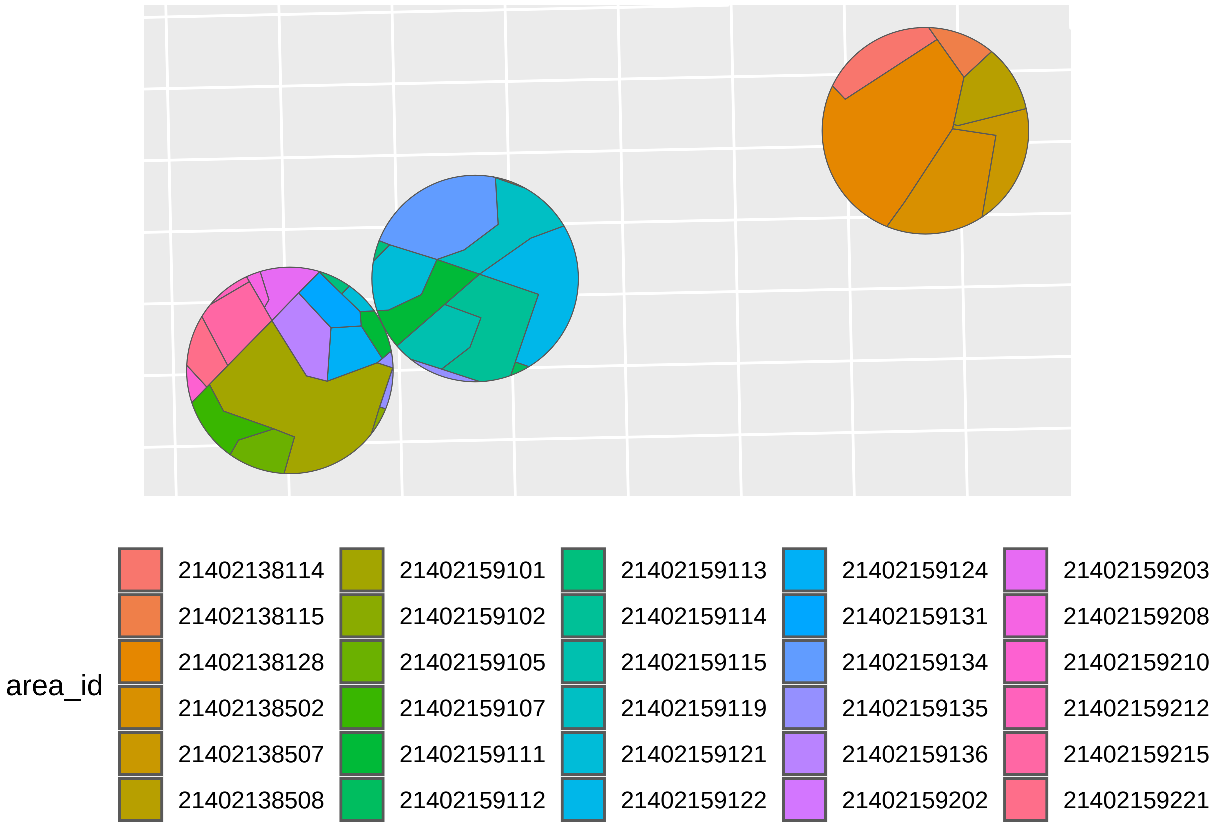

Figure 7: Step 3, stop catchments for the Mornington Penninsula Tourist Railway, showing intersections with SA1 zones

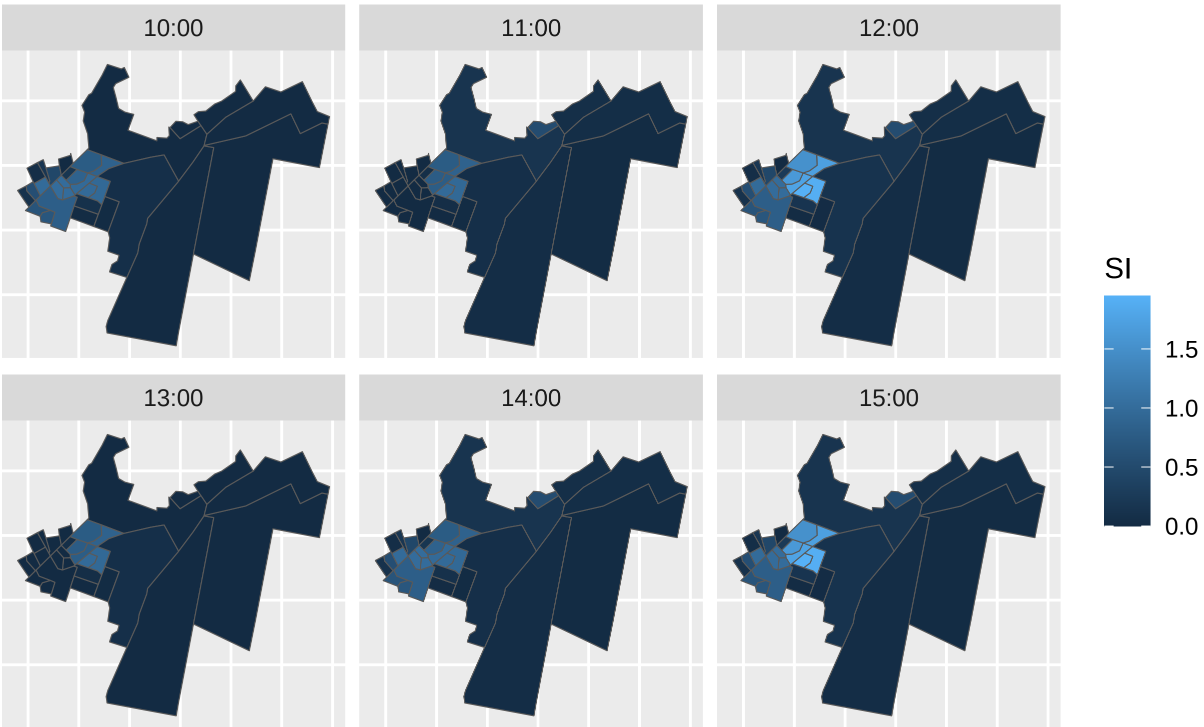

Figure 8: Mornington Penninsula Tourist Railway hourly SI values for December 30, 2018

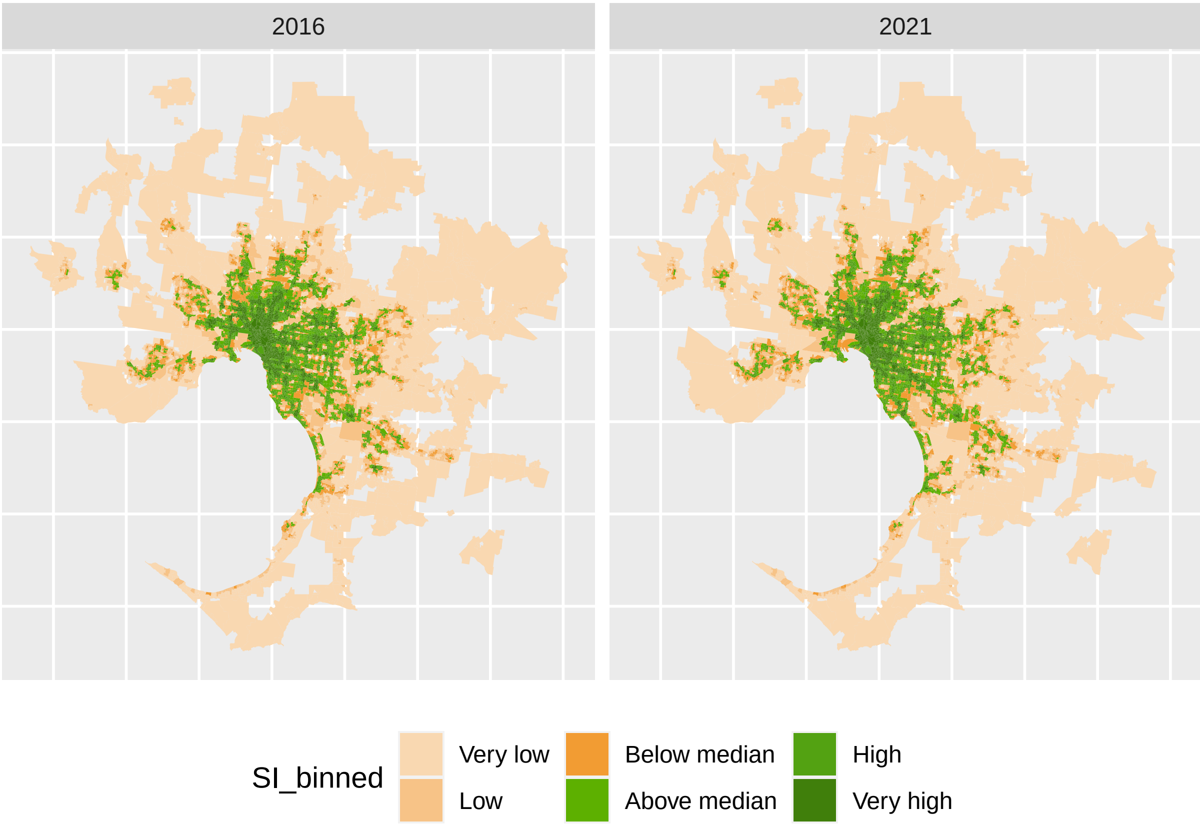

Figure 9: SI scores, census day 2016 and 2021

4.2. SI scores

4.2.1. IMRAD

4.3. Comparing cases

4.3.1. Population and equality

4.4. Purpose of transit in the city's transport policy

4.5. Indexes and comparing cities

5. Discussion

5.1. Limitations and directions for furture research

6. Conclusions

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