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

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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 a focus of previous research[4]. Much of this presents methodologies for calculating social needs and transit supply so as to locate areas where people who most need public transportation are not getting it. However, such methodologies appear to only rarely be revisited, reused or otherwise applied to other cases or time periods in subsequent research. This may in part be because applying an existing methodology to another location or time period might not generate sufficient 'new' knowledge for publication, and/or be more an activity for practitioners than for researchers. As well, describing a new methodology in a research paper might only require presentation of enough results to demonstrate the concepts, rather than widespread application to multiple geographic contexts, which might necessitate the development of software tools to facilitate broader usage.

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 across a few Australian cities.

But there does not appear to have been much further use of this approach in research or practice. It is unclear whether the gaps identified in this previous research have become narrower or being resolved in the almost two decades since the original analysis. Nor is it clear whether the identified spatial patterns of

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[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 (2011b); Delbosc and Currie (2011a); Engels and Liu (2011); Pavkova et al. (2016); Delbosc and Currie (2011c); 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).

transit need, supply and gaps are generalizable to other places, beyond Hobart (Currie et al., 2003; Currie, 2004) and Melbourne (Currie and Senbergs, 2007; Currie, 2010).

This is perhaps in part because at the time it was first published the data needed to calculate the transit Supply Index (SI) for a particular location was not typically readily available. The Currie (2010) analysis of Melbourne was based on combining multiple operator databases and service frequency data that had been manually extracted from transit agency websites. To apply the methodology elsewhere would appear likely to have required a bespoke data collection, cleaning and analysis effort. Nowadays, however, the General Transit Feed Specification (GTFS) allows timetable data to be published in a standardized format. More than 10,000 transit agencies release 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 use these approaches with GTFS data relatively easily appears limited.

This gap provides 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 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 formulation of the Transit Supply Index (SI), 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 those in: the extensive Transit Cooperative Research Program (TCRP) Report 88 guidebook on developing performance-measurement systems (Ryus et al., 2003); and those used across benchmarking databases and programs (Florida Transit Information System, 2018; International Association of Public Transport (UITP), 2015; Imperial College London, undated). 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/or complex to explain or understand, especially for those who are not planners, engineers or other technical specialists. 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, or demonstrate impacts to politicans, the general public or others. Contrasting examples are provided by the metrics in the Transit Capacity and Quality of Service Manual (TCQSM) and the Transit Score metric (Walk Score, 2023). Transit Scores are readily available on the Transit Score website for locations with a published GTFS feed. The meaning of these Transit Scores also appears easy to explain, with the highest possible score of 100 representing the sort of transit accessibility that might be xperienced in the center of New York. However, the Transit Score algorithm is a black box, and cannot be calculated independently or generated for proposed

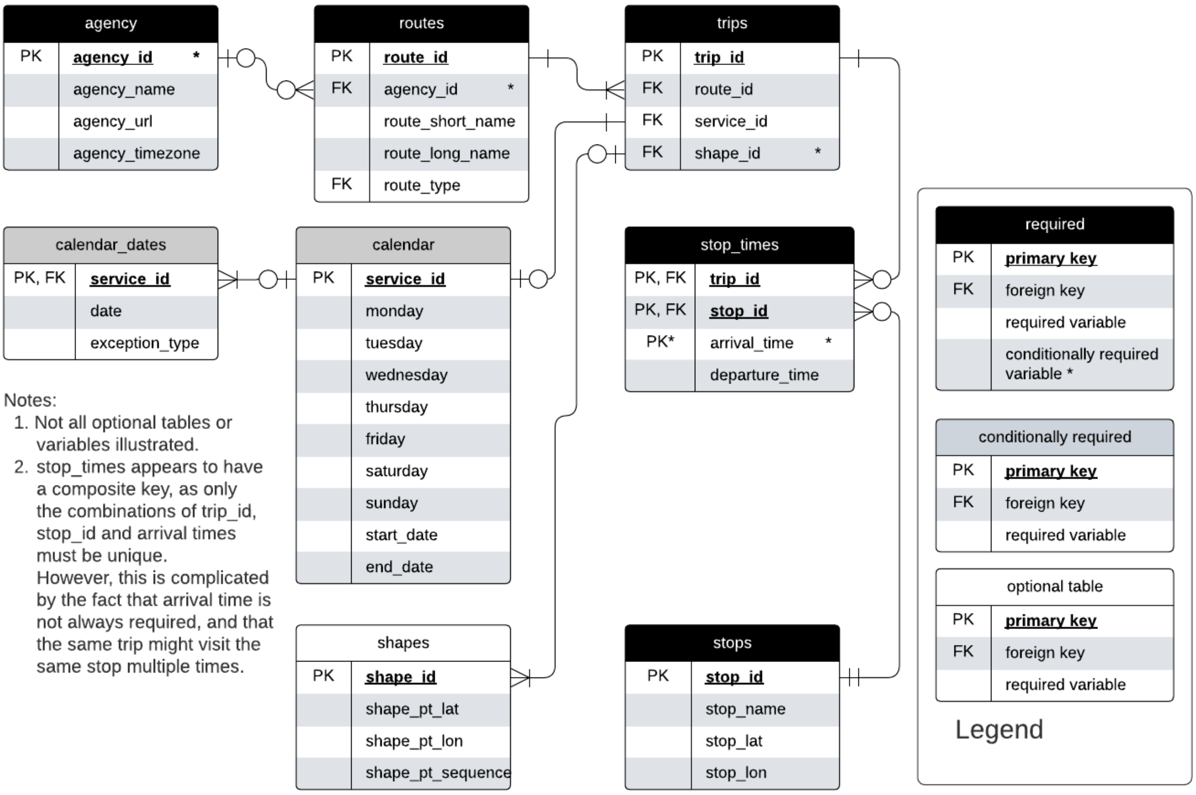

Figure 1: GTFS entity relationship diagram. Source: adapted by author from Alamri et al (2023) and the GTFS Schedule Reference (16/11/2023 revision).

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 (good) to F (bad), and these can be calculated independently, given sufficient data. Wong (2013) provides an example of what can be done combining GTFS data with metrics that can be independently calculating, reporting TCQSM scores across 50 transit operators.

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 structure, indicatating how data is stored as a series of tables (agency, routes, trips etc.) linked by primary and foreign keys (agency_id, route_id, trip_id etc.). While there are many software tools for analyzing, visualizing or otherwise manipulating GTFS data, one to calculate Transit Supply Index (SI) 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:

- $SI_{area,time}$ is the Supply Index for the area of interest and a given period of time;

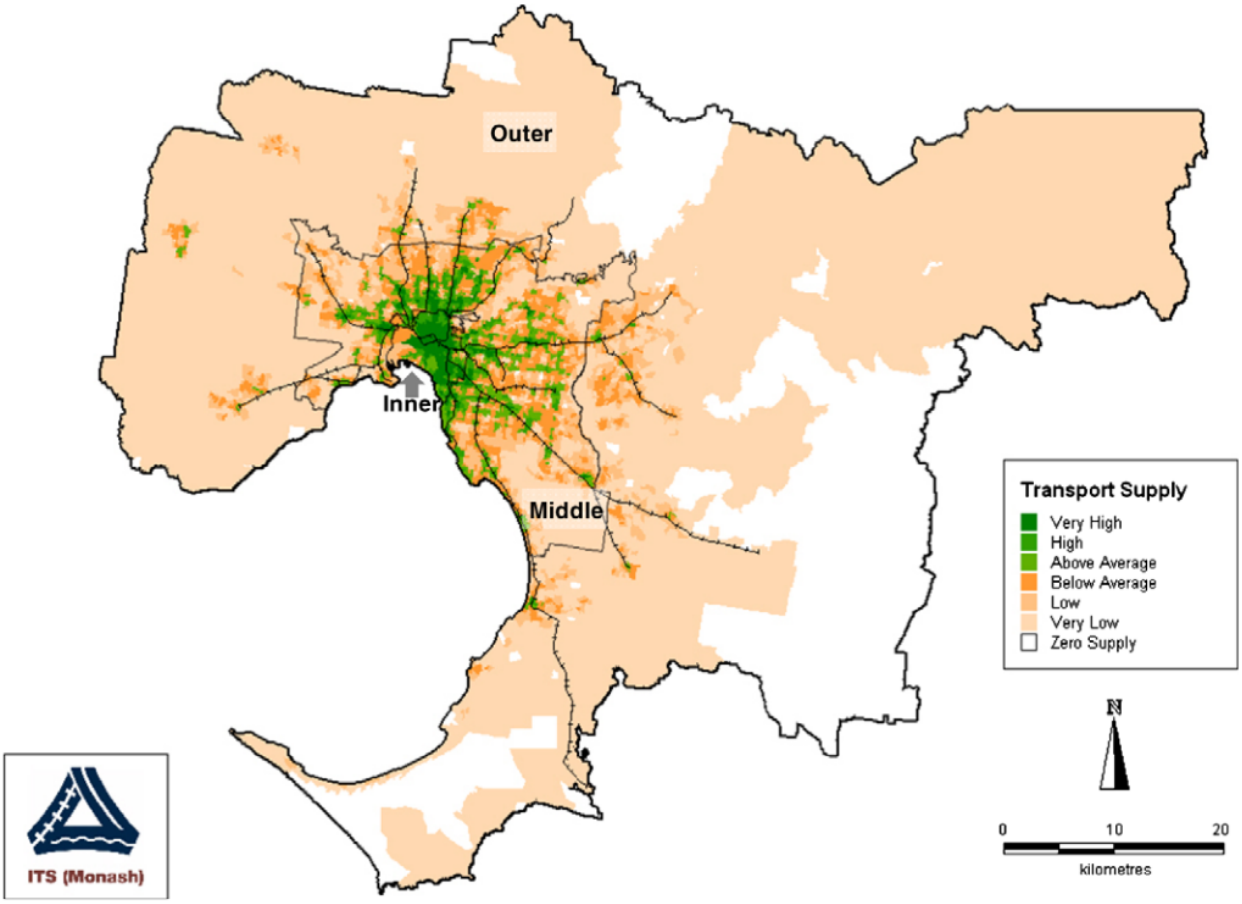

Figure 2: Distribution of supply measure scores – Metropolitan Melbourne (2006), Source: Currie (2010)

- $Area_{Bn}$ 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);
- $Area_{area}$ is the area of the area of interest; and
- $SL_{n,time}$ is the number of transit arrivals for each stop for a given time period.

Currie (2010) reported SI scores across Greater Melbourne in 2006, as shown in Figure 2. The general patterns appear to be higher levels of transit supply in the middle and inner suburbs and along passenger railway lines. Outer areas tend to have very low SI scores or no transit supply at all.

2.3. Social need and needs gap

As well as measuring transit supply, 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. Figures 3 and 4 reproduce the resultant chart and map combining needs and supply to identify gaps.

The results indicated 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."
They also suggested that planning for transit service provision using this approach would be "substantially

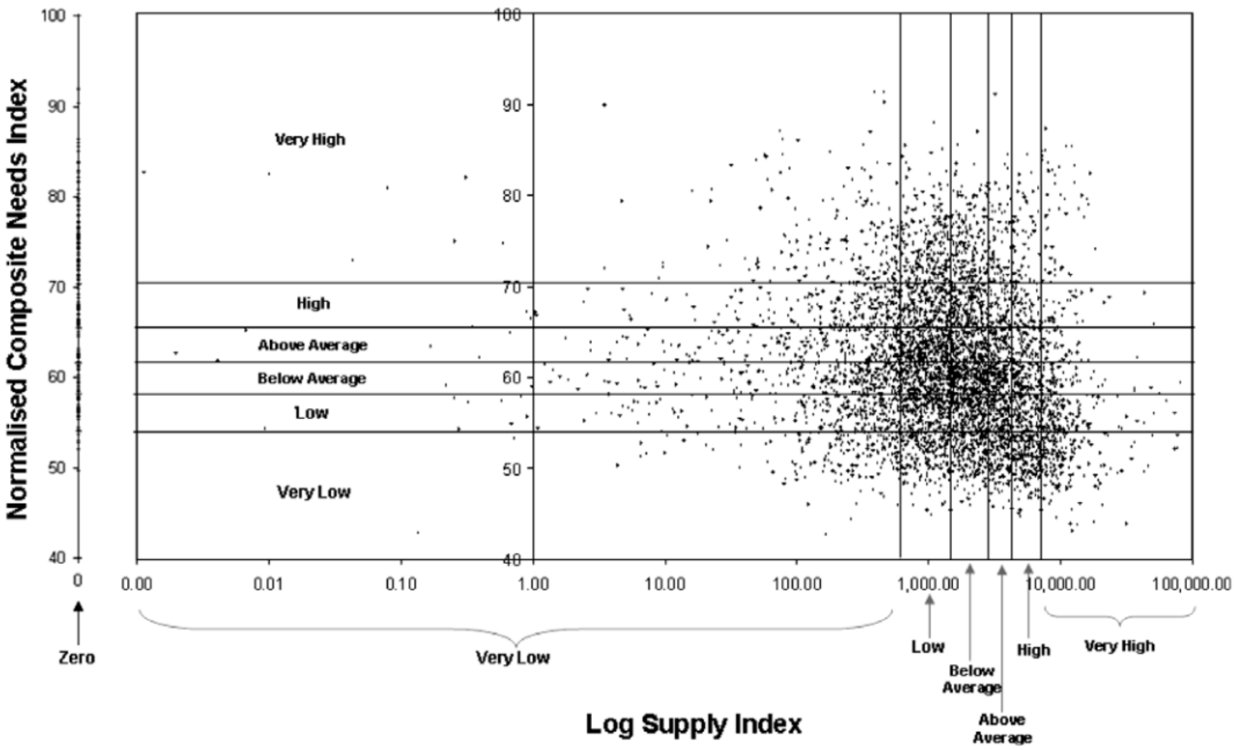

Figure 3: Log supply score and need index values – Melbourne needs-gap study, Source: Currie (2010)

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. 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 may still be uncommon.

It is also unclear whether the patterns in Melbourne identified in Currie (2010), where areas with very high transport needs but zero or very low transit supply tend to be in outer areas 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 to calculate SI tools from GTFS data, 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 of tools for calculating the SI from GTFS data using the R programming language (R Core Team, 2023). The recommendations of Wickham and Bryan (2023) informed the package setup and development approach. 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). Australian Bureau of Statistics (ABS) data was also used, sourced via the strayr and absmapsdata packages (Mackey et al., 2023). Some code was adapted from examples, vignettes and other documentation in these 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

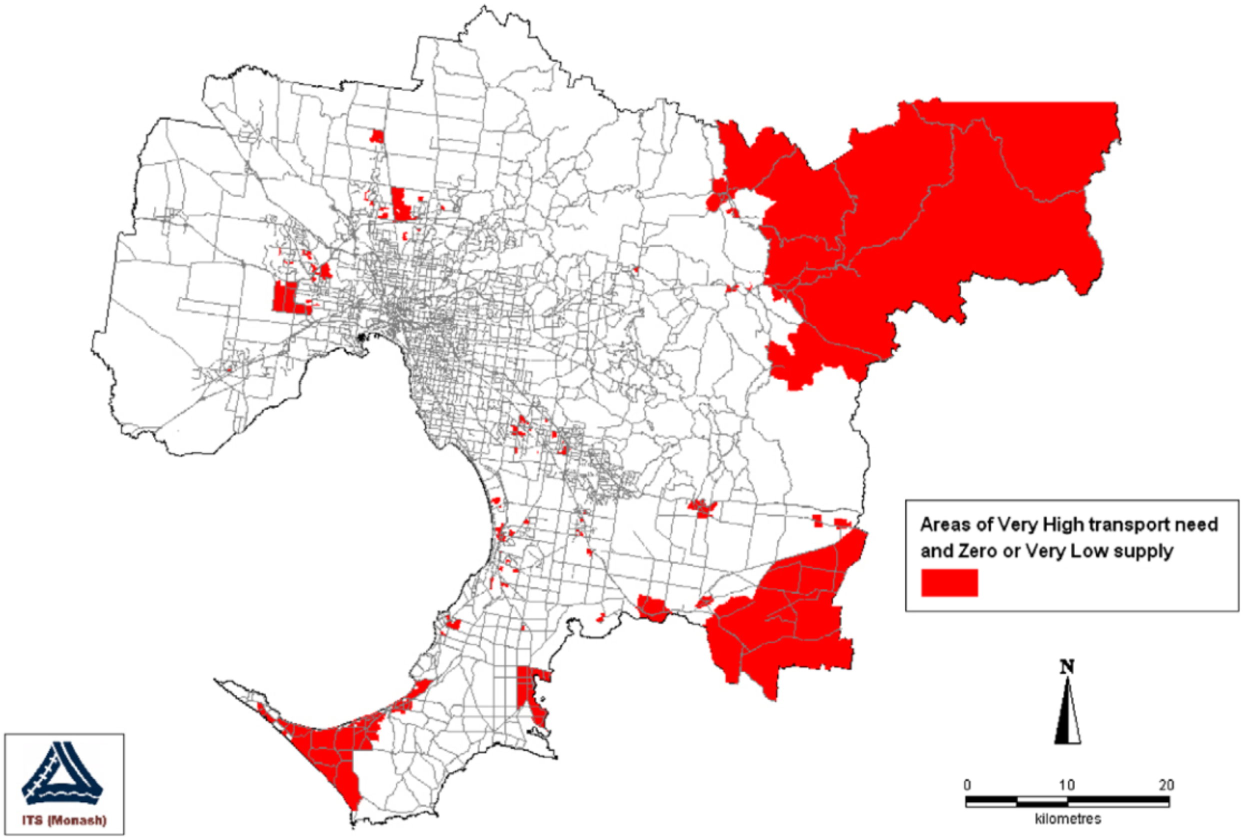

Figure 4: Melbourne needs-gap – very high transport need areas with zero or very low public transport supply, Source: Currie (2010)

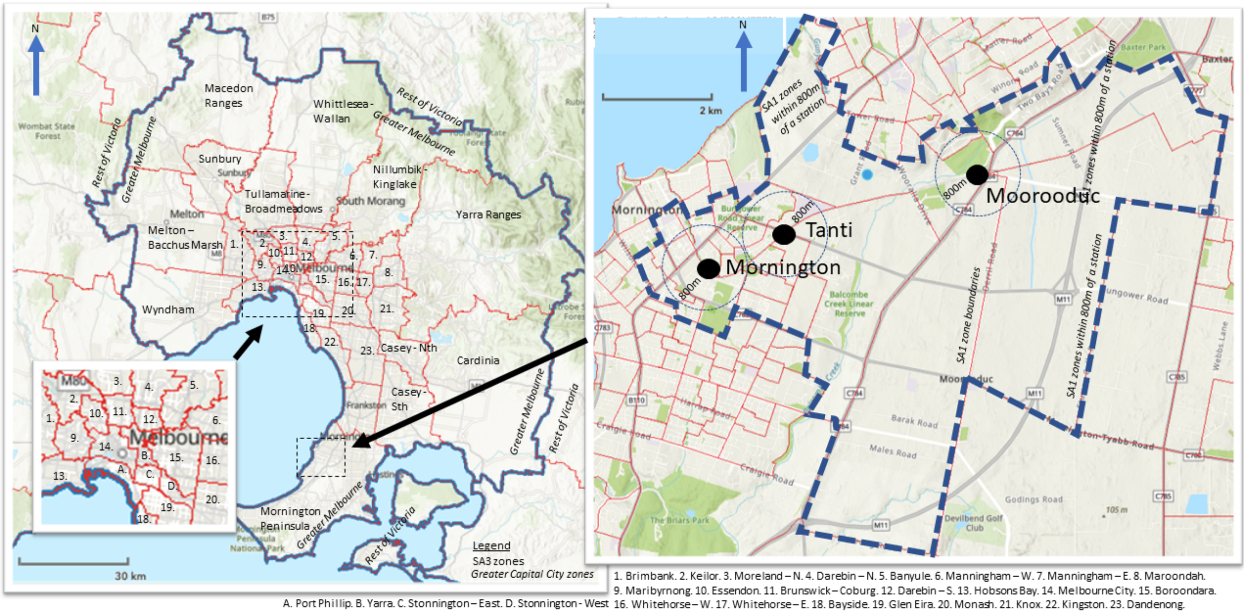

Figure 5: Areas of interest

(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. Adopting the Mornington Peninsula Tourist Railway network, which consists 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[5] across the Greater Melbourne Greater Capital City statistical area (Figure @ref(Melbourne_map), left); and SA1 zones[6] within 800 metres of the Mornington Penninsula railway (Figure @ref(Melbourne_map), right).

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[7]. A GTFS feed from 2018 was selected for the purposes of tests, and for demonstrating the code and outputs reported here.

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 Greater Melbourne and 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.

[5]These are generally similar to Local Government Area (LGA) boundaries.
[6]SA1 zones are the smallest geographical areas for which results are reported in the Australian census.
[7]see https://transitfeeds.com/p/mornington-railway/806/latest/stops

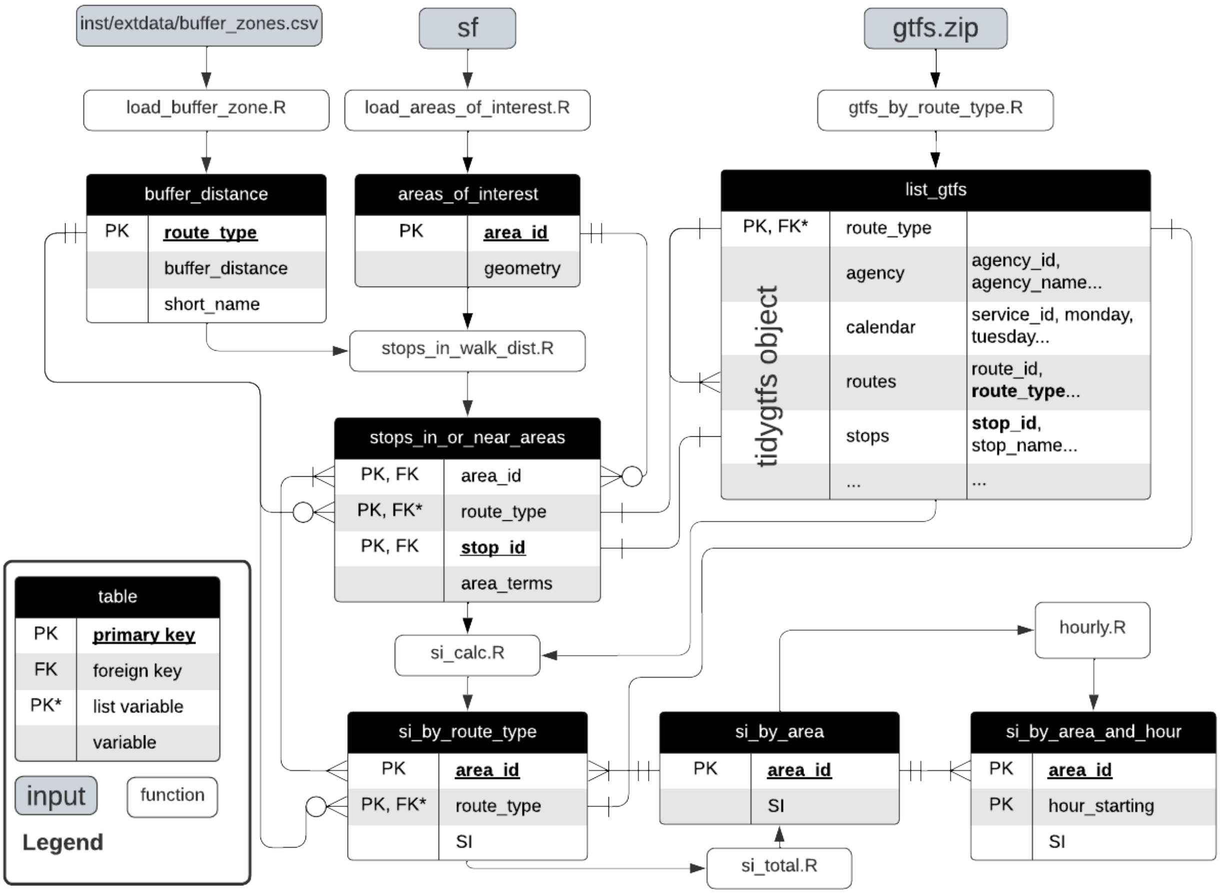

Figure 6: Entity Relationship Diagram (ERD) showing the data structure and functions related to the gtfssupplyindex package

4. Results

4.1. Code structure and functionality

Developed code is available and documented on github (see Reynolds (2024)). The structure of the package, functions developed, and data tables are shown in Figure @ref(fig:SI_ERD), which indicates how the package takes input from three files: a gtfs feed (gtfs.zip); a sf object describing the geometry of the areas of interest 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 (Figure @ref(fig:SI_ERD), bottom-right), which reports the SI score for each hour of a day specified by the user.

The various functions included in the package and their output are explained in the following, using the Mornington Peninsula GTFS as a worked example[8] 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 function into an sf object, using the sf package (Pebesma,

[8]This paper itself was prepared in Rmarkdown and is available at https://github.com/James-Reynolds/gtfssupplyindex_main_paper. Code snippets used to produce the outputs of the worked example can be viewed there.

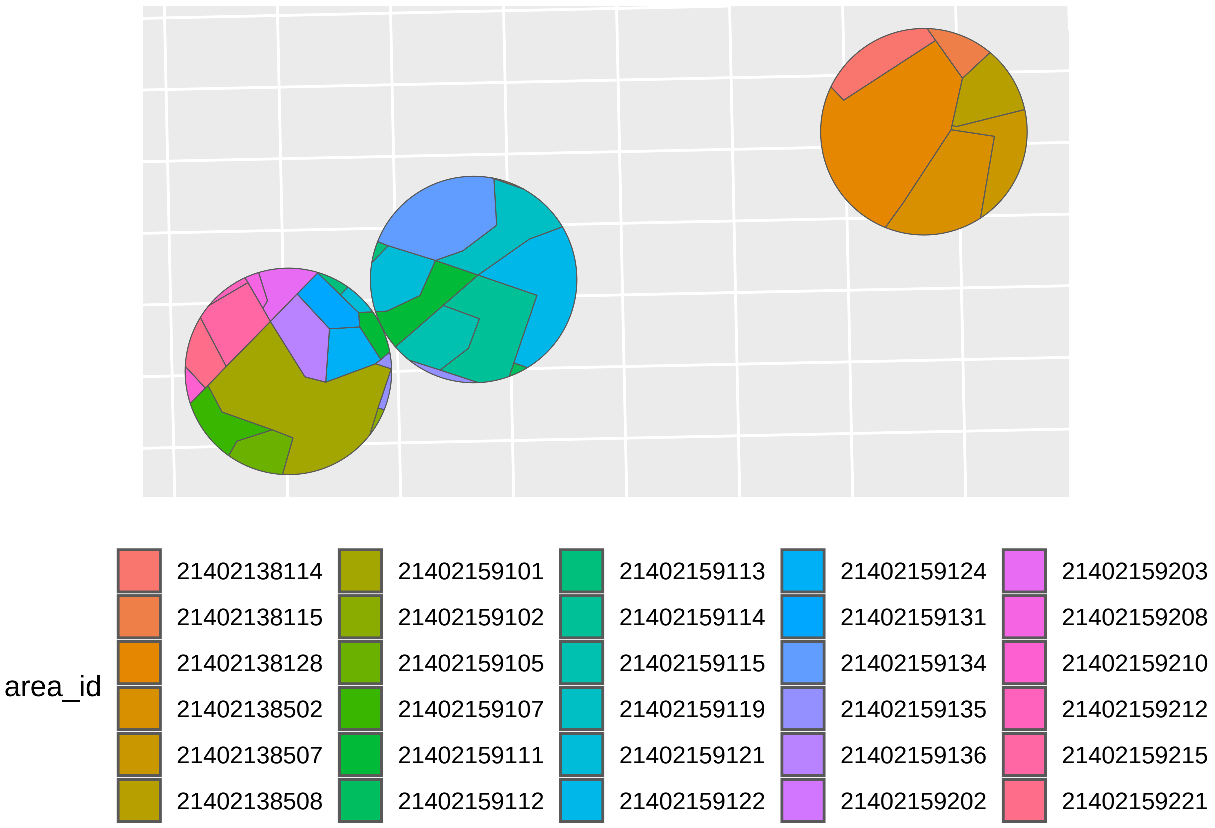

Figure 7: Step 3, stop catchments for the Mornington Penninsula Tourist Railway, showing intersections with SA1 zones

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 another function (load_buffer_zone).

(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).

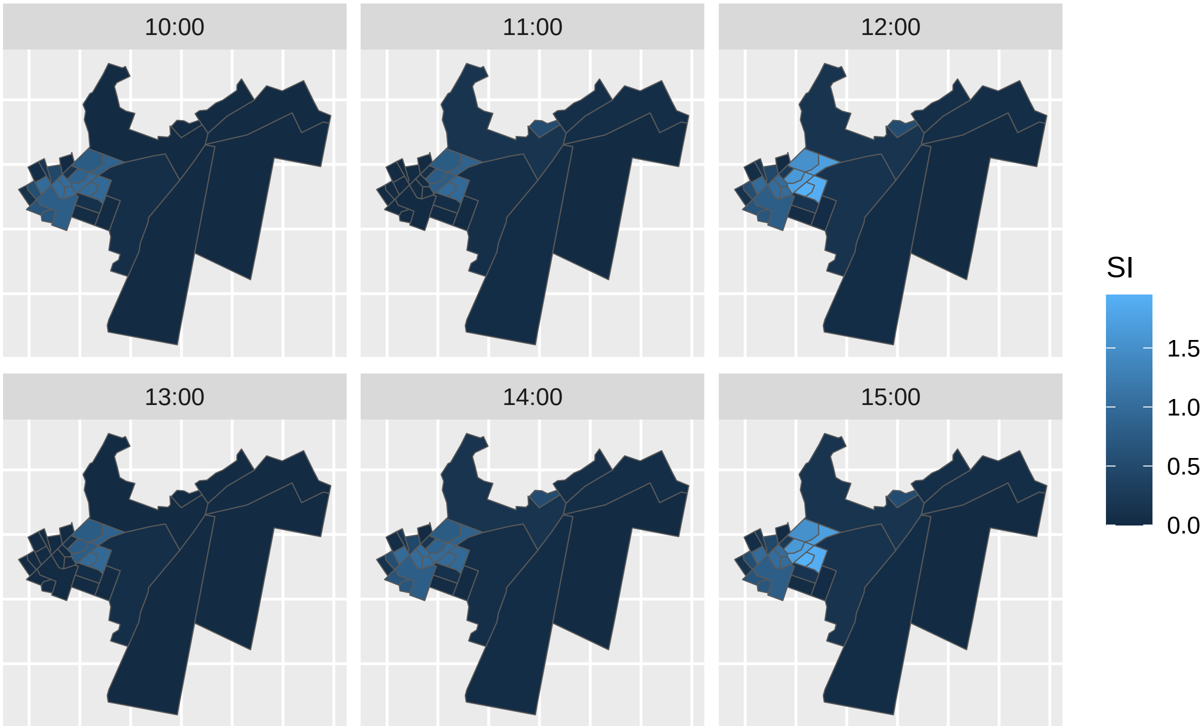

Figure 8: Mornington Penninsula Tourist Railway hourly SI values for December 30, 2018

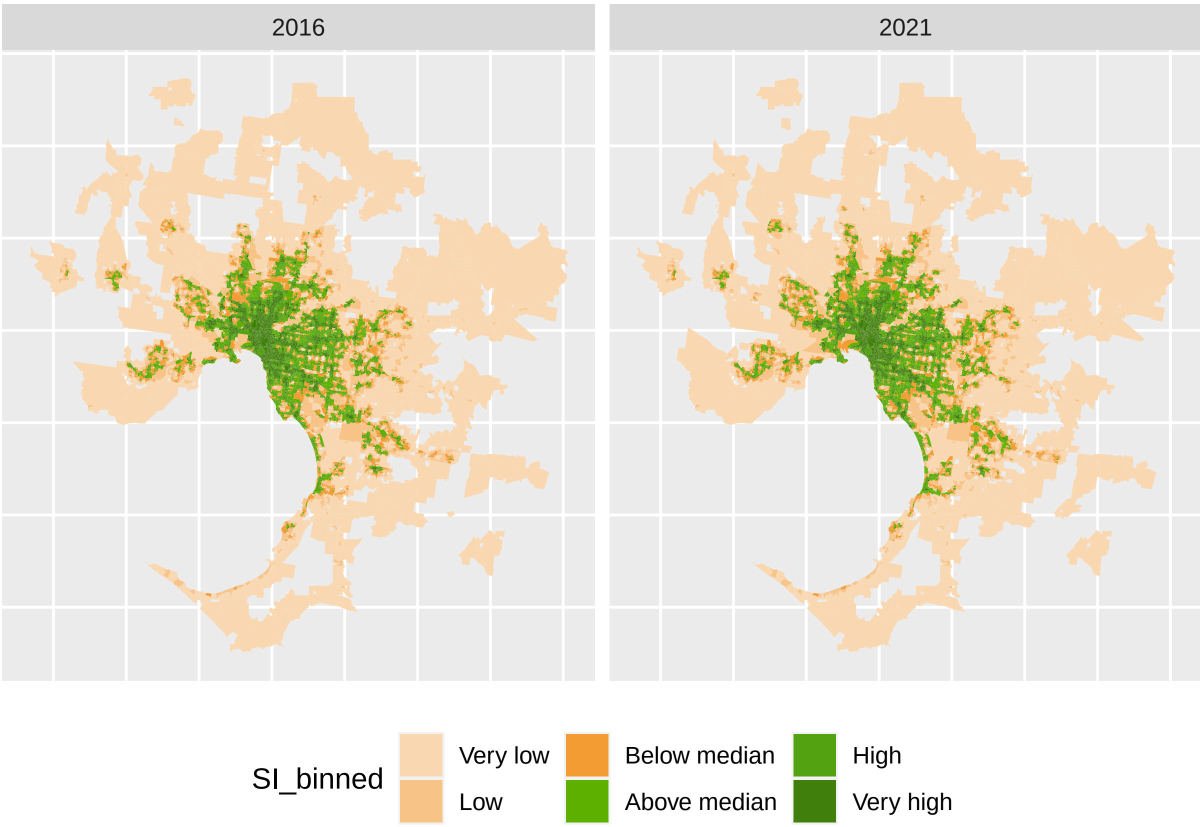

Figure 9: SI scores, census day 2016 and 2021

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*

5.2. *Directions for furture research*

6. Conclusions

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