Leveraging GTFS data to calculate an open-source Transit Supply Index

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Word Count: 684 words + 0 table(s) × 250 = 684 words

Submission Date: August 2, 2023

ABSTRACT

TBC.

Keywords: Transit, Public transport, GTFS, Benchmarking,

INTRODUCTION

Transit service level indicators include those in the Transit Capacity and Quality of Service Manual (TCQSM) (1), the Transit Score metric and many more. Practitioners, researchers and advocates seeking to use such metrics may face two inter-related challenges: firstly, there is the problem of calculating the metrics themselves for a specific location; secondly, is the challenge of explaining the metrics, their meaning and importance those who are not specialists in transit, such as politicians, other decision-makers or the general public.

The TCQSM specifies Levels of Service (LOS) between A and F across a range of factors including service span, frequency, speed, and the proportion of population serviced. Previous research by Wong (2) overcame some challenges of using the TCQSM, by using Python, PostgreSQL and R software and GTFS feeds as input to automate the calculation of daily average headways, route length and stop numbers. This indicators, however, are route based and so do not include any consideration of geographic or population coverage. Further metrics addressing these topics and much detail about their calculation and meaning are included in the TCQSM, such as the Service Coverage Area (pp. 5-8 to 5-21). However, these appear highly detailed, may required bespoke GIS or other analysis, and it might be challenging to explain these measures (beyond the fact at A is good and F is bad) to non-technical decision-makers, stakeholders or others who might be involved. Transit Score provides a similarly easily understood rating scale, scoring locations out of 100 (3). However, the algorithm is patented and effectively a black box, meaning that it is not possible to calculate scores independently to understand how the metric might change with cahnges to the transit system or surrounding environment.

The Supply Index developed by Currie and Senbergs (4) may provide a metric that is relatively easy to calculate, open (rather than a black box), and relatively simple for a non-technical audience to understand, engage with and use. This Index is based on calculating the number of transit arrivals at stops within an area of interest, with an adjustment made for the amount of the area of interest that is within a typical walk access distance of each stop. However, it does not appear to have been widely used, perhaps in part because it still required an analyst to obtain sources of timetable and geographic data. Since the publication of Currie and Senbergs (4) such data has become much easier to obtain with more than 10,000 agencies now providing timetable and network data using the General Transit Feed Specification (GTFS) format (5). A gap, however, is that there is not yet a method for calculating the Currie and Senbergs (4) Supply Index directly from GTFS data.

This paper reports the development of R code to calculate the Supply Index of Currie and Senbergs (4) directly from GTFS data. The code is developed using data from a single case: the GTFS for Victoria in Australia, which includes Greater Melbourne. Cross-case comparison to Toronto, Canada, and Washington DC, USA, is also undertaken to test the results and gain understanding of how the Supply Index might be useful for practitioners, researchers and advocates. The motivation for this research is to better understand how GTFS data might be used to produce benchmarking metrics that can be calculated using open-source code, that can be used to access proposed network changes and which may be relatively easy for non-technical specialists to understand.

RESEARCH CONTEXT

Even a brief search shows that there is a very large number of metrics available for benchmarking transit services, for example: the Transit Cooperative Research Program (TCRP) Report 88 provides an extensive guidebook on developing a performance-measurement system (6); online databases are provided by the Florida Transit Information System (FTIS) (7) and the International Association of Public Transport (UITP) (8) have online databases, while the Transport Strategy Centre of Imperial College London runs extensive annual benchmarking programmes across over 100 transit provides around the world (9). The Fielding Triangle (10) provides a framework for understanding how such metrics combine service inputs, service outputs and service consumption to describe cost efficiency, cost effectiveness or service effectiveness measures. At a larger scale, Litman (11) and Litman (12) discuss some of the traffic, mobility, accessibility, social equity, strategic planning and other rational decision-making frames that might underlie such transit metrics, while Reynolds et al. (13) extends this into models of how institutionalism, incrementalism and other public policy models might apply to decision-making processes. Further examples are provided by Guzman et al. (14), who develop a measure of accessibility in the context of policy development and social equity for Latin American Bus Rapid Transit (BRT) based networks, and the street space allocation metrics based around 10 ethical principles from Creutzig et al. (15).

However, many of these metrics are difficult to calculate, complex to explain or understand, and likely not well suited to communication with those who are not transit planners or engineers, or otherwise technical specialists. However, where pre-calculated metrics are immediately available it may not be possible for generate metrics for proposed system changes or know exactly how scores are calculated. The TCQSM and Transit Score may provide contrasting examples: with respect to the first challenge, TCQSM metrics may require large amounts of network, service, population and other data to be assembled before the indicators can be calculated; whereas Transit Scores are readily available on the Walk Score (3) website for locations with a published GTFS feed (eliminating the need for any calculations). With respect to the second challenge, the meaning of the Transit Score appears easy to explain (the closer to 100, the better), but as the score is calculated by a patented algorithm (effectively a black-box) it may not be easy to understand or explain the connection between real-world conditions and the score, or what might need to be done to improve the score and service levels. Nor does it appear to be possible for Transit Scores to be generated for proposed changes to networks. The TCQSM, in contrast is open-source, in that Kittleson & Associates et al. (1) provide a manual describing all the metrics and how to calculate them. However, the calculations themselves appear to be complex, which may be a barrier to use by practitioners, researchers, advocates or others who are not transit scheduling specialists. While Wong (2) provides open-source code (`https://github.com/jcwong86/GTFS_Explore_Tool`) this is 11 years old and does not appear to be currently maintained. Future research may involve reviewing this code and using it to analyse modern GTFS feeds. However, in this paper the aim is more modest, in that the objective is to develop code to calculate the simpler Suppy Index metric from Currie and Senbergs (4).

The Suppy Index

The Supply Index is shown in Equation 1. Minor adjustments have been made to generalise the equation, as Currie and Senbergs (4) focused on the context of Melbourne's Census Collection Districts (CCD) and calculations based on a week of transit service.

$$SI_{area,time} = \sum \frac{Area_{Bn}}{Area_{area}} * SL_{n,time} \tag{1}$$

$SI_{area,time}$ is the Supply Index for the area of interest and a given period of time. $Area_{Bn}$ is the buffer area for each stop (n) within the area of interest. In Currie and Senbergs (4) 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.

An advantage of the Supply Index is that it is a relatively simple number to calculate, understand and explain. It describes the number of transit arrivals at stops within an area of interest and time frame, multiplied by a factor accounting for the proportion of the area of interest that is within typical walking distance of each stop. Hence, more services, more stops and higher frequencies would all result in an increase in Supply Index score. The Supply Index, however, does not incorporate further aspects, such as service span, off-peak share of service or service speed. However, including such metrics may increase the complexity of calculating and describing the index to non-transit specialists. Such simplicity is helped by the way that the Index is additive, in that SI~area, time~ scores can be aggregated to calculate an overall score across multiple time periods or for a region encompassing multiple areas of interest.

Currie and Senbergs (4) calculated the SI~area, time~ for various CCDs in Melbourne using a timetable database provided by the Victorian Public Transport Authority (PTA). This predated the widespread availability of GTFS data, which provides a standardised format for timetable data that is produced by many transit systems. GTFS is an open, text-based format that was developed originally to allow transit information to be included in the Google Maps navigation platform (5). A question, therefore, is how to calculate the SI using GTFS data so that $\mathrm{SI}_{\mathrm{areas}}$ can be calculated and compared for any area of interest where transit service information is available in the GFTS format.

METHODOLOGY

This study adopts a case research approach by developing code to calculate Supply Indexes for Melbourne (Australia), Toronto (Canada) and Washington D.C. (USA). The case research approach serves two purposes: firstly the selected cases where used to develop, test and verify the functionality of the code produced in this study. Secondly, aspects of the the selected cases were explored;, such as the impact of forthcoming upgrades and issues of level-boarding access (i.e. non-step suitable for wheelchair, pram, mobility-aid etc.) to the Supply Index scores.

Code development

Various analysis tools are available that make us of GTFS data, including the tidytransit package (**?**) for the R statistical programming language (16). Poletti (17) provides code to calculate a departure timetable from a GTFS feed, and this was adapted to calculate arrivals at a stop and the $\mathrm{SL}_{\mathrm{Bn}}$ term.

The gtfstools R package (18) was used to split input GTFS feeds by mode to facilitate the buffer zone calculation. Buffer zones of 400 metres for bus and Light Rail Transit (LRT) services and 800 metres for heavy rail, as per Currie and Senbergs (4). There is an extended mode definition that includes modes beyond the 10 in the GTFS standard (19), but these are not dealt with by the gtfstools package. Further research may seek to extend this such that other modes can be included, but for the purposes of this study the buffer zone was set at 400 metres for cable trams, aerial lifts such a gondalas and trolleybuses, and at 800 metres for ferries, funiculars and monorails.

Where transit stops are located close to boundaries their catchment areas may fall into multiple areas of interest. The sp package from (**?** , **?**)) provides tools for manipulating geographic data and shape files in R. This is used to calculate the proportion of each stop's catchment area that falls into each geographical area of interest. GTFS files define stop locations based on latitude and longitude (**?**), whereas the $Area_{Bn}$ calculation needs to be provided in the same units as the $Area_{area}$ variable. This therefore necessitates the use of a geographic transform so that calculations can be undertaken in metres.

The SI_{area} was calculated on a mode-by-mode and stop-by-stop basis, by first determining the amount of the catchment area ($Area_{Bn}$) that falls into each geographical area of interest for the stop in question. This is combined with the area for each geographical area of interest ($Area_{area}$) and the number of stop arrivals within the (SL_{Bn}) to calculate the contribution to the index scores made by just that single stop for every area of interest (the SI~area, time, mode, n~); these are then added to a cumulative total field for each area of interest; and the calculations are repeated until all stops and modes in the GTFS file have been included.

Case research approach

These three cases were selected as they are familiar to the researchers, and as there is likely to be enough variety in how the GTFS feeds, potential areas of interest and other aspects are set up such that the developed code will likely be generalis-able to other places. Additionally, the case selection continues the long-standing practice of comparing Melbourne and Toronto, as well as grounding one of the three cases in the context of the transit system where the Transportation Research Board Annual Meeting is located (which is likely to be familiar to many readers).

Melbourne, Victoria, Australia

Greater Melbourne is a geographic area that is similar to that of the metropolitan areas of Paris or London, but with only around 5 million people has about one-third of the population. It consists of a inner Central Business District (CBD) with appartments, commercial skyscrapers and extensive sporting facilities nearby; surrounded by low-density, predominately single-family-housing-dominated, inner, middle and outer suburbs.There are predominately radial train and tram networks, but for most of the suburban areas the reality is that transit is provided by circuitious bus routes that are mostly used by those who cannot otherwise drive. An extensive freeway (and tollway) network provides connections across the Greater Melbourne area, further around Port Phillip Bay to Geelong (south-west) and the Mornington Penninsula (south-east) as well as to regional centres elsewhere in Victoria. There is a state-wide regional train and bus network, which also provides connections into South Australia, New South Wales and the Australian Capital Territory (Canberra) and local bus services in many regional towns and cities. However, accessibility to most of the city and state tends to be car-dominated, with transit mode share only accounting for XX% across Greater Melbourne and YY% across Victoria. The journey-to-work transit mode shares, however, are ZZ% across Greater Melbourne and PP% for travel into the CBD, which is reflective of the monocentric nature of the railway network, which focuses on Southern Cross Station (Spencer Street) for regional services and on a five-station City Loop (Southern Cross, Flinders Street, Parliament, Melbourne Central and Flagstaff) the helps to distribute commuters to workplaces across the CBD.

Melbourne's GTFS feed is published by Public Transport Victoria (PTV). There are over 400 historical releases of the available on the transitfeeds.com website, with the first dating from March 2015 (20). The Australian census is undertaken in early August every 5 years, with the last two being in 2016 and 2021. GTFS feeds were therefore selected for the first week of August of each year for the purposes of this test analysis, so that the date of measurement of the Supply Index

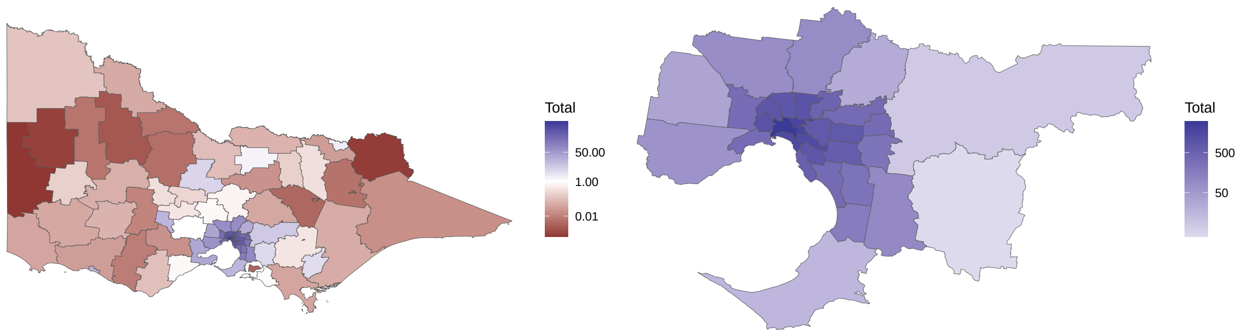

FIGURE 1 SI for 2021 census day (August 10th) by LGA

matches the census dates.

Minor corrections were made to the GTFS files to remove duplicate stop_ids. These involved minor discrepancies in either the stop name, latitude or longitude. The Australian Bureau of Statistics (ABS) provides a range of shape files and other resources, and this study made use of the absmapsdata R package (21) to access the 2021 Local Government Area (LGA) boundaries for the Greater Melbourne area. The EPSG:28355 transform (**?**) was used to shift longitude and latitude into metres, as per the Geocentric Datum of Australia 1994 (GDA95 / MGA zone 55) coordinates.

Toronto, Ontario, Canada

Washington DC, USA

RESULTS

The code is available at `https://github.com/James-Reynolds/Transit_Supply_Index_GTFS` as an Rmarkdown file (used to typeset this paper). The following subsections discuss the results of cases studies used to develop and test the code.

Victoria, Australia

Transit Supply Index

Transit needs

Level-boarding accessibility

The metro tunnel - adding services

The suburban rail loop

Toronto

Level-boarding accessibility

Transit City: what might have been

Viva transit: what was achieved

Downtown relief lines

Many proposals - look at a few of them?

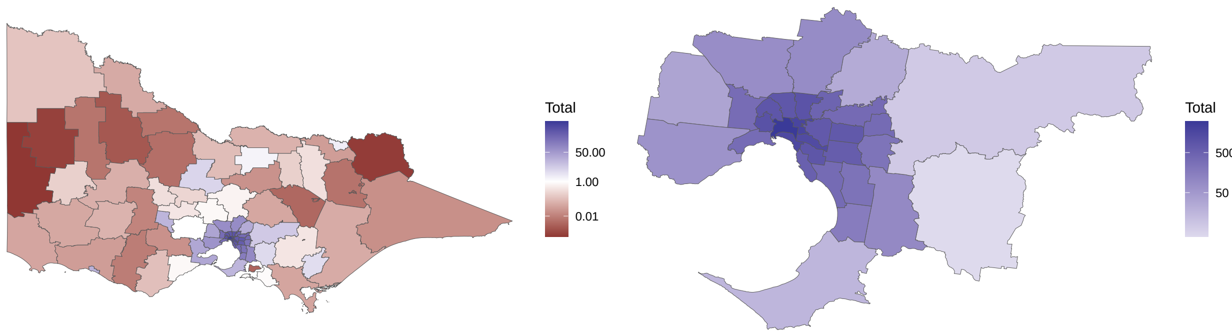

FIGURE 2 SI for 2016 census day (August 9th) by LGA

Washington DC

Level-boarding accessibility

Cross-case comparison

DISCUSSION

CONCLUSIONS

AUTHOR CONTRIBUTION STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: A. Anonymous, D. Zoolander; data collection: B. Security; analysis and interpretation of results: A. Anonymous, B. Security; draft manuscript preparation: A. Anonymous. All authors reviewed the results and approved the final version of the manuscript.

ACKNOWLEDGEMENTS

This document was prepared using the `rticles` template, created by Gregory Macfarlane, which is based on the LaTeXoriginally posted by David Pritchard in 2009 and updated it in 2011, soon after TRB began allowing PDF submissions. Gregory Macfarlane and Ross Wang made adjustments to the template, and Ross Wang now maintains the LaTeXtemplate at `https://github.com/chiehrosswang/TRB_LaTeX_tex`. Gregory Macfarlane created the `rticles` template in 2021.

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