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# LEVERAGING GTFS DATA TO ASSESS TRANSIT SUPPLY, AND GAPS BETWEEN SOCIAL NEEDS AND SERVICE PROVISION

# *Introduction*

Transit service level indicators include those in the Transit Capacity and Quality of Service Manual (TCQSM) [Kittleson & Associates et al., 2013], the Transit Score metric [Walk Score, 2023] 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 and service pattern; 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[1]. This scoring scheme appears likely to help towards the second aforementioned challenge; it is relatively simple to explain that A is good and F is bad[2], and the detail within Kittleson & Associates et al. [2013] provides a resource for anyone wanting to better understand what the scores mean. However, calculation of many of TCQSM metrics may need specialised software and datasets[3] and it might be challenging to explain these measures[4] or how to improve them to non-technical decision-makers, stakeholders or others involved in transit management or advocacy. The introduction of the General Transit Feed Specification (GTFS) [MobilityData, undated] [5] and widespread release of schedule data in this format, however, has helped towards making transit metrics more broadly availabile. An example is provided in previous research by Wong [2013] that developed code to calculate of some of the TCQSM metrics[6] directly from GTFS feed data. GTFS data also underlies many online journey planning systems[7], and Transit Score, which scores locations out of 100 for transit service levels [Walk Score, 2023][8]. However, the TransitScore algorithm is patented and effectively a black box, meaning that it is not possible to calculate scores independently or understand how the metric might change with alteration to the transit system or services, or the surrounding environment. TransitScore, therefore fails the first of the aforementioned challenges; in that practitioners, researchers and advocates can only use those scores provided by Walk Score [2023], which reflect only current service patterns.

[1] Including service span, frequency, speed, the proportion of the population serviced, competitiveness of travel times to car-based travel, and many more.

[2] It also matches to the A to F LOS scoring used in many traffic capacity analysis calculation systems and software.

[3] For example, the Service Coverage Area metric in the TCQSM (pp. 5-8 to 5-21) may require GIS or other analysis, on-top of accurate data about population densities, stop locations and service schedules.

[4] Beyond a simplistic A is good and F is bad

[5] GTFS is an open, text-based format that was developed originally to allow transit information to be included in the Google Maps navigation platform [MobilityData, undated].

[6] Wong [2013] calculated daily average headways, route length and stop numbers for 50 transit operators.

[7] Notably Google Maps, from back when it was called the Google Transit Feed Specification.

[8] 100 representing the highest levels of transit service provision, and being roughly equivalent to what might be experienced in the centre of New York; but which was actually calibrated using scores for the centre of San Francisco, Chicago, Boston, Portland, and Washington, D.C. [Walk Score, 2023]

Previous research by Currie and Senbergs [2007] developed a Transit Supply Index 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 timetable and geographic data and undertake the calculation themselves. Since the publication of Currie and Senbergs [2007], however, such data has become much easier to obtain with more than 10,000 agencies now providing GTFS data [MobilityData, undated]. A gap, however, is that there is not yet a method for calculating the Currie and Senbergs [2007] Supply Index directly from GTFS data.

This paper reports the development of R code to calculate the Supply Index of Currie and Senbergs [2007] 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 comparisons to Toronto, Canada, and Washington DC, USA, are 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 that may be relatively easy for non-technical specialists to understand and use when making decisions about or advocating for changes to existing services.

# *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 [Ryus et al., 2003]; online databases are provided by the Florida Transit Information System (FTIS) [Florida Transit Information System, 2018] and the International Association of Public Transport (UITP) [International Association of Public Transport (UITP), 2015]; while the Transport Strategy Centre of Imperial College London runs extensive annual benchmarking programmes across over 100 transit provides around the world [Imperial College London, undated].

The Fielding Triangle [Fielding, 1987] 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 [2003] and Litman [2016] 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. [2017] 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. [2017], 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 introduced by Creutzig et al. [2020].

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. Where pre-calculated metrics are immediately available it may not be possible for practitioners, researchers or advocates to independently generate metrics for proposed system changes or to even know exactly how scores for the existing services levels are calculated. The TCQSM and Transit Score may provide contrasting examples: with respect to the first challenge, TCQSM metrics may re-

quire large amounts of network, service, population and other data to be assembled before the indicators can be calculated; whereas Transit Scores are readily available[9]. With respect to the second challenge, the meaning of the Transit Score appears easy to explain[10], but as the score is calculated by a patented algorithm 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[11]. While Wong [2013] provides open-source code for calculating some TCQSM metrics [12] this is now 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, with the objective being to develop code to calculate the Suppy Index metric from Currie and Senbergs [2007].

[9] The Walk Score [2023] website shows scores for locations with a published GTFS feed, eliminating the need for any calculations.

[10] The closer to 100, the better.

[11] In that Kittleson & Associates et al. [2013] provide a manual describing all the metrics and how to calculate them.

[12] `https://github.com/jcwong86/GTFS_Explore_Tool`

## *The Suppy Index*

Equation 1 shows the Supply Index[Minor adjustments have been made to generalise the equation, as Currie and Senbergs, 2007, focused on the Equation 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, 2007, 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.].

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

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 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 also 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 [2007] calculated the $SI_{[area,\ time]}$ for various Census Collection Districts (CCDs)[13] in Melbourne using a timetable database provided by the Victorian Public Transport Authority

[13] CCDs predate the introduction of Statistical Areas 1, 2, 3, and 4 (SA1, SA2, SA3, SA4), and other geographical divisions currently used by the Australian Bureau of Statistics (ABS), which may be more familiar to readers

(PTA). This predated the widespread availability of GTFS data. A question, therefore, is how to calculate the SI using GTFS data so that $SI_{areas}$ can be calculated and compared for any area of interest where transit service information in that 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[14].

## *Code development*

Various analysis tools are available that make us of GTFS data, including the tidytransit package [Poletti et al., 2023] for the R statistical programming language [R Core Team, 2022]. Poletti [undated] provides code to calculate a departure timetable from a GTFS feed, and this was adapted to calculate arrivals at a stop and the $SL_{Bn}$ term.

The gtfstools R package [Herszenhut et al., 2022] 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 [2007][15].

Where transit stops are located close to boundaries their catchment areas may fall into multiple areas of interest. The sp package [Pebesma, 2023] provides tools for manipulating geographic data and shape files in R. This was used to calculate the proportion of each stop's catchment area that falls into each geographical area of interest[16].

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

[14] A key issue in case-based research is the duality criterion, being the need to simultaneously: be engaged with depth of the individual cases included in the study; yet also be seeking findings that are generalisable to more than just the case that are studied. This study responds to this criterion by first testing the developed code across three different transit systems, which is expected to be sufficient to validate that it is generalisable to most GTFS feeds, not specific to the quirks of the Victorian GTFS feed. Additionally, this study engages with a range of issues (level-boarding access, new routes and services, and cancelled projects) across these three cities, again seeking to demonstrate how the Supply Index code might be adapted to a range of other issues and places.

[15] There is an extended mode definition that includes modes beyond the 10 in the GTFS standard [Herszenhut et al., undated], 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 gondolas and trolleybuses, and at 800 metres for ferries, funiculars and monorails.

[16] GTFS files define stop locations based on latitude and longitude [MobilityData, undated], whereas the $Area_{Bn}$ calculation needs to be provided in the same units as the $Area_{area}$ variable, necessitating the use of a geographic transform as part of the code.

calculate the contribution to the index scores made by just that single stop for every area of interest; 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*

The three cases were selected as they are familiar to the researchers. 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 a transit system that may be familiar to many readers[17].

[17] Washington DC is where the Transportation Research Board Annual Meeting is held each year.

#### *Victoria, Australia*

Victoria is the southern-most state on the Australian mainland. The state capital is in Melbourne, which has a similar metropolitan area to of Paris or London. However, with only around 5 million people Greater Melbourne has about one-third of the population density. It has an inner Central Business District (CBD) with apartments, commercial skyscrapers and extensive sporting facilities nearby; surrounded by low-density, predominately single-family-housing-dominated, inner, middle and outer suburbs.

There are train and tram networks radiating from the CBD, 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.

Victoria's GTFS feed is published by Public Transport Victoria (PTV)[18]. 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.

[18] There are over 400 historical releases of the available on the transitfeeds.com website, with the first dating from March 2015 [Transit Mobility Data,, 2023].

Minor corrections were made to the GTFS files to remove duplicate stop_ids[19]. 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 [Mackey, 2023] to access the 2021 Local

[19] These involved minor discrepancies in either the stop name, latitude or longitude.

Government Area (LGA) boundaries for the Greater Melbourne area. The EPSG:28355 transform [EPSG, 1995] 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 following subsections discuss the results of cases studies used to develop and test the code[20].

[20] The code is available at `https://github.com/James-Reynolds/Transit_Supply_Index_GTFS` as an Rmarkdown file (used to typeset this paper).

## *Victoria, Australia*

### *Transit Supply Index*

Figure 1 show the $SI_{LGA2021,10/8/21}$ values for Victoria (left) and Greater Melbourne (right).

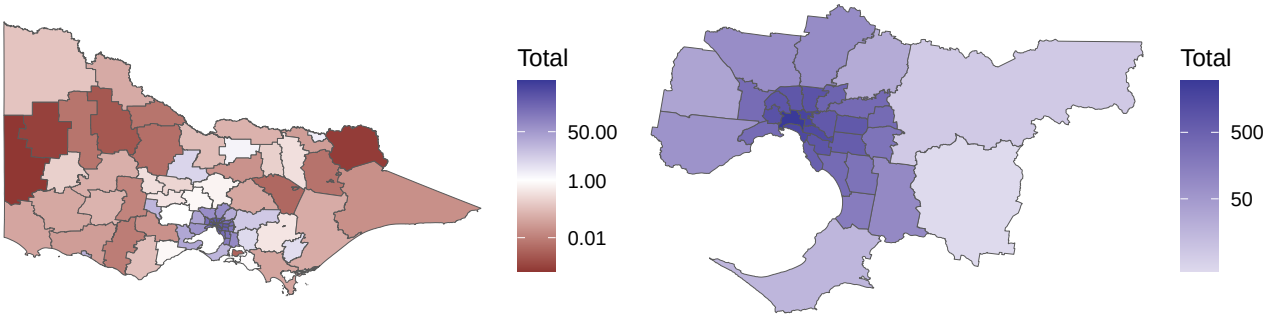


Figure 1: SI for 2021 census day (August 10th) by LGA

In general, Figure 1 indicates that the amount of transit service is higher for LGAs that are closer to the centre of Melbourne.

Figure 2 compares the SI for 2021 and 2016 for each LGA. It indicates that there are significant differences in the SI scores in 2016 and 2021. However, it appears that the change has been relatively small, with the average SI increasing from 208.6 to 218.1.

Figure **??** shows that there was a significant change in SI for LGAs within Greater Melbourne, rising from 548.4 to 573.2. There was no significant change amongst LGAs in the rest of Victoria (Figure 5).

Figure 6 maps numerical changes in SI between 2016 and 2021. These are also shown in Figure 7. There was a significant difference in changes in SI between LGAs in Greater Melbourne or the Rest of

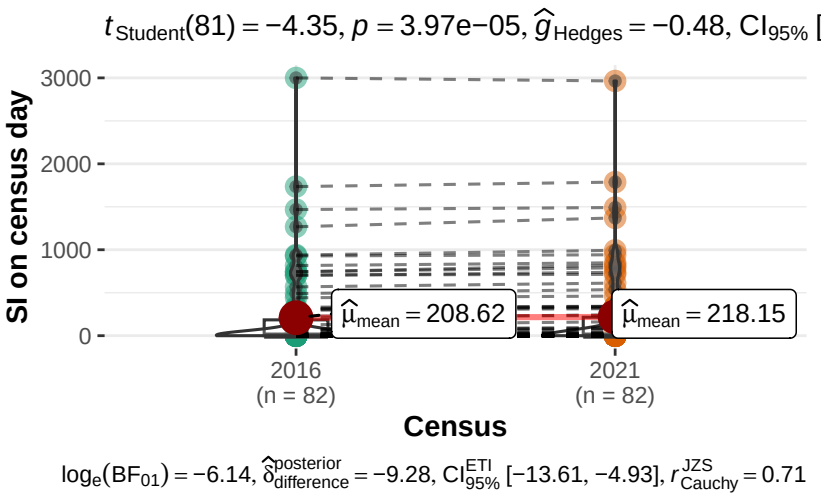


Figure 2: SI on census day, by year and LGA for all of Victoria, Greater Melburne and non-Greater Melbourne parts of Victoria

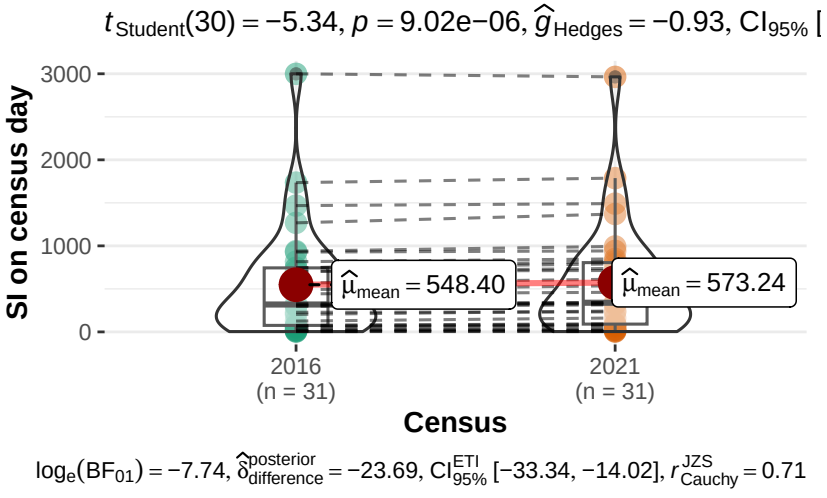


Figure 3: SI on census day, by year and LGA for all of Victoria, Greater Melburne and non-Greater Melbourne parts of Victoria

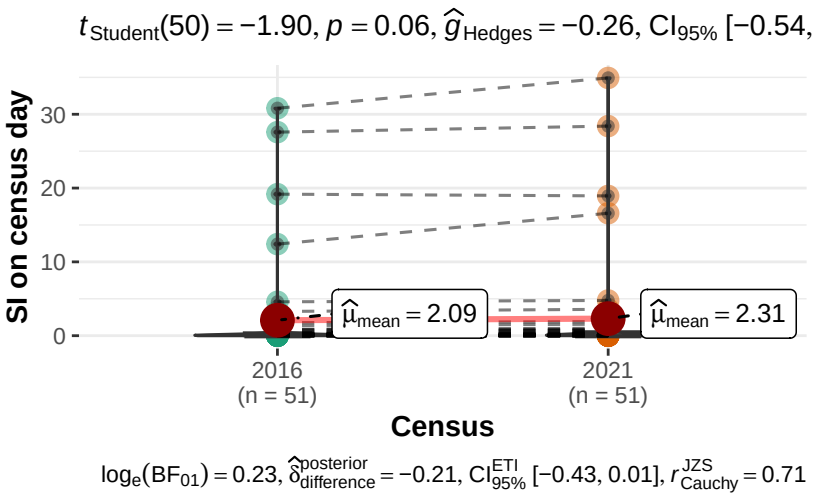


Figure 4: SI on census day, by year and LGA for all of Victoria, Greater Melburne and non-Greater Melbourne parts of Victoria

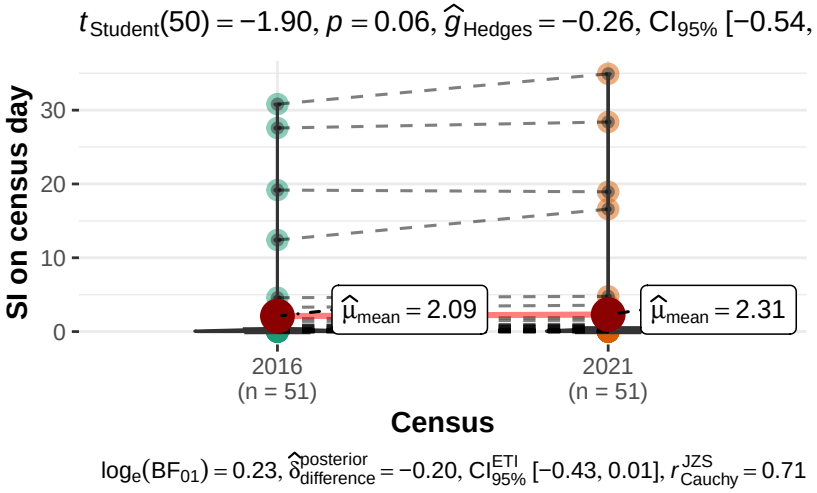


Figure 5: SI on census day, by year and LGA for all of Victoria, Greater Melbourne and non-Greater Melbourne parts of Victoria

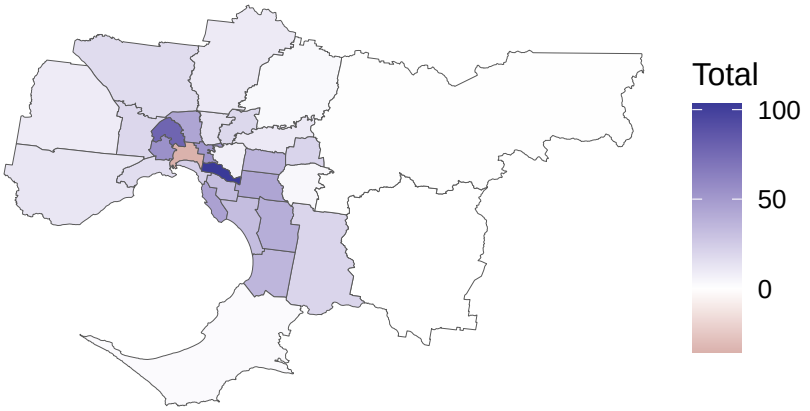


Figure 6: Change in SI on census day 2016 to 2021, by LGA

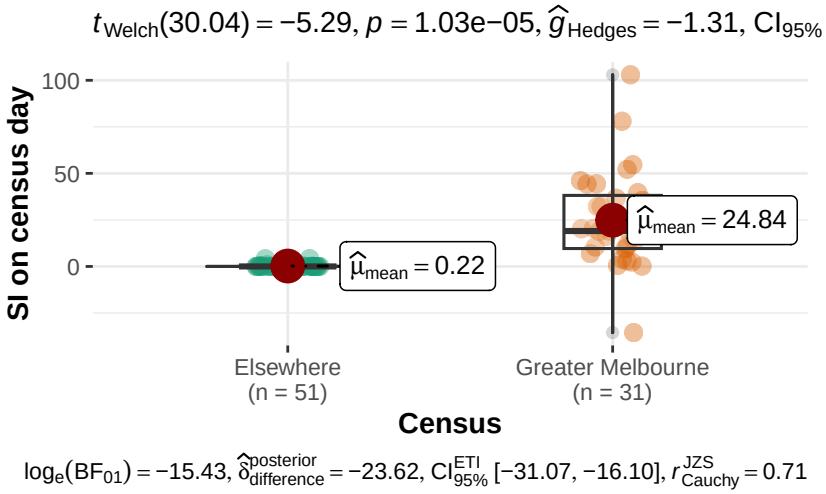


Figure 7: Change in SI on census day 2016 to 2021, by LGA

Victoria. The SI increased by an average of 24.84 for Greater Melbourne LGAs, whereas there was little to no change for LGAs elsewhere. However, there was one LGA in Greater Melbourne where the SI in 2021 was lower than for 2016: being the City of Melbourne itself, where the SI score fell by -36.

*Transit needs*

*Level-boarding accessibility*

*The metro tunnel - adding services*

*The suburban rail loop*

*A transit-centric city (<15 min services)*

*Squaresville*

*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?

*A transit-centric city (<15 min services)*

*Squaresville*

*Washington DC*

*Level-boarding accessibility*

*A transit-centric city (<15 min services)*

*Squaresville*

*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.

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