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Measurement of effective transit supply index between OD pairs

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Abstract

Public Transit (PT) Supply Index (SI) is primarily estimated to prove the differences in demand and supply to provide an understanding of social issues related to PT, such as equity, and social inclusion. The definition of SI is yet not clear from the literature; thus, it is usually mixed with accessibility, and availability of transit service. This study revisits the supply index estimation problem with the more detailed and robust approach. A route-based equation is developed in which the variables include walk buffer areas of stops, the total area of the zone, straightness of route provided to that zone, and average Available Seating Capacity (ASC) of transit services. The equation provides Origin-Destination (OD) based SI, that is SI for each OD pair. Furthermore, the equation also incorporates the number of transfers needed to travel from the origin zone to the destination zone and speed between those zones. Most of the data required for analysis are taken from either static Google Transit Feed Specifications (GTFS) or smartcard data. Though the analysis is only carried out at a few OD pairs, when the method is applied to all zones it is expected to provide detailed insight into the transit supply, therefore can be helpful for planners to visualize and improve the complex and cumbersome networks in a more effective manner.

1 Introduction

The introduction of big data in transportation system such as smartcard (SC) data, automatic vehicle location (AVL) data, etc., enables researchers and planners to work out more unorthodox and accurate methods of analysis(Kurauchi and Schmöcker, 2017). Over a period of time, many tools have been developed, which assesses the performance of the transit system and its spatial distribution in rural and urban areas. Primarily, evaluation of the transit service is carried out in the context of transportation needs and its provision, equity, and social inclusion to meet the mobility needs of citizens (El-Geneidy et al., 2016, Jaramillo et al., 2012, Currie and Delbosc, 2010). In many studies, transit accessibility and connectivity are used to quantify the transit provision to an area (or zone). However, the accessibility quantifies the ease with which a transit system can be accessed from an origin or destination perspective. The transit connectivity discusses its connectivity within and across the zones to provide better mobility, while the transit supply index refers to the transit resources provided to a zone. Hence, the SI of transit service enables transit planners and practitioner to analyse the transit network for its resource allocation.

Keeping in view the transportation needs for ever-increasing urban population and complexity of transit network, supply index (SI) was introduced to estimate and visualize the spatial distribution of transit resources supplied to zones more effectively (Currie and Wallis, 1992). The advent of high computation powers and improved Geographic Information System (GIS) based software along with big data techniques enables the researchers to estimate SI in more detailed, thereby more accurate models can be computed and the results can be visualized more effectively by employing advanced GIS-based platforms (Qi et al., 2019, Chen et al., 2018). Therefore, there is a need to update the current techniques to cater for the more powerful computational techniques and data advancement in the transportation sector. Hence, this study revisits and the supply index formulation, and provide more insights into the transit network and identify the potential zones for improvement.

2 Literature review

In the first study of SI found in literature, three variables were considered that is vehicle/sq. km, number of services operated in a zone, and taxi subsidy scheme (Currie and Wallis, 1992) for SI estimation. Over time, researchers have included many other variables. In another study carried on Hobart, Australia, Currie (2004) calculated SI based on the purpose-wise travel time from a zone. In another study, Currie (2010) developed and applied an equation to calculate SI on a bigger city of Melbourne, Australia. The same equation is later used by many other researchers in their studies to calculate SI (Toms and Song, 2016, Ricciardi et al., 2015, Delbosc and Currie, 2011). The equation is based on variables: 1. No. of walk/access buffers; 2. total buffer area from stops; 3. total area of the zone; and 4. number of transit trips per week. Similar to Currie (2010), Carleton and Porter (2018) estimated SI by incorporating road length instead of a buffer area in a zone.

Jaramillo et al. (2012) introduced the relative capacity term in SI estimation. Wang et al. (2014) and Bejleri et al. (2018) carried SI estimation based on Geographical Information System (GIS) by comparing bus-served people-gather land use for each zone. In the most detailed study so far, Chen et al. (2018) incorporate service coverage, service level, and service accessibility.

All studies cited above have estimated SI by using specific indicators, but none of them so far utilized the actual transit routes operating between the selected zones, and the actual number of trips to get effective index. Therefore, this study addresses these problems by using the big data available to the transit planners such as SC data. This study develops a transit SI incorporating the actual transit trips, and quality of transit provided. The study assumes that effectively there is no transit supply provided if transit service is provided between two zones but is not being used by any passenger in limited time duration (let's say, one week).

3 Methodology

The methodology section is divided into two sub-sections. First sub-section explains the formulation of SI, and the second sub-section describes the methodology applied to calculate the transit SI to give proof of the concept.

3.1 Transit supply estimation equation

public transit SI between two zones can be calculated by:

$$SI_{ij} = \frac{\sum_{r=1}^{R}\sum_{n=1}^{N}\left[\left(Area_{B_{n,iR}}\right)\sum_{1}^{m}\{S_r \times \sum_{1}^{run}\left(PT_c^m - O_{n,run}^m\right)\}\right]}{Area_i} \times \frac{1}{(1+N_{t,r,m})} \times \frac{1}{TT_{ij,r,m}/L_{ij,r}} \quad (1)$$

Where, r is the route in consideration, R is the total routes that serve zone ‘i’ and ‘j’ (in observed data i.e. passenger uses these routes while travelling from ‘i’ to ‘j’ either directly or with transfer(s)) (i.e., R ∀ serving ‘i’ and ‘j’), $Area_{B_{n,iR}}$is the total buffer area in the zone ‘i’ of transit routes R, N is the number of total stops buffer areas in a zone, $Area_{Bn}$ is the buffer area in a zone of stop n, $Area_{zone}$ is the total area of zone considered, PT_c^m is the Total capacity of PT of mode ‘m’, $O_{n,j}^m$ is the current occupancy of mode ‘m’ at stop ‘n’ of zone ‘j’, N is the total number of stops buffer served by route ‘r’ in the zone, and ‘m’ is the transit mode uses stop ‘n’. $N_{t,r,m}$ is the number of transfer required while travelling using route ‘r’ and mode ‘m’. $TT_{ij,r,m}$ is the total travel time while travelling from ‘i’ and ‘j’ using route ‘r’ and mode ‘m’, and $L_{ij,r}$is the length of route ‘r’ between zones ‘i’ and ‘j’. The final unit of the SI is the available seats per zone per duration. The duration can be any time, for example, morning peak, evening peak, weekend, or an hour of analysis.

In equation 1, $\frac{\sum\sum_{n=1}^{N} Area_{B_n}}{Area_{zone}}$ provides the route- based a total number of transit walk buffers in a zone when further summed for all routes. The buffer area to the zone area ratio indicates the extent of the area of being served by transit services. The term $\sum_{r=1}^{R}\sum_{n=1}^{N}\sum_{1}^{m}\sum_{1}^{run} PT_c^m - O_{n,run}^m$ give the average ASC for a trip of transit service over each stop representing the quality of transit service provided to a zone. If the capacity is taken as the taken capacity, then this term shows the denied boarding condition. The term $\frac{1}{(1+N_{t,r,m})} \times \frac{1}{TT_{ij,r,m}/L_{ij,r}}$ introduces the connectivity of transit services provided between two zones. To distinguish between the attractiveness of two services, term S_r is introduced. S_r is defined as the ratio of Euclidian distance to the route distance. Straightness of route factor differentiates between slow and fast services. Hence, the proposed equation considers not only consider routes that serve the two zones selected for analysis, but it also quantifies its quality and connectivity.

4 Proof of study concept

This section elucidates the application of the transit SI estimation equation demonstrated in above sub-section.

To calculate the SI, the datasets required are 1. SC data; 2. Static GTFS feed; and 3. Geographical zones. One-week SC data consists of the transactions (records of boarding and alighting stops with time stamps) made by passengers. One-week data is used in the study because it is assumed that during all possible routes (or combination of routes) are at least used once a week. Therefore, the OD pairs between which there is no transaction recorded, it is assumed that SI for that OD pair is zero. A GIS-based platform is used to calculate the walk buffer of 400m around the stops, and its percentage in zones (if it lies in more than one zone).

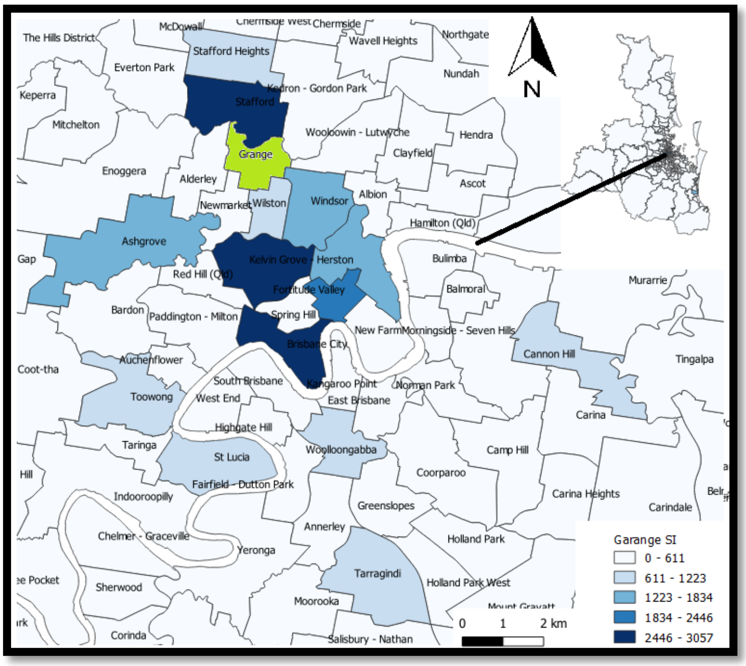
To calculate the average ASC, it requires the sequence-wise stops/station/terminal of each transit route. The missing routes/stops are taken from live GTFS feed. By employing either GTFS or live GTFS feed, straightness of route is calculated.

For selected OD zones ‘i’ and ‘j’, all the transactions which are made from ‘i’ to ‘j’ are extracted. The subset data is employed to find all the routes taken between ‘i’ and ‘j’ along with the minimum number of transfer taken and travel time of individual routes during the one-week time. For all the possible routes, the algorithm calculates the ASC for each stop of the route considered, which is the difference of cumulative boardings and alightings along the path (all the stops along the path) of that route. SI of OD pair ‘i’ to ‘j’ is the summation of individual SI of each stop lies in the originating zone.

5 Results

This section extends the discussion on results of SI estimation after employing the developed formulation and methodology discussed in the previous section. The transit supply values are calculated manually from Grange (in green) to other selected destinations and are shown in Figure 1. To calculate average ASC, SC data of 7th March 2017 is used, which is a typical working day. The results in Figure 1 are from the morning peak period only, which is from 06:00 am to 08:30 am. In total there are 8 different bus routes passes through Grange, which are the first contact of passengers while travelling from Grange to any other zone.

Figure 1: Supply values (Grange as origin)



Future extension of this study is to outspread the application of this model to the whole network and all modes operated. The results so far indicate that this method provides more realistic results as compared to the previous studies on SI. It is because of the proposed method uses the actual datasets (smartcard data) for routes identification, and number of transit trips occured, while the previous studies employed the scheduled data. Also, this study provides results at the OD level, while the existing methods only consider the origin zone and do not take into account the destination zone.

6 Conclusion

This study revisits the supply index, which is the quantification of resources for a zone. This study provides the concept that the supply of transit resources can be further distributed among OD pairs. To calculate the effective supply of resources, this study further develops an equation based on the term average ASC, which is calculated from one-day SC data. The equation developed further incorporates the buffer area around stops, total zonal area, transit mode (by incorporating straightness ratio of the route), the number of transfer required to travel between origin and destination, and the speed of transit mode taken.

The current result shows a good understanding of SI values. Therefore, future work may include but not limited to automation of algorithm to cater for multi-modes. Although the developed equation has provision for the multi-modal transit system, it is still required to apply it on other modes, for example, train, metro, ferry, etc. Further, challenging part is to visualize the results, as the number of results becomes *nxn* instead of *2xn* when compared to previous studies to get the maximum out it.

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