Is Public Transport Spatially and Temporally Equitable? A case-study in South-East Bangalore*

Navitha Parthasarathy
Sachit Rao
International Institute of Information Technology, Bangalore, India
navitha.p;sachit@iiitb.ac.in

Abstract

The need to develop equitable public transport in cities, while balancing contradictory demands, has been well recognized. In this paper, this issue is addressed by analysing the frequency and distribution of buses and bus stops, as provided by the state government-owned Bangalore Metropolitan Transport Corporation (BMTC), in the south-eastern fringe of Bangalore, India. This region of Bangalore is selected as it contains a mix of residential and industrial units and hence, diverse measures of equity can be determined. With this approach, first, bus stops that are between 1-3 kilometers from an arterial road are identified; BMTC data reveals that arterial roads in Bangalore are serviced at a very high frequency by buses. Second, the frequency with which buses service these stops are determined and then grouped according to the time of day - early morning, afternoon, etc. Using these results and data from government surveys, the concepts of availability and accessibility - which form measures of evaluating equity - are tested. In addition to these measures, the results can also be used to determine the impact on pollution - which may occur with the increased use of private vehicles - and on employment and other economic opportunities.

1 Introduction

Litman [Lit02] categorises the various types of transport equity, how they overlap, and their impacts on designing transport policies. In the context of this paper, the category entitled "vertical equity with regard to income and social class" is appropriate, as the focus is on analysing the availability of public transport in a region of the south Indian city of Bangalore, which straddles two *taluks* (or sub-districts) - Anekal and Bangalore South - and hosts industries, both formal and informal, as well as residents with varying wage levels [Gov18].

BMTC is the sole public bus transport operator for the city of Bangalore with upwards of over 6000 daily scheduled buses and close to 70,000 trips[1]. The report by CSTEP [CST15] presents a population density map of the Bangalore region superimposed on the BMTC network and recommends that it is for the low density regions,

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[1] `https://www.mybmtc.karnataka.gov.in/info-1/BMTC+Glance/en`

which are in the suburban parts of the city, that the public bus service is suited. The area of study selected in this paper is one such region that lies in the south-east part of the city. The report [CST15] also presents various scenarios, which consider the Bangalore Metro Rail network and an estimated population increase, and the investments that have to be made by BMTC for each scenario such that it can cater to atleast 30% of passenger trips. It is clear from this report that the bus service provided by BMTC will continue to remain crucial, and in one scenario, will prove to be the "backbone of public transport services". Consequently, the analysis presented in this paper, of public transport in suburban regions, can be used to make the service more vertically equitable.

Vasudevan et al. [VMB+14] present the reforms undertaken by the BMTC to improve its service quality. They describe the evolution of the "BIG Bus" system, which is based on a direction-oriented network model rather than a destination-oriented model. In the new model, buses are scheduled to ply at high frequency on the major arterial roads of Bangalore, along with supplementary feeder buses operating at an even higher frequency, which would connect suburban regions in the vicinity of these arterial roads. This model was piloted on Hosur Road - which lies in the area of study considered in this paper - and later extended to other arterial roads. Another innovation adopted by the BMTC, in the context of vertical equity, is the introduction of the *Atal Sarige* bus system, which has been developed for the urban poor to reach their destinations. Shastry and Bhatt [SB13] present a detailed analysis of the *Atal Sarige* buses and whether it is indeed accessible to the urban poor. Their analysis reveals that 1) the frequency of these buses is low, as there are few buses and routes; 2) less than 20% of the urban slums, whose residents this system is meant to serve, have a bus stop serviced by these buses that are less than 400 metres; and 3) users would need to often use a regular bus, which is more expensive, to access the *Atal Sarige* bus network.

Equity in public transport, and the city of Bangalore in particular, has received considerable attention in the literature. Baindur and Rao [BR16] analyse the effect of fare increase in travel patterns amongst the economically weaker residents of the city. They consider a centrally located region in the city - hence well connected by buses - which houses residents as well as businesses that hire support staff, both of whom lie in the low-income to lower middle-income groups. The dissertation of Chava [Cha16] focuses on an industrial area within Bangalore city and the possible gentrification in such areas, as well as exclusion from public transport, caused by "transit oriented developments", which includes both the Bangalore Metro Rail and the BMTC system. Pangotra and Sharma [PS06] focus on the role of public transport in limiting the number of private vehicles in Bangalore. They present numerous models, that consider population and income growth as well as the introduction of the Metro Rail and an upgraded BMTC fleet, and conclude that the BMTC system will continue to play a crucial role; these findings are similar to that presented in [CST15]. Sabapathy et al. [SFS12] study the difference in commuting patterns, using different forms of transport, between employees in the Information Technology sector and a traditional Public Sector Unit, in Bangalore. Their analysis shows that the change in travel patterns increases spatial inequity and recommend that policies that encourage the use of public transport and that are not focussed on improving infrastructure for high-income commuters should be developed.

These references highlight the important role played, and also expected to play, by the BMTC system in meeting basic transport needs as well as ensuring that various forms of equity are not grossly violated. With this background, the contributions of this paper aim to answer the primary question of determining how accessible is public transport in suburban regions of the city that consist of both residents as well as places of work? Accessibility is determined by the frequency with which bus stops are serviced. By answering this question, using data that exhibits the spatial and temporal distribution of bus services, the resulting answers may be expected to highlight

1) If commuters, who could be residents or employees of businesses in these regions or both, can use public transport at frequent intervals during the day. This will indicate whether commuters have the ability to choose when they can travel or are they constrained to have a fixed behaviour.

2) The distances commuters would have to travel, say using other modes of transport, to access bus stops that are serviced at greater frequency than those that are in proximity to their residences or places of work.

3) Ease of last-mile connectivity and consequently, if commuters have to rely on private vehicles, thus worsening equity from an environmental perspective.

4) If commuters from low-income groups can live in areas of their choice or are restricted to living near their places of employment. In contrast, the temporal distribution analysis may also indicate if commuters with high incomes would be suitably incentivised to choose public transport.

The main results of this paper are derived using data provided by the BMTC, such as the time-tables published on their website and GPS traces of buses that operate in the selected region of study; the latter is made exclusively available to the host institution of the authors by BMTC. The paper is organised as follows: In Sec. 2, the methodology that is followed to determine the spatial and temporal distribution is described. In Sec. 3, the results and analysis of these results are presented. Finally, concluding remarks and future directions are outlined in Sec. 4.

2 Methodology

The area of study that is selected lies in the south-eastern suburban region of Bangalore; Bangalore is the capital city of the south Indian state of Karnataka. An arterial road, called Hosur Road, as it connects Bangalore with the town of Hosur in the neighbouring state of Tamil Nadu, passes through the region. To justify the choice of this region of Bangalore, consider the map, as shown in Fig. 1, which shows bus termini that have more than 50 routes assigned to them. The stop locations are marked using their GPS coordinates and are listed in the bus stop data for the year 2018, as provided by BMTC.

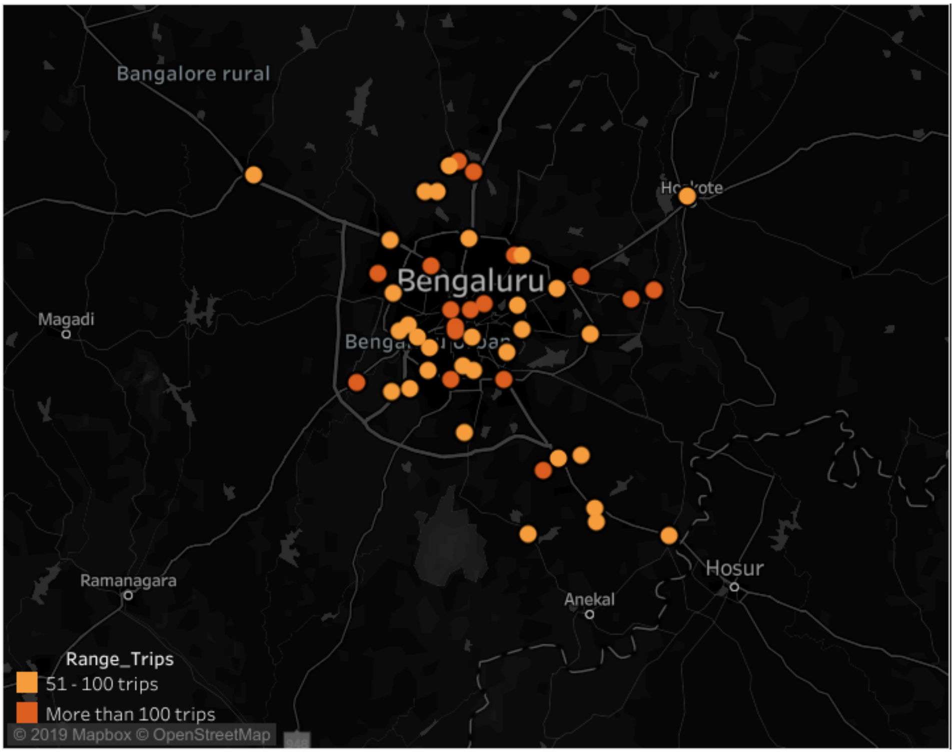


Figure 1: Bus termini with more than 50 trips in Bangalore City

As can be seen, the south-eastern region has a greater number of high-frequency termini when compared with other regions that are almost at the same distance from the city centre. This spatial distribution also matches the effort of implementing the direction-oriented network model along the arterial roads of the city. A cursory glance at this map may lead to the conclusion that this region will have a high degree of connectivity and hence, a greater measure of equity. However, since the direction-oriented network model also requires the implementation of feeder services that connect to the arterial road, the spatial distribution of stops in the vicinity of the arterial road are next identified. The temporal distribution at these stops, which are expected to have an even higher frequency and are used to make the primary arguments of this paper, are presented later in this section.

2.1 Spatial Component

The spatial locations of these stops are shown in Fig. 2 and the study region is marked by the dashed ellipse.

Since it is natural that as distances of the suburban regions from the city centre increase, the population density in these regions also reduce. Correspondingly, as shown in Fig. 2, the number of stops also reduce and simultaneously, the spatial spread increases. Only the bus stops that lie within the 1-3 km range are considered

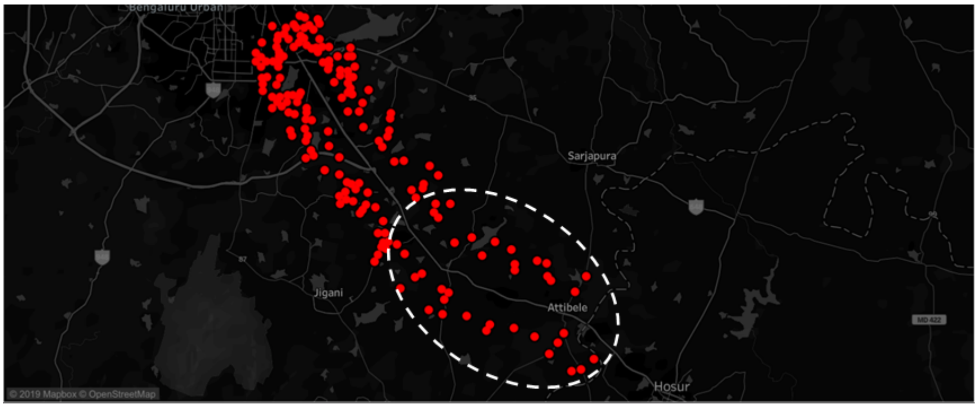


Figure 2: Bus stops that are between 1-3 kms from Hosur Road and the chosen area of study

Table 1: Census information for Anekal and Bangalore South sub-districts combined

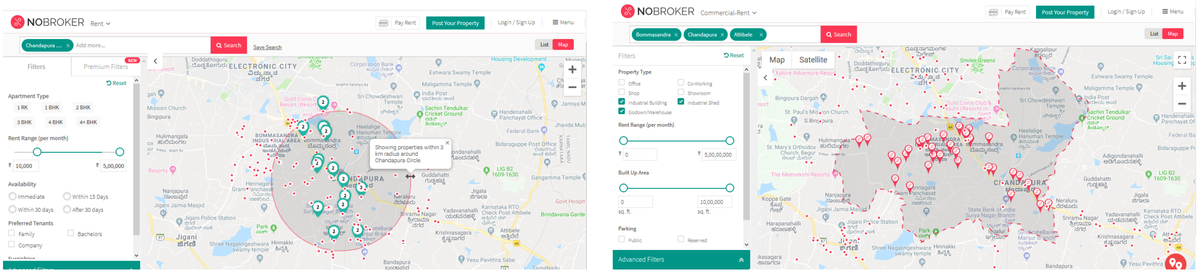
Parameter	**Value**	**% of Bangalore Urban**
Projected Population (2021)	8,96,806	6.3
Factories (Garments, Textiles, etc.)	4,175	50
Employees in factories (Male and Female)	5,40,759	57.1
Industrial Sheds and Plots	877	37.1
Small-scale industries (Leather, Paper, etc.)	76,016	55.2
Employees in small-scale industries	9,47,771	64.5

in the analysis, as the spatial locations of these stops are expected to act as a deterrent from adopting public transport. This is based on the observation, as mentioned in [Cha16] and references within, that in the Indian context, commuters do not walk to a public transport access point that is greater than 800 metres or takes longer than 10 minutes. Hence, even though the arterial road has numerous buses plying at high frequency, commuters who work/live within 1 km of these stops, may prefer - at least those in the high-income groups - to use private vehicles or other modes of transport to access the arterial road, thus increasing the traffic density on roads that connect to the arterial road. This may also constrain employees, from the low-income and lower middle-income groups, whose places of work are close to these stops to change their travel patterns.

The area of study, as marked in Fig. 2, is considered for equity analysis, which, according to government data for the year 2017-18, [Gov18], contains several industries as well as dwellings with a residential population. This area contains parts of both the Anekal and Bangalore South sub-district jurisdictions and as a measure of its importance in the overall context of Bangalore city, selected census information from these sub-districts, as published in [Gov18] and presented in Table 1, are used. As can be inferred, this combined area is projected to host more than 6% of the resident population and more importantly, this area houses businesses and other establishments which employ more than 50% of the working population of the city. Thus, even though the area of study marked in Fig. 2 forms only a part of the both sub-districts, it may contain several of these establishments and dwellings. Additional information is needed to support this hypothesis and will be a part of future work.

Partial support to this hypothesis is provided by results of a search for both residential and industrial units, available for sale or rent, provided by an online real-estate platform[2] in the chosen area. These search results, which are shown in Fig. 3, clearly indicate the large number of such entities in the area and their proximity to the arterial road. Thus, the chosen area of study has the potential to highlight the measures of equity and their impacts.

[2]`https://www.nobroker.in/about/about-us`



(a) Residential Units

(b) Industrial Units

Figure 3: Residential and industrial units available for sale or rent, as listed by an online real-estate platform

2.2 Temporal Component

Having introduced the spatial spread of the bus stops in the area under study, as shown in Fig. 2, in this section, a temporal analysis of the services in these stops are presented and discussed. The following steps are followed:

1) According to the data management system of BMTC, several of these locations are serviced by the same bus route(s), but plying in different directions. As a result, the bus stops are listed differently, but are actually in close proximity to each other; for instance, such stops could be on either side of a road. To highlight the aspects of equity, those stops that are within a distance of 250 metres of each other are clubbed together and treated as one stop.

2) The schedules of the buses plying to these stops are then obtained from the time-table published by BMTC on their website as well as their mobile app. Multiple sources have to be used as not all bus schedules can be found from either source.

3) The time when a bus departs a stop is determined. Again, based on data availability, the time is found from the schedules provided by BMTC or by estimating it using an average speed and distance from the origin; for the latter, some of the features as provided by apps such as Google Maps are used.

Remarks: By analysing the GPS trace data of a few routes passing through a stop, there were instances when buses did not make the scheduled number of trips for that route. Owing to some of these gaps in the data, while the temporal analysis should be performed using the GPS data, in this paper, the “ideal” scenario, which is where buses ply as scheduled, is used for analysis.

3 Results and Analysis

Since the spatial component is fixed, to better understand the variations in the temporal component, the frequency with which buses service the selected stops, in a day, are determined for the following time ranges:

1) Before 8 am

2) 8 am - 12 pm

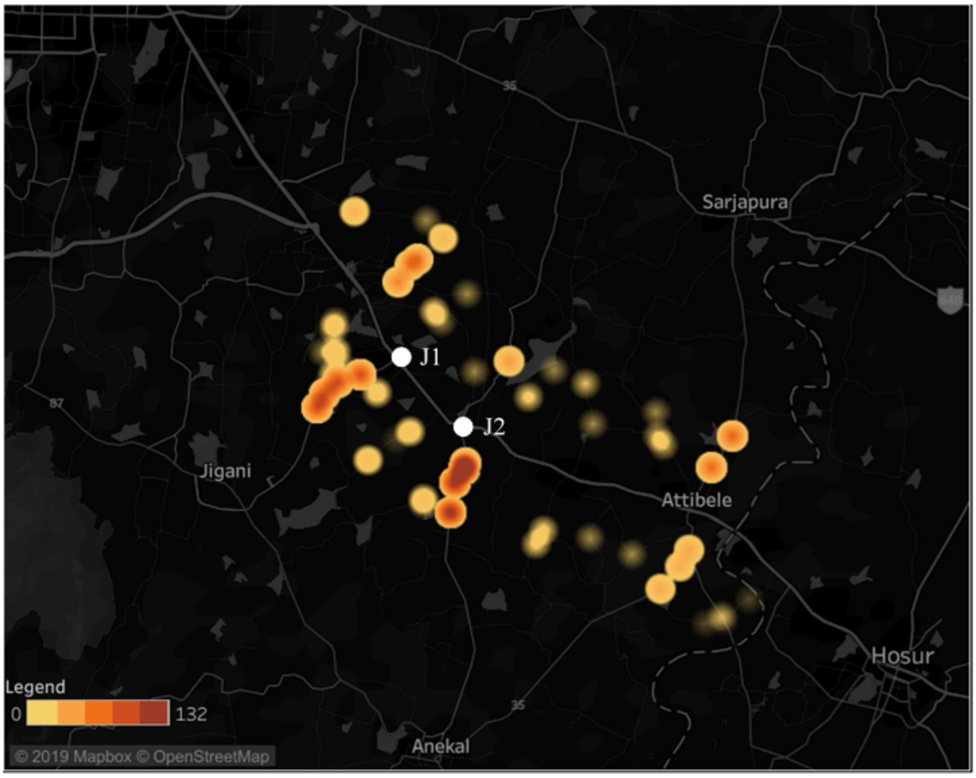
3) 12 pm - 4 pm

4) 4 pm - 8 pm

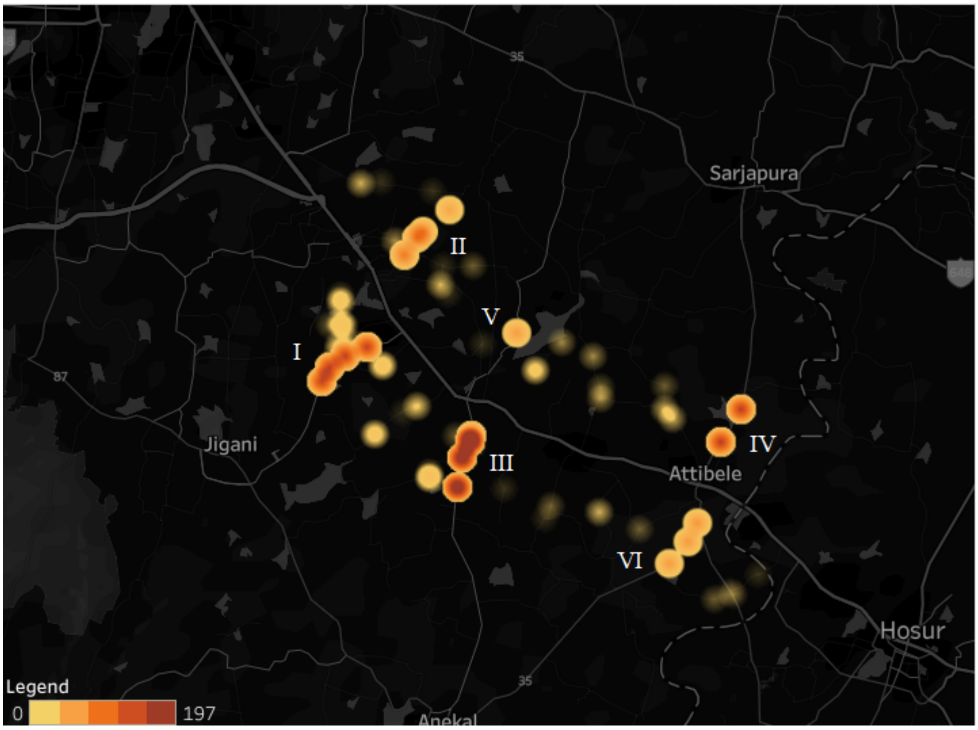
5) After 8 pm

Except for the time ranges ‘12 pm - 4 pm’ and ‘After 8 pm’, the other time ranges are when the bus services might be used be most, especially by residents commuting outside the area or by employees working in the selected area. Ticket sales data on some of these routes will indicate this aspect and this analysis will be considered in the future. The frequency of buses in the selected time ranges are shown in Figs. 4a–4e. It is remarked that the BMTC schedule data does not distinguish between weekday, weekend, or public holiday services, hence, the results presented here may not be applicable on all days. However, assuming that these are the schedules for a normal working day, they may be used to understand issues of inequity.

Prior to analysing the results in the chosen area of study, the number of trips of buses plying on the arterial Hosur Road are presented. This is as shown in Fig. 5. As can be seen, a minimum of about 1400 trips, with



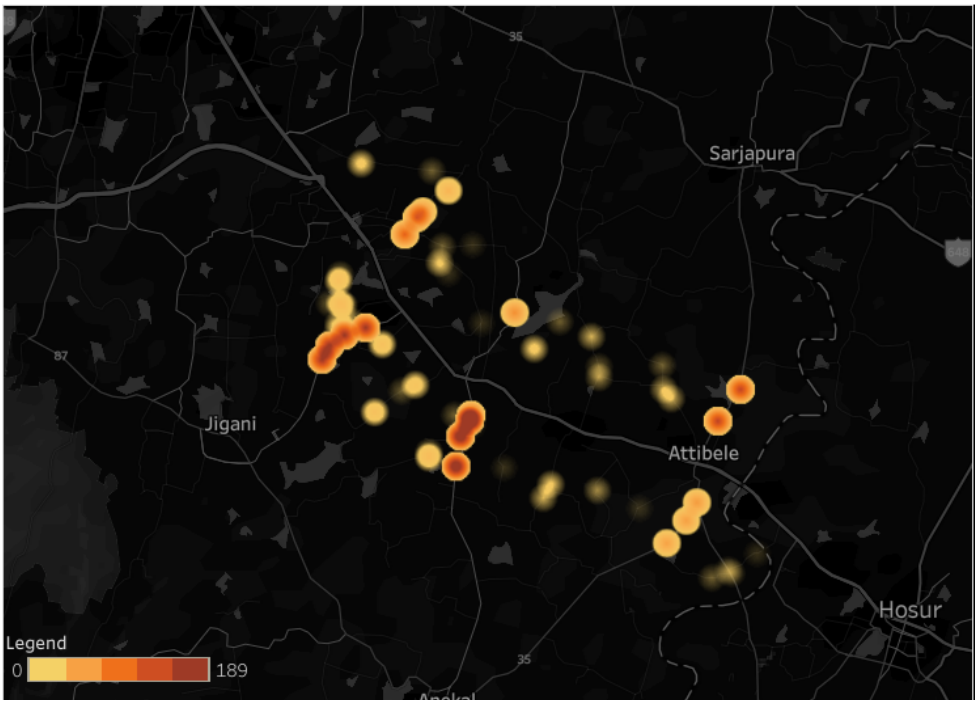
(a) Before 8 am



(b) 8 am - 12 pm

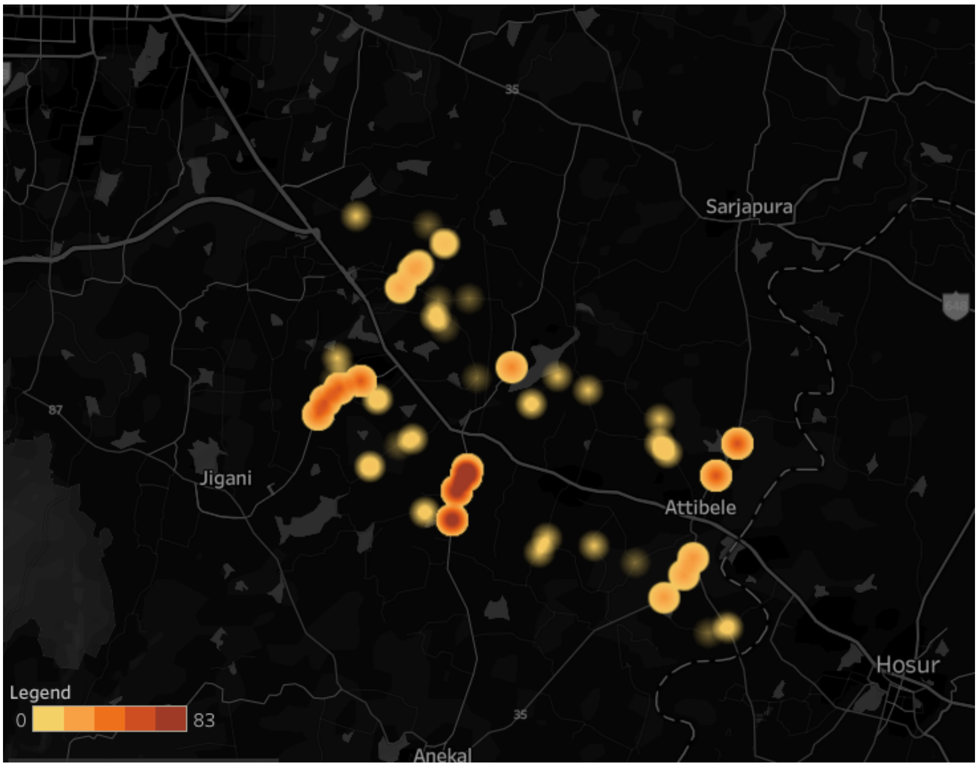
Figure 4: Frequency of buses in the selected time ranges in a day

(c) 12 pm - 4 pm



(d) 4 pm - 8 pm

Figure 4: Frequency of buses in the selected time ranges in a day (contd.)



(e) After 8 pm

Figure 4: Frequency of buses in the selected time ranges in a day (contd.)

a maximum of over 5000 (close to 10% of *all* the scheduled trips), ply on most of the stops on Hosur Road. Note that this data again does not distinguish between weekdays or weekends; includes buses plying in both directions; as well as counts the luxury air-conditioned buses operated by BMTC. These luxury buses form less than 5% of trips on this stretch.

Now, considering the results shown for the different times in a day, as shown in Fig. 4, it can be immediately seen from these figures that only a few roads that connect to the arterial Hosur Road have a 'high' frequency of bus services. These are the roads, enumerated by moving north-west from the south-east, that may be considered to connect 1) Anekal-Attibele-Sarjapura; 2) Anekal-Chandapura Junction-Dommasandra; and 3) Jigani-Bommasandra-Huskur. Bommasandra and Chandapura Junction are marked as J1 and J2 in Fig. 4a, respectively, while Huskur is close to the area marked by the roman numeral II in Fig. 4b. In fact, a few of the stops marked with the roman numerals I-VI in Fig. 4b do have areas of interest. For example, the stops marked by I are in the vicinity of the Bommasandra Industrial Area; the stop marked by II has a fruit market (Singena Agrahara) close to it; and III consists of a large residential area bearing the name of Suryanagara. On the other hand, by observing maps offered by several online platforms, it appears that the areas marked by IV, V, and VI do not have any such noticeable concentrations of dwellings or industrial areas.

The buses plying on these roads are expected to play the role of the feeder buses that form part of the BIG Bus system, which in turn, are dictated by the direction-oriented model, as described in [VMB$^+$14]. The disparity in the number of trips of the buses on the three roads listed and the ones on the arterial road are evident. Thus, this indicates a deviation from the proposed direction-oriented model. Also, note that there are fewer than 10 trips on which the luxury buses are operated in the selected area.

In spite of the difference between the frequency on the arterial road and others, the relatively high frequency bus service along these roads could be the reason for the high concentration of residential dwellings and industrial plots that have been built along these roads, as shown in Fig. 3. While this result may be argued to be obvious, that is, regions that have high bus frequency will also have a higher density of such dwellings and plots and vice versa, such a concentration may lead to greater inequity, as the cost of these entities may also be high and thus unaffordable to many. Indeed, though it is only with ground-based surveys that this conclusion can be strongly justified, it can be conjectured, following [Cha16], that such a concentration may lead to gentrification.

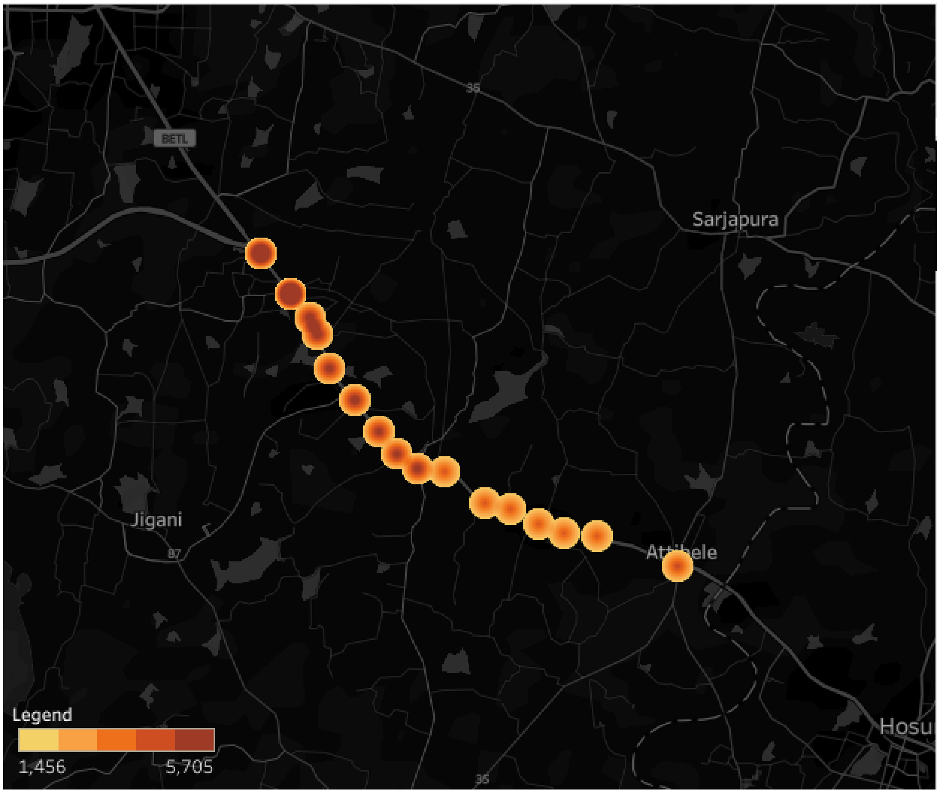


Figure 5: Number of trips on the arterial Hosur Road

Even though there are several luxury buses plying on the arterial road, which may motivate commuters from high-income groups to use them, as these do not connect areas beyond the arterial road, such commuters may be discouraged from using them as they do not assure last-mile connectivity. This claim also needs further justification since, other modes of transport, such as shared-rides and two-wheeler rentals, even for one-way trips, have begun their operations, mainly to address the last-mile connectivity problem.

It can also be observed, from Fig. 4, that the areas between the Anekal-Attibele-Sarjapura and Anekal-Chandapura Junction-Dommasandra roads see significantly high variation in frequency; the highest frequency is observed to be only after 4 pm. Data also reveals that some of these areas have *no* buses plying there at all. This would imply that commuters who have to reach these areas would have to rely on alternative modes of transport, including private vehicles, thus leading to either a change in travel patterns, which may include not having the flexibility to commute outside the time intervals when buses are available. A similar result can be observed to hold even between the Anekal-Chandapura Junction-Dommasandra and Jigani-Bommasandra-Huskur roads. Also, BMTC data does not indicate the presence of buses that connect the areas IV-V or III-VI directly, that is, commuters wishing to travel between these areas are forced to travel from and to the arterial road. All these factors increase the pressure on the few roads on which the bus frequency is high.

These results do not differentiate between the directions of travel of the buses in the considered stops. As a result, though the bus frequency approaches 200 in certain stops between 8 am - 4 pm, only close to half theses buses would actually be plying in one direction. While there may be a demand for buses on the roads listed above, the presence of high-frequency buses may reduce the ridership on some routes as most seem to ply between the same origin-destination pairs. In both these matters, a more fine-grained analysis will also be taken up in the future.

4 Conclusions

The results presented in this paper, which forms the first of a more detailed study of equity in public transport, can act as a foundation for future work in similar regions in Bangalore city. Many such avenues have been identified, for example, the use of ticket sales data; performing surveys on the field; considering directions of travel; and more importantly, suggest new bus routes that can balance the needs of commuters as well as BMTC itself.

Acknowledgement

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