BUZZIT: An Interactive Tool to Analyse the Network of Public Bus Services in Singapore

Adeline Chin, Amelia Lee, Nicole Goh
Singapore Management University, School of Information Systems, Class of 2018

Abstract --
BUZZIT is an application that allows users to gain an overview of the overall public bus service network in Singapore through the use of interactive visual techniques and computational methods to understand the centrality indexes of bus stops across the country. BUZZIT is designed to provide city planners the ability to at a glance, identify bus stops that are highly connected, relative to all other bus stops across Singapore, and aid them in the efficient and cost saving management of resources.

Keywords – Singapore, LTA, Public Bus Services, Bus Network, Geospatial Analytics, Centrality indexes, Betweenness, Closeness

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1. Introduction

Taking a public bus could be one of the most hassle free and accessible modes of public transport in Singapore. Bus transport takes up a significantly large portion of public transport in Singapore with a daily average of over 3.9 million rides taken per day as of 2017, an increase of 1.2 per cent from the previous year. There are a total of more than 300 bus services scheduled to operate in Singapore and are currently operated by 4 main bus operators - Go-Ahead Singapore, SBS Transit Ltd, SMRT Buses Ltd and Tower Transit Singapore.

However, for those living towards the periphery of Singapore, public buses can be quite bad in terms of travel time. For a destination that is 30-40 minutes of travel time by train, public buses can take 45 minutes to an hour.

While there are existing applications to map out the entire bus route for a selected bus, they do not provide a clear representation of the connectivity of a certain bus stop relative

to the other bus stops across Singapore, and are often restricted to reflecting the route for only one bus. This proves as a challenge for city planners to accurately identify highly connected bus stops in order to facilitate their decision making process of whether or not to convert the bus stops of high centrality into a connecting point, or even a hub.

Our project thus aims to identify the locations of highly connected bus stops based on the concept of centrality, which are further calculated using mathematical indices such as betweenness index and closeness index. It will also provide an overview of all the routes of the bus services which pass through that particular bus stop.

This paper reports on our research and development effort to design and implement a web-based geo-visual tool to analyse the connectivity of public buses in Singapore.

2. Related Work

The research paper, "Spatial Network Analysis of Public Transport Systems: Developing a Strategic Planning Tool to Access the Congruence of Movement and Urban Structure in Australian Cities", introduces a GIS-based tool designed to assess centrality and connectivity in urban public transport networks. (Scheurer, Curtis & Porta, 2007)

The paper introduces a range of measures and indicators to explain the common observation that public transport seems to be utilised more frequently to places in the city with greater centrality. It also goes on to define a place with high centrality in a geographical sense can be understood as spatial proximity to a high number and range of urban activities, while in a network sense, can be measured according to the configuration of a movement system around nodes and edges and their distribution over, and their relationship to the activities within, the urban space.

The indicators highlighted in the paper were degree centrality, closeness centrality, betweenness centrality, efficiency centrality and information centrality.

Degree centrality, defined as the proportion of nodes directly connected to the node in question out of the totality of the nodes within the network.

Closeness centrality, defined as the inverse average distance between the node in question and all other nodes within the network. The closeness centrality of any node can be calculated as

$$C_C(i) = \Sigma_j \frac{1}{a_{ij}}.$$

Betweenness centrality, defined as the average proportion of paths between any two nodes within the network that traverse the node in question, out of the total number of possible paths between these two nodes. The betweenness centrality of any node can be calculated as

$$C_B(i) = \sum_{s \neq i \neq t} \frac{\sigma_{s,t}(i)}{\sigma_{s,t}}$$

Where $\sigma_{s,t}$ is the number of shortest paths connecting *s* to *t* and $\sigma_{s,t}(i)$ is the number of shortest paths connecting *s* to *t* but passing through *i*

3. BUZZIT as a Network Analysis tool

In this section, we will go into detail the process of data preparation, as well as the methods and technologies that were incorporated in the process of creating the web application.

3.1 Data Collection

We utilised the island-wide bus stop data that is available in the LTA Data Mall to extract the geographical location. In addition to the geographical locations, we also want to know which URA planning areas and planning subzones the bus stops were situated in. Hence, we retrieved the MP14_SUBZONE_NO_SEA_PL in shapefile format from data.gov.sg to further group the bus stop locations into subzones.

3.2 Data Preparation

Although we had the locations of the bus stops, the stops were not connected according to the route of the bus services. The route for a specific bus service was not clearly displayed with the data that we had at hand.

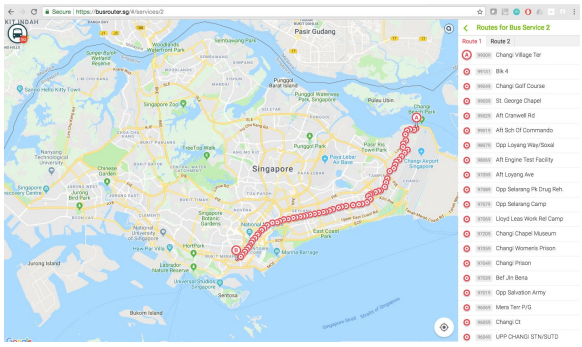


Figure 1: Bus route for bus service 2 on BusRouter SG app

Using the data available on the BusRouter SG app (https://busrouter.sg/#/), we wrote a Python script to scrape the 3 different types of busses - Trunk Bus Service, Feeder Bus Service and Nite Bus Service, and for each of the services, extract the bus number, its direction, bus stop code, as well as the name of the bus stop.

```
busses = []
types = ["Trunk Bus Services", "Feeder Bus Services", "Nite Bus Services"]
bus_types = soup.find_all('ul')
type_counter = 0
for type in bus_types:
    bus_numbers = type.find_all('li')
    for bus_num in bus_numbers:
        bus_no = bus_num.text.strip().split()[0]
        extension = bus_num.find('a').get('href')
        type = types[type_counter]
        busses.append([bus_no, extension, type_])
    type_counter += 1
```

Figure 2: A snippet of the Python code

To ensure that one bus stop is linked to the next bus stop for a specified bus service, we drew up columns which clearly indicated the coordinates of the source and destination of a bus stop.

For example, for bus service 2, the bus travels between Changi Village Terminal (source) and Blk 4 (destination) for its first two stops. In this case, at the Changi Village Terminal bus stop, the source will be the coordinates of its own bus stop location and

the destination will be the coordinates of the location of Blk 4's bus stop location.

F	G	H	I	J	K	L	M
Source Code	Source Name	Dest Code	Dest Name	Source Lat	Source Long	Dest Lat	Dest Long
99009	Changi Village Ter	99131	Blk 4	1.389698122	103.9876255	1.388941867	103.987343
99131	Blk 4	99049	Changi Golf Course	1.388941867	103.987343	1.387499945	103.9857336
99049	Changi Golf Course	99039	St. George Chapel	1.387499945	103.9857336	1.387685814	103.9820213
99039	St. George Chapel	99029	Aft Cranwell Rd	1.387685814	103.9820213	1.386640868	103.9795931
99029	Aft Cranwell Rd	99019	Aft Sch Of Commando	1.386640868	103.9795931	1.383708976	103.9784486
99019	Aft Sch Of Commando	98079	Opp Loyang Way/Soxa	1.383708976	103.9784486	1.378590167	103.9787007

Figure 3: A snippet of the Excel sheet generated by the python script

The data collected provided us with bus stop locations, but we had to manually geocode before using it as markers on the map.

3.3 Tools and Technologies used

Our team then developed the web application using the RShiny web application framework powered by the programming language R, which is commonly used in statistical computing and graphics. R offers a set of comprehensive built-in functions and the flexibility to work with third-party packages.

In addition to the shiny framework, we used several third party packages, such as leaflet, maptools, rgdal and shinythemes.

3.4 Application Description

3.4.1 Overview

By selecting a bus service, the application will generate the bus route for the specified bus service with markers representing the locations of the bus stops. In addition, when the user hovers on the markers, useful information about the bus stop will be displayed, such as the name of the bus stop as well as the betweenness and closeness centrality values.

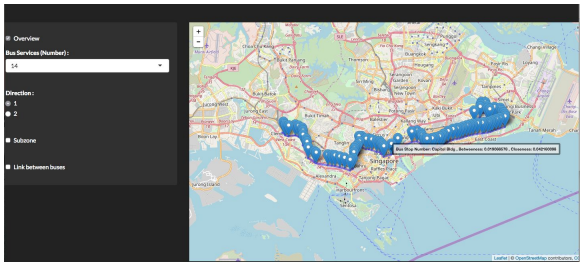


Figure 4: An overview of the route bus 14 takes

3.4.2 Subzone Filtering

To facilitate the ease of searching for a bus service, the bus numbers can be filtered by toggling around the subzone filter on the left. In this case, city planners will be able to immediately pick out and analyse the bus services within that particular subzone, should they wish to focus on that planning area.

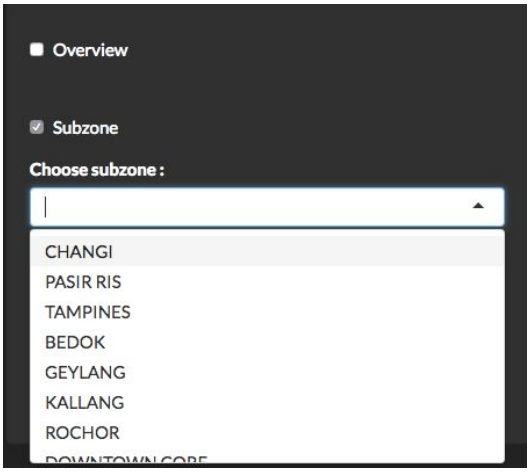


Figure 5: Selection of subzone

3.4.3 Bus Network per bus stop

When the user selects a bus service, a list of all the bus stops that the bus passes through will be generated.

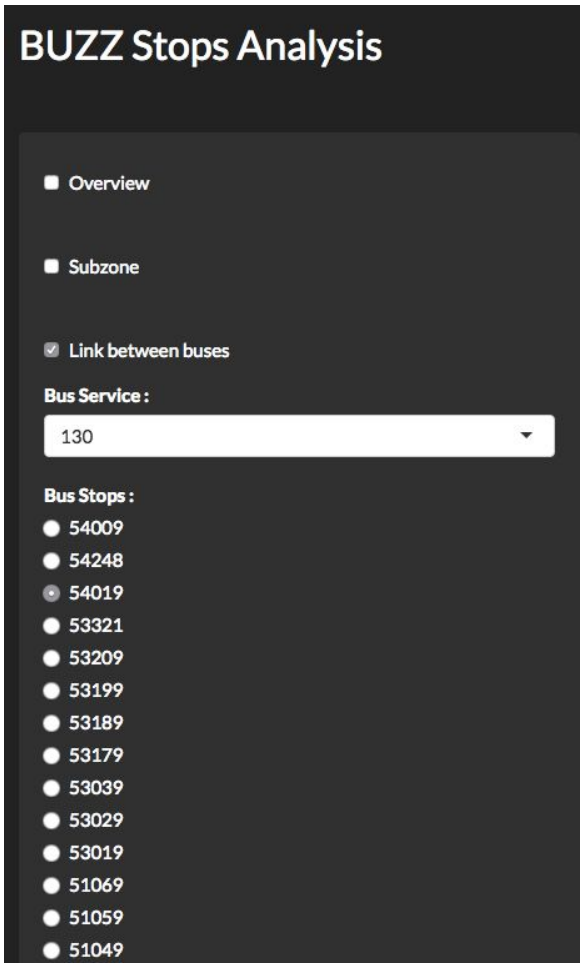


Figure 6: Selection of bus stop that bus 130 passes

Upon selecting one of the bus stops, an overview map of all the locations of bus stops will be reflected. The markers are the location of bus stops of all the other buses that passes through bus stop 54019.

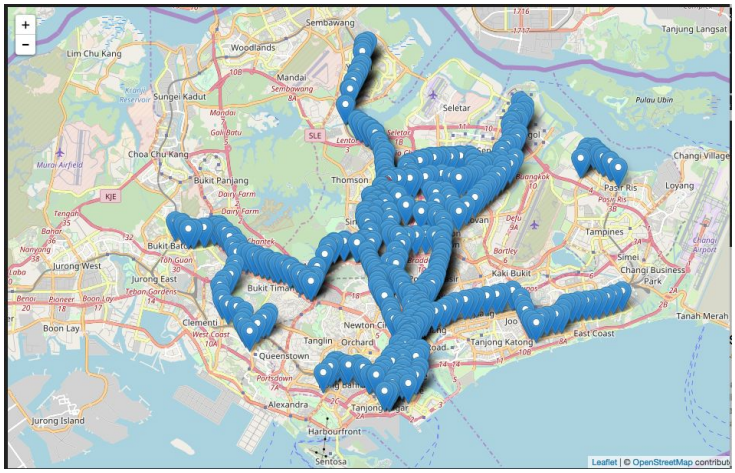


Figure 7: An overview of all the bus routes that includes the selected bus stop

4. Results

The measure for closeness centrality represents the average distance between a bus stop and all other bus stops within the network. The measure with a higher value indicates greater centrality.

The betweenness centrality index captures the relative importance of each bus stop in the network as a whole.

One of the interesting insights brought about from our network analysis is that Tanglin turned out to be the subzone which had the highest centrality for the bus stops located within the subzone, taking into consideration its average closeness and betweenness index.

Bus Numb	Bus Type	Direct	Index	Source Co	Source Name	Dest Cod	Dest Name	Source La	Source Lo	Dest Lat	Dest Lon	PLN_AREA	veeness Ce	seness Cer
9	unk Bus Servic	1	50	95089	Opp Changi Beach CP 5	95079	Opp Changi Beach CP 4	1.38962	103.99593	1.39019	103.99252	CHANGI	0	0
19	unk Bus Servic	1	37	95089	Opp Changi Beach CP 5	95079	Opp Changi Beach CP 4	1.38962	103.99593	1.39019	103.99252	CHANGI	0	0
35	unk Bus Servic	1	13	95161	Bef Changi Ferry Rd	95171	Prologis	1.37252	104.00456	1.37463	104.00207	CHANGI	0	0
35	unk Bus Servic	1	21	96429	CHANGI LODGE 2	96219	Tanah Merah Ferry Ter	1.31372	103.99538	1.3152	103.98889	CHANGI	0	0
36	unk Bus Servic	1	4	94099	Aft E.C. Sea Sports Club	93049	Lagoon View	1.31149	103.9503	1.31073	103.93299	BEDOK	0	0
36A	unk Bus Servic	1	3	94099	Aft E.C. Sea Sports Club	93049	Lagoon View	1.31149	103.9503	1.31073	103.93299	BEDOK	0	0
89	unk Bus Servic	1	56	95089	Opp Changi Beach CP 5	95079	Opp Changi Beach CP 4	1.38962	103.99593	1.39019	103.99252	CHANGI	0	0
103	unk Bus Servic	1	32	68171	Bef Yishun Ave 8	59461	Opp Blk 419	1.42704	103.85535	1.42336	103.84696	YISHUN	0	0
117	unk Bus Servic	1	16	68171	Bef Yishun Ave 8	59479	OPP BLK 430B	1.42704	103.85535	1.42006	103.84842	YISHUN	0	0
123	unk Bus Servic	1	42	14521	Merlion Plaza	14539	Beach Station Bus Terminal	1.25643	103.82091	1.25143	103.81855	UTHERN ISLAN	0	0
160	unk Bus Servic	1	41	46219	Johor Bahru Checkpt	46109	W'Lands Checkpt	1.46543	103.76827	1.44694	103.76925	WOODLANDS	0	0
170	unk Bus Servic	2	2	46219	Johor Bahru Checkpt	46109	W'Lands Checkpt	1.46543	103.76827	1.44694	103.76925	WOODLANDS	0	0
170X	unk Bus Servic	2	2	46219	Johor Bahru Checkpt	46109	W'Lands Checkpt	1.46543	103.76827	1.44694	103.76925	WOODLANDS	0	0
247	unk Bus Servic	1	17	25571	OPP WEST STAR	25591	OPP WYETH PHARMACEUTICALS	1.31544	103.63524	1.31025	103.63509	TUAS	0	0
248	unk Bus Servic	1	23	26079	Bef Tuas Loop	26089	Bef Tuas Ave 20	1.32061	103.63676	1.32215	103.6351	TUAS	0	0
249	unk Bus Servic	1	15	22429	Opp Natl Oxygen Pte Ltd	22089	Natsteel	1.30726	103.69908	1.30589	103.70088	BOON LAY	0	0
254	unk Bus Servic	1	24	26111	Tru-Marine	24691	Aft Tuas Rd	1.31464	103.65426	1.31344	103.65713	TUAS	0	0
402	unk Bus Servic	1	8	3421	Marina Bay Cruise Ctr	3411	Opp Marina Sth Pier	1.26694	103.85965	1.27159	103.86301	STRAITS VIEW	0	0
950	unk Bus Servic	1	10	46219	Johor Bahru Checkpt	46109	W'Lands Checkpt	1.46543	103.76827	1.44694	103.76925	WOODLANDS	0	0

Figure 8: Screenshot of bus stops with values of 0 for both betweenness index and closeness index

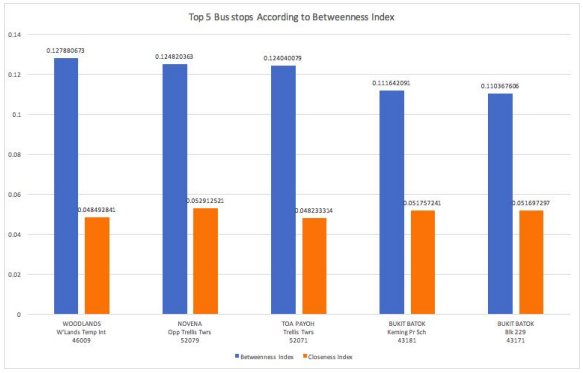


Figure 9: Top 5 bus stops ranked according to their betweenness index

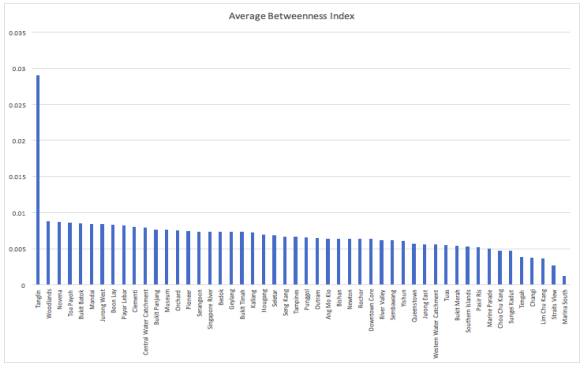


Figure 11: Subzones ranked according to their average betweenness index

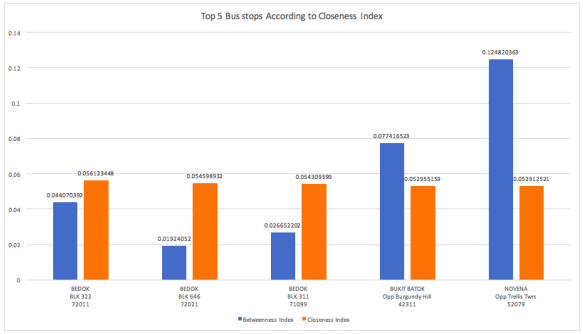


Figure 10: Top 5 bus stops ranked according to their closeness index

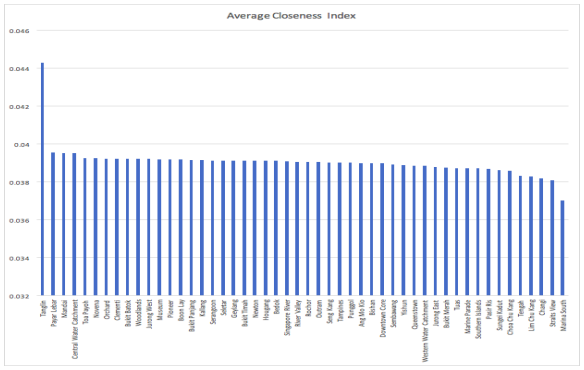
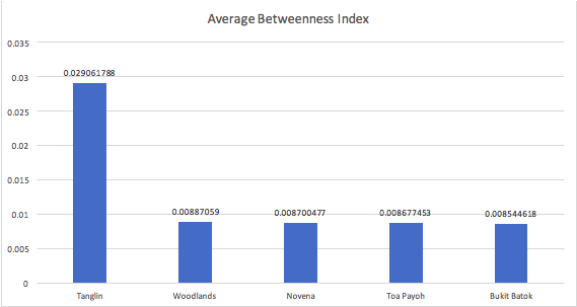
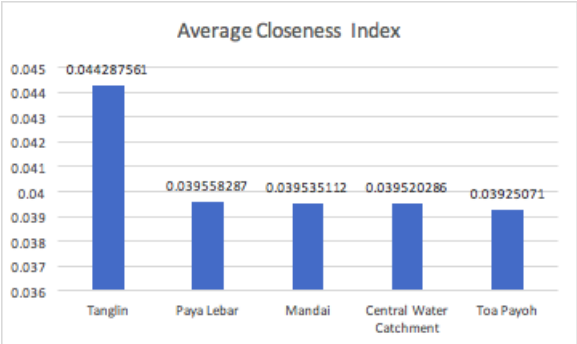


Figure 12: Subzones ranked according to their average closeness index

In order to get the average betweenness index for different subzones, we calculated the average value of the betweenness index for all the bus stops located within the subzone. We further ranked the subzones, and the top 5 subzones turned out to be Tanglin, Woodlands, Novena, Toa Payoh and Bukit Batok.



We did the same to retrieve the average value of the closeness index and the top 5 subzones turned out to be Tanglin, Paya Lebar, Mandai, Central Water Catchment and Toa Payoh.



5. Discussion

One of the interesting insights derived from our network analysis is the fact that Tanglin tops the list as the subzone which is most connected to the rest of Singapore and Marina South is the subzone which is least connected to the rest of Singapore. According to Urban Redevelopment Authority's 2013 Masterplan, Marina South Bus Interchange is currently in the planning process of being upgraded into an Integrated Transport Hub.

As one of the subzones that is on the periphery of Singapore, Marina South has relatively low bus connectivity to the rest of Singapore, which causes citizens to rely more heavily on the MRT trains to get to other areas of Singapore.

6. Future Work

6.1 Feedback

During the IS415 Poster Day on 11th April 2018, we shared our project with some industry experts, professors, instructors and fellow schoolmates. Feedback that we gathered included a consideration to include the analysis of human traffic, as a bus stop with high centrality may not necessarily equate to one that is highly used by people.

We feel that our project could be further enhanced by incorporating heat map analysis into the application to gain deeper insight in terms of understanding human traffic flow. Currently, our project is limited when it comes to studying the number of riders who actually use the bus route

because data on passengers taking public buses is not publicly accessible.

As the network analysis indices mentioned above- degree centrality, betweenness and closeness indexes provide us with information on how "useful" each bus stop is relative to all other bus stops in Singapore, by combining the real time heat map analysis together with our network indices will aid city planners in their decision to better manage their resources, such as the removal of certain bus stop if it is used less frequently, and perhaps channel those resources to highly connected areas in Singapore.

Acknowledgement

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References

RMIT, J. S., Dr, Curtin, C. C., A/Prof, & Politecnico di Milano, S. P., Dr. (2007). Spatial Network Analysis of Public Transport Systems. *Developing a Strategic Planning Tool to Assess the Congruence of Movement and Urban Structure in Australian Cities,* 1-23.