

Study of transport feasibility for SUTD students

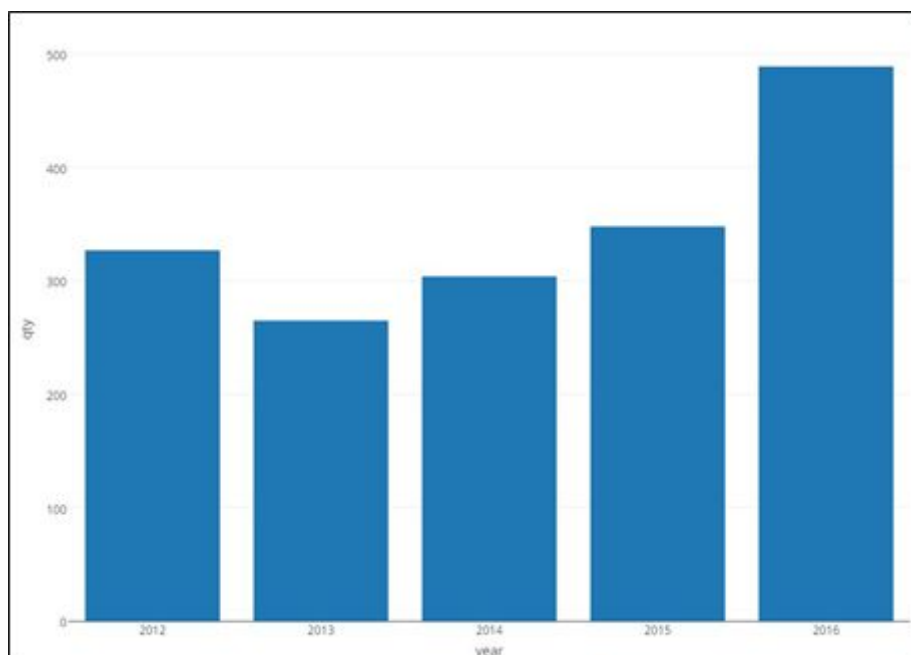
Team Maphack

Problem statement

SUTD is situated at the far eastern region of Singapore, and has led to long travel times for students from their homes to SUTD's campus. The nearest public transportation services include Expo, Tanah Merah and Simei MRT stations. However, these options also encompass a 10 minute walk or bus ride after taking the train.

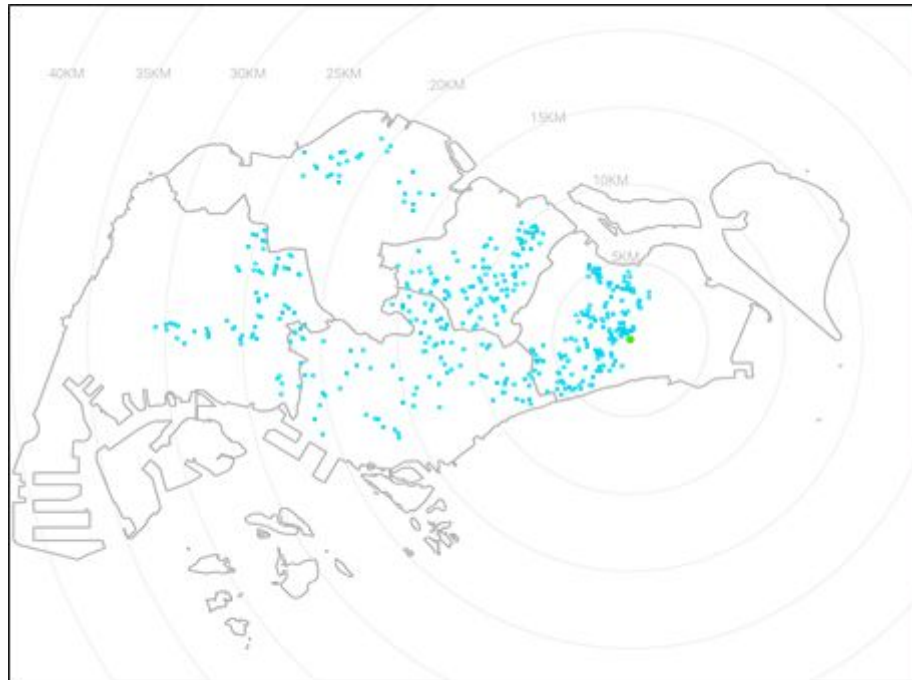
Although the SUTD Housing was put in place to mitigate transportation issues, there are limitations to which SUTD Housing can offer. SUTD Housing has a capacity of 1100 residents, that accommodates pre-graduate, post-graduate and visiting students. SUTD students are guaranteed a placing under the student residential program in their freshmen year. In the subsequent years, acquiring a placing for hostel is subject to availability, and based on a first come first serve basis. It is also important to note that expansion works for SUTD Housing is highly unlikely for the next 3 years.

The intake of SUTD students has been increasing every year while the number of hostel rooms remain the same. The graph below shows the number of matriculations each year from the pioneer batch and there is a general increase in the number of students matriculated. This would mean that the number of students staying out of school will also increase.



Number of Matriculations per year, 2012-2016 [1][2]

Based on the student population data we have obtained, we have mapped out the local residence of the student population. Through this visualization, it serves to identify visually how the student population is spread across Singapore. 5km ring buffers were also drawn starting from SUTD, for readers to visualize how distance played a part in where students lived.



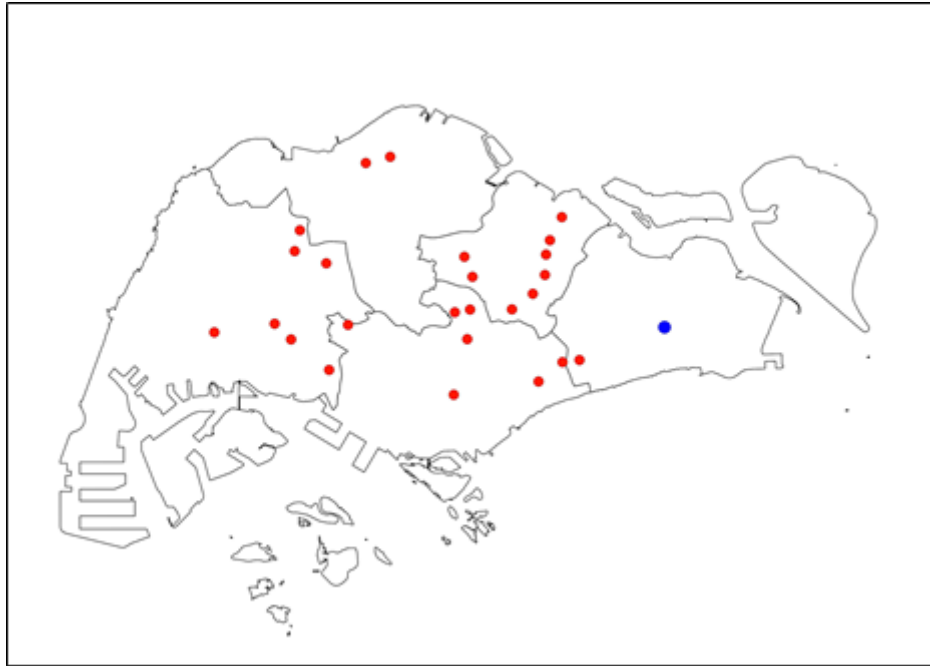
Student local residence (485 entries)[2]

Refining the scope

Taking into consideration operating costs of chartered services, we decided that it was not worthwhile to provide this service to areas with low student residence. Hence, only MRT stations with 5 or more students situated nearby will be offered this service.

In addition, students staying in a location too close to school will be better off taking public transport, due to insignificant time and cost savings. Therefore, with travel time savings of 10 minutes or less to campus will be excluded from this service.

The number of students that we are concerned with is now 224 students across the entire Singapore which is still a sizeable number. The total number of pickup points has reduced from 102 MRT stations to 25.



Proposed pick-up locations across Singapore

Solution

We would like to propose a chartered bus service with multiple routes which picks students up from selected MRT stations. This solution aims to shorten the travel times for students. To determine the optimised bus routes we have designed an algorithm which determines the best bus routes to pick up all the students. This algorithm takes into account the bus capacity of 45 and the shortest average travel time of the students.

Data processing

The following are raw data obtained with their attributes listed. The student residence data is obtained from the SUTD Student administration while the list of MRT names is received from Data.gov.sg

MRT station
- Name

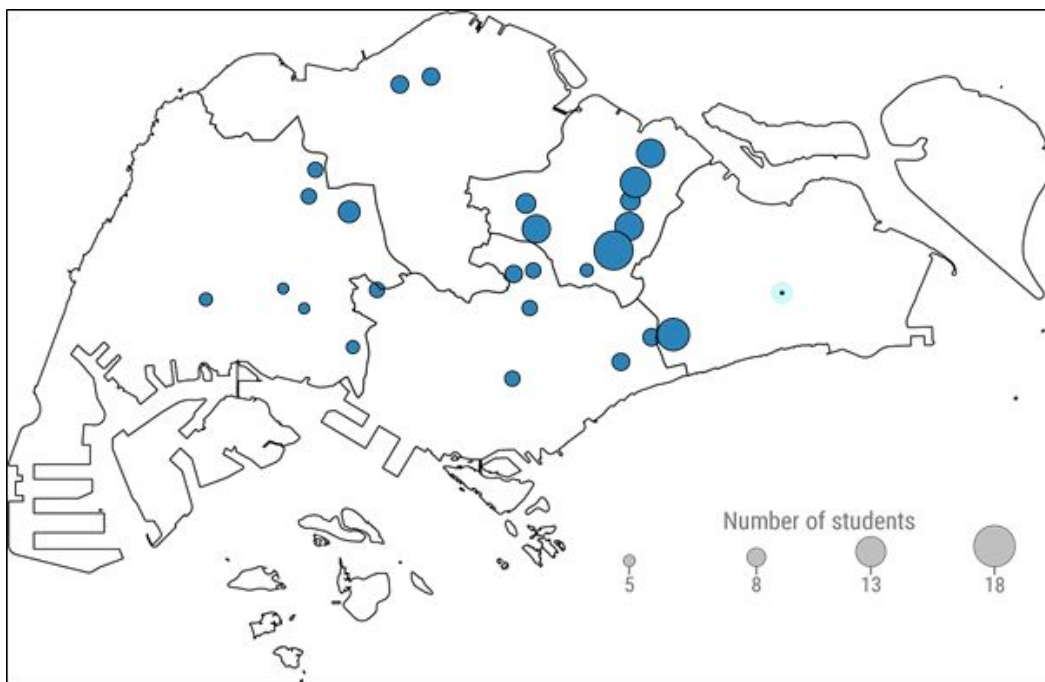
Student Residence
- Postal code

We first had to determine the spatial coordinates of the MRT stations and location of the student's residence. Google maps API was used to determine the longitude and latitude. We then determined the MRT station closest to the students' residence using MMQGIS, hub distance tool. The resulting table added the MRT station name, longitude and latitude were added to the respective student residence data. After which these data is exported to R studio for further processing. The information that

we require was the number of people at each MRT station which was the frequency of the MRT station from the dataset. This was achieved in Rstudio by first converting the data to a data frame followed by getting the frequency table. The resulting processed dataset is as follows.

MRT Station

- Name
- Longitude
- Latitude
- Frequency

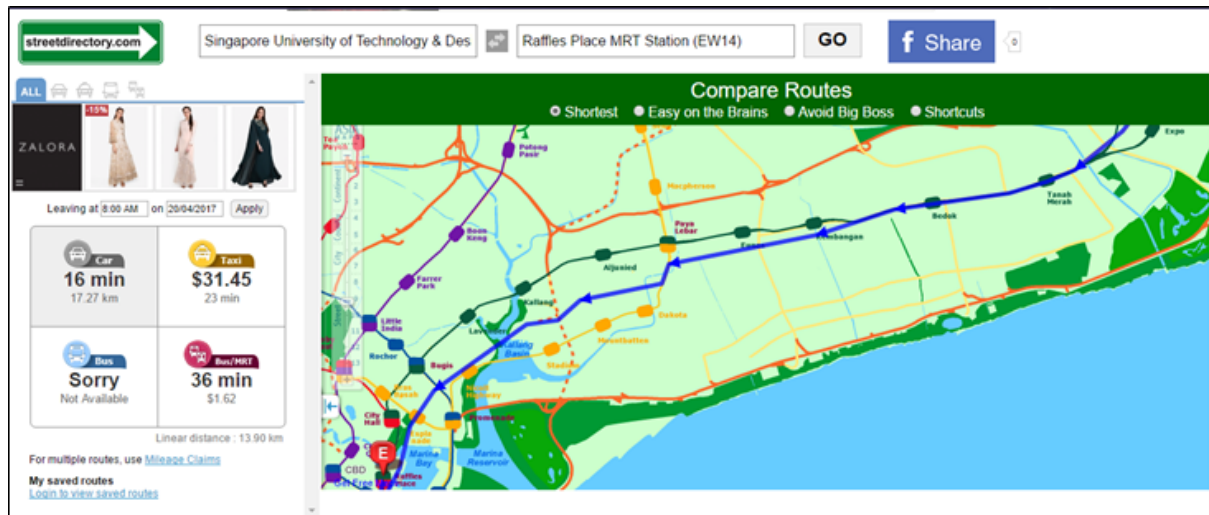


Number of people at each proposed pickup location

Data Mining from streetdirectory.com

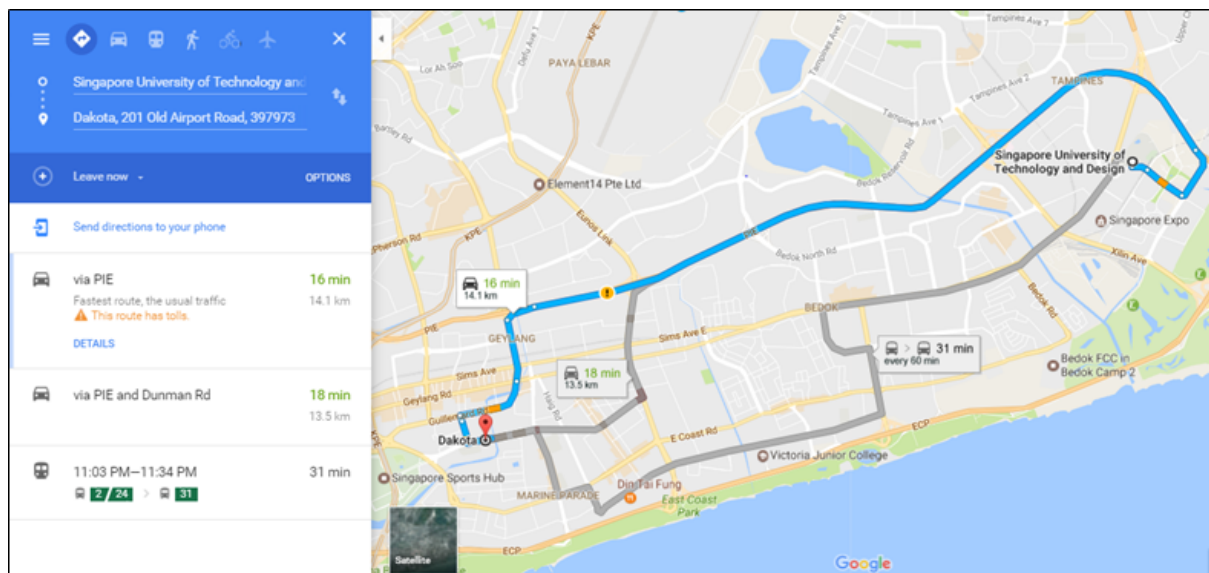
In order to generate the best route for the shuttle bus, we need data of travel time between all MRT stations and from all MRT stations to SUTD. Also, we need two separate sets of these data for different modes of transportation, namely by MRT or by car. Unfortunately, such data is not readily available.

Therefore, we wrote a Python script which allowed us to mine data from streetdirectory.com. Streetdirectory.com is a website that allows us to get estimated travel times of various modes of transport. With this information we would be able to estimate travel times along the planned routes. We have also programmed the code to output the data in csv format which can be easily read in QGIS and RStudio.



Data mining from Streetdirectory.com

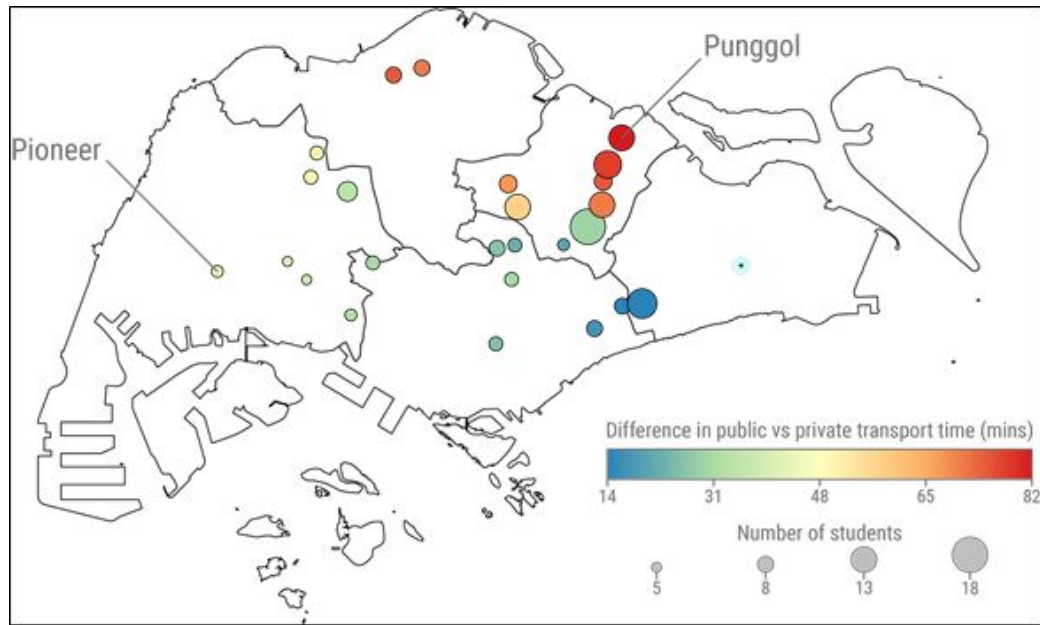
Apart from the issues we faced coming up with the codes to work on the website, another challenge that we had was that the data obtained was not complete. There is a substantial number of missing data points which are crucial to our analysis. These missing data points are due to lack of information on the website. To fill up the rest of the unavailable data, we turned to Google maps which we could only extract the information manually. We had to first find out all the missing data points, search the locations on Google maps and then manually extracting the data and input them into the csv file.



Data mining from www.google.com.sg/maps

From the processed dataset, we have plotted the location of the MRT stations against the frequency and the time difference between public and private travel. From the plot, we observe that relative distance does not necessarily correlate to difference in travel times of public and private transport. We noted that Punggol was

the area with highest student population, and highest travel time as well. Punggol's relative distance to SUTD is half that of Pioneer MRT Station, however, it has twice the difference in travel time. This is mainly due to the Punggol MRT lying at the edge of the MRT network. This is crucial in validation of our study, as we can observe that a large population of SUTD students experience high travel times, which can be avoided through usage of a chartered service or private transport.



Time deviation between public and private transport

Generating Bus Routes

We implemented a brute force algorithm that will cover all possible cases, in order to obtain the most optimized route. However, computational time to attempt all routes will take exceedingly long time to run. Hence, we decided to introduce certain constraints that we deduced will generate inefficient results. The constraints introduced are the following:

- Each route has to pick up between 35 - 50 students so that the number of chartered bus is reduced
- Each travel route also has to take less than an hour so that unrealistic route times are eliminated
- Each travel route will make at most 4 stops so as to reduce travel time

After all these constraints are put in place, we are able to generate the routes in a short amount of time. A total of 37,000 individual routes were generated. Each route was then permuted to find the optimum travel time for that particular combination.

Subsequently, we had to determine the optimized combination of routes based on the optimized paths we have found earlier.

To do this, we came out with our own scoring system to rate the effectiveness of each route. This scoring is done by allocating equal weightage to both the route travel time and the number of people served for the route.

This is calculated according to the following algorithm:

$$\text{Score} = \frac{\text{No. people served}}{\text{Max No. people served}} + \frac{\text{Max time taken} - \text{Time taken}}{\text{Max time taken}}$$

A score closest to 2 will give the best result as a maximum score of 1 can be obtained for each factor.

A screenshot of the result of our first iteration is shown below.

Score	Route Travel Time	Number of pax served	Route			
1.663333333	19	49	Hougang MRT Station	Buangkok MRT Station	Sengkang MRT Station	Punggol MRT Station
1.633333333	22	50	Serangoon MRT Station	Kovan MRT Station	Hougang MRT Station	Punggol MRT Station
1.63	21	49	Ang Mo Kio MRT Station	Hougang MRT Station	Buangkok MRT Station	Sengkang MRT Station
1.62	18	46	Hougang MRT Station	Kovan MRT Station	Kembangan MRT Station	
1.616666667	23	50	Ang Mo Kio MRT Station	Serangoon MRT Station	Kovan MRT Station	Hougang MRT Station
1.616666667	23	50	Buangkok MRT Station	Kovan MRT Station	Eunos MRT Station	Kembangan MRT Station
1.613333333	22	49	Ang Mo Kio MRT Station	Buangkok MRT Station	Sengkang MRT Station	Punggol MRT Station
1.613333333	22	49	Sengkang MRT Station	Buangkok MRT Station	Kovan MRT Station	Eunos MRT Station
1.61	21	48	Buangkok MRT Station	Hougang MRT Station	Kovan MRT Station	Eunos MRT Station
1.606666667	20	47	Serangoon MRT Station	Kovan MRT Station	Buangkok MRT Station	Sengkang MRT Station
1.6	24	50	Yio Chu Kang MRT Station	Kovan MRT Station	Buangkok MRT Station	Sengkang MRT Station
1.6	18	45	Hougang MRT Station	Kovan MRT Station	Sengkang MRT Station	
1.596666667	23	49	Ang Mo Kio MRT Station	Yio Chu Kang MRT Station	Sengkang MRT Station	Punggol MRT Station
1.59	21	47	Sengkang MRT Station	Kovan MRT Station	Kembangan MRT Station	
1.586666667	20	46	Serangoon MRT Station	Kovan MRT Station	Hougang MRT Station	Buangkok MRT Station
1.583333333	25	50	Bishan MRT Station	Marymount MRT Station	Ang Mo Kio MRT Station	Hougang MRT Station
1.583333333	19	45	Kovan MRT Station	Sengkang MRT Station	Punggol MRT Station	
1.58	24	49	Yio Chu Kang MRT Station	Hougang MRT Station	Kovan MRT Station	Buangkok MRT Station
1.58	24	49	Dakota MRT Station	Kovan MRT Station	Buangkok MRT Station	Sengkang MRT Station
1.58	24	49	Marymount MRT Station	Kovan MRT Station	Buangkok MRT Station	Sengkang MRT Station
1.58	24	49	Kovan MRT Station	Dakota MRT Station	Eunos MRT Station	Kembangan MRT Station
1.58	24	49	Yio Chu Kang MRT Station	Ang Mo Kio MRT Station	Kovan MRT Station	Buangkok MRT Station
1.576666667	23	48	Ang Mo Kio MRT Station	Hougang MRT Station	Buangkok MRT Station	Punggol MRT Station
1.576666667	23	48	Bishan MRT Station	Kovan MRT Station	Buangkok MRT Station	Sengkang MRT Station

Scores derived after 1st iteration

After deciding on the first route, we then remove the stations from our initial pool of MRT stations, and run through the remaining pool with the algorithm again. The result of the second iteration is shown below.

Score	Route	Travel Time	Number of pax served	Route		
1.58	24	49	Kovan MRT Station	Dakota MRT Station	Eunos MRT Station	Kembangan MRT Station
1.57333333	22	47	Serangoon MRT Station	Kovan MRT Station	Eunos MRT Station	Kembangan MRT Station
1.56666667	26	50	Yio Chu Kang MRT Station	Kovan MRT Station	Eunos MRT Station	Kembangan MRT Station
1.56666667	26	50	Ang Mo Kio MRT Station	Marymount MRT Station	Bishan MRT Station	Toa Payoh MRT Station
1.56	24	48	Marymount MRT Station	Bishan MRT Station	Kovan MRT Station	Kembangan MRT Station
1.56	24	48	Yio Chu Kang MRT Station	Ang Mo Kio MRT Station	Kovan MRT Station	Eunos MRT Station
1.55333333	22	46	Ang Mo Kio MRT Station	Kovan MRT Station	Kembangan MRT Station	
1.55	27	50	Yio Chu Kang MRT Station	Marymount MRT Station	Kovan MRT Station	Kembangan MRT Station
1.55	27	50	Yio Chu Kang MRT Station	Ang Mo Kio MRT Station	Bishan MRT Station	Serangoon MRT Station
1.54666667	26	49	Yio Chu Kang MRT Station	Bishan MRT Station	Kovan MRT Station	Kembangan MRT Station
1.54666667	26	49	Marymount MRT Station	Kovan MRT Station	Eunos MRT Station	Kembangan MRT Station
1.54333333	25	48	Bishan MRT Station	Kovan MRT Station	Eunos MRT Station	Kembangan MRT Station
1.54333333	25	48	Yio Chu Kang MRT Station	Ang Mo Kio MRT Station	Marymount MRT Station	Kovan MRT Station
1.54	24	47	Yio Chu Kang MRT Station	Ang Mo Kio MRT Station	Bishan MRT Station	Kovan MRT Station
1.53666667	23	46	Yio Chu Kang MRT Station	Ang Mo Kio MRT Station	Serangoon MRT Station	Kovan MRT Station
1.53333333	28	50	Ang Mo Kio MRT Station	Bishan MRT Station	Toa Payoh MRT Station	Eunos MRT Station
1.53333333	28	50	Yio Chu Kang MRT Station	Marymount MRT Station	Bishan MRT Station	Kovan MRT Station
1.53	27	49	Bishan MRT Station	Marymount MRT Station	Ang Mo Kio MRT Station	Serangoon MRT Station
1.52666667	26	48	Toa Payoh MRT Station	Kovan MRT Station	Eunos MRT Station	Kembangan MRT Station
1.52666667	26	48	Yio Chu Kang MRT Station	Serangoon MRT Station	Kovan MRT Station	Kembangan MRT Station
1.52333333	25	47	Marymount MRT Station	Serangoon MRT Station	Kovan MRT Station	Kembangan MRT Station
1.52333333	25	47	Marymount MRT Station	Ang Mo Kio MRT Station	Kovan MRT Station	Eunos MRT Station
1.52	24	46	Bishan MRT Station	Serangoon MRT Station	Kovan MRT Station	Kembangan MRT Station
1.52	24	46	Toa Payoh MRT Station	Serangoon MRT Station	Kovan MRT Station	Kembangan MRT Station

Scores derived after 2nd iteration

We repeated this process and obtained the following results.

Route	1st stop	2nd stop	3rd stop	4th stop	5th stop
1	Hougang	Buangkok	Sengkang	Punggol	-
2	Yio Chu Kang	Ang Mo Kio	Marymount	Bishan	Toa Payoh
3	Yew Tee	Chua Chu Kang	Bukit Panjang	Beauty World	Somerset
4	Kovan	Dakota	Eunos	Kembangan	-

After 4 iterations, we could not obtain any combinations that was able to accommodate our requirements, thus we decided to relax the requirements and allow 6 stations into our algorithm for the last route.

Thus, we obtained the following route:

5	Pioneer	Chinese Garden	Jurong East	Clementi	Woodlands	Serangoon
---	---------	----------------	-------------	----------	-----------	-----------

However, even with this, Admiralty was left out from the final collection of routes. To insert Admiralty into the routes, we analysed the routes, and realised that Yio Chu Kang, Ang Mo Kio, Marymount, Bishan and Toa Payoh are very close to Serangoon, and Admiralty was very close to Woodlands.

Thus, we decided to re-tweak the routes manually, and obtained the final routes as follows:

Route	1st stop	2nd stop	3rd stop	4th stop	5th stop	6th stop
1	Hougang	Buangkok	Sengkang	Punggol	-	-
2	Yio Chu Kang	Ang Mo Kio	Marymount	Bishan	Toa Payoh	Serangoon
3	Yew Tee	Chua Chu Kang	Bukit Panjang	Beauty World	Somerset	-
4	Kovan	Dakota	Eunos	Kembangan	-	-
5	Pioneer	Chinese Garden	Jurong East	Clementi	Woodlands	Admiralty

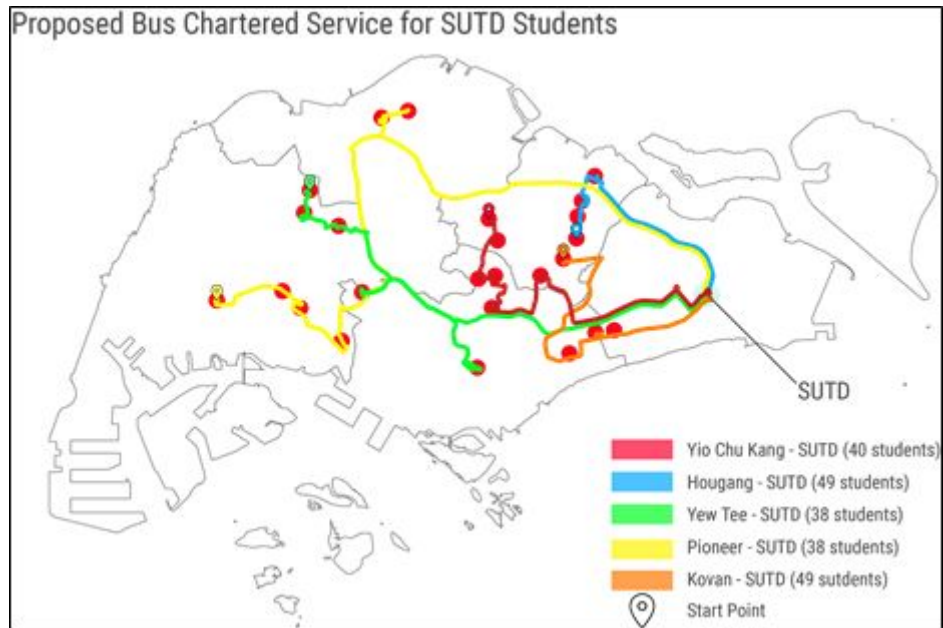
The source code and csv files for these steps can be found here :

<https://github.com/imny94/Maps1-Final-Data-Visualisation-Project>

The algorithm is computed using a series of scripts run in the following order :

- 1) pathFinderUpdater.py
- 2) RouteSelector.py
- 3) SortOptimisedRoutesByTravelTime.py
- 4) RouteEvaluation.py

After we obtained the routes, we plotted the routes by getting the points along the road from StreetDirectory. This is done using the following script , GetRoutePoints.py. Using these points, we then connect them together to get a final plot of the routes of these bus routes.



Map of proposed bus routes

Analysis

MRT Station	Travel time to SUTD using Public Transport	Number of Students Aggregated to Station
Admiralty MRT Station	94 min	8
Ang Mo Kio MRT Station	75 min	13
Beauty World MRT Station	52 min	7
Bishan MRT Station	40 min	7
Buangkok MRT Station	87 min	9
Bukit Panjang MRT Station	59 min	10
Chinese Garden MRT Station	66 min	5
Choa Chu Kang MRT Station	77 min	7
Clementi MRT Station	59 min	6
Dakota MRT Station	30 min	8
Eunos MRT Station	24 min	8
Hougang MRT Station	84 min	13
Jurong East MRT Station	63 min	5
Kembangan MRT Station	22 min	15
Kovan MRT Station	43 min	18
Marymount MRT Station	43 min	8

Pioneer MRT Station	73 min	6
Punggol MRT Station	93 min	13
Sengkang MRT Station	89 min	14
Serangoon MRT Station	35 min	6
Somerset MRT Station	43 min	7
Toa Payoh MRT Station	45 min	7
Woodlands MRT Station	97 min	8
Yew Tee MRT Station	79 min	7
Yio Chu Kang MRT Station	87 min	9

Using the travel time from each station to SUTD via public transport, we can calculate the average time-savings of students travelling to school as compared to the travel time for the shuttle bus.

The Average Travel Time is computed by summing the travel time from each station on the route, multiplied by the number of students aggregated to that station, and then dividing by the total number of students served for the given route.

The results can be seen below.

Route	Average Travel Time (public transport)	Travel Time (shuttle bus)	Time Savings
Yio Chu Kang - SUTD	73 mins	31 mins	42 mins
Hougang - SUTD	88 mins	19 mins	69 mins
Yew Tee - SUTD	61 mins	40 mins	21 mins
Pioneer - SUTD	78 mins	61 mins	17 mins
Kovan - SUTD	31 mins	24 mins	7 mins

From the above data we can see there are indeed time savings for SUTD students should the chartered bus service be implemented.

While we understand that this might not be the optimal collection of routes as we have not tried all possible route combinations, it was computationally impossible to test out all possible route combinations that were possible, due to the sheer number

of combinations that are possible. Therefore, we believe that although not ideal, our solution gives a relatively good collection of routes, despite using a greedy algorithm to generate the routes used as we still do see significant time savings using the routes we have proposed, where a total of 156 mins in time savings is obtained using the bus routes proposed.

Conclusion

Based on feedback given with regards to the housing allocation scheme, SUTD Housing has decided to factor in student's travel time as part of its allocation decision, to a small extent. The main deciding factors would be number of infractions, commitments to student activities, followed by travel time. As such, we might expect to see a minute shift in trends in the geographical locations of students without residence in SUTD. However the methodology presented in this paper can be used to determine the most optimal routes for the new dataset.

It is also critical we note that SUTD would have a train station available on campus by the end of 2017. This station lies on the Downtown Line and is relatively close to the East-West Line as well, which connects through Expo MRT Station. This added convenience serves to benefit students who are currently travelling by train to SUTD from the Downtown or East-West Line. This new addition removes the need to take the bus or walk from current MRT stations (Expo or Tanah Merah), cutting travel times by up to 10 minutes. Hence, we would need to re-evaluate the radius of exclusion zone when the new station is open. Additionally, expansion works in other regions of Singapore could also improve travel times through public transport. One example would be the Cross Island Line^[3] which connects Punggol directly to MRT stations near SUTD. Although it will be expected to launch in 2030, a re-evaluation of the model will be necessary when the time comes.

References

- [1] Moe 2015 Education Statistics Digest - <https://www.moe.gov.sg/docs/default-source/document/publications/education-statistics-digest/esd-2015.pdf>
- [2] SUTD Student Housing Data, CAA 17 Apr 2017.
- [3] Cross Island Line - https://en.wikipedia.org/wiki/Cross_Island_MRT_Line