PROPOSAL & STUDY OF A POTENTIAL MONITORING & EVALUATION FRAMEWORK FOR LTA ON-DEMAND BUS ROUTING SERVICE

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EXECUTIVE SUMMARY:

The business objective of the document is to build a monitoring and evaluation framework for the on-demand bus service proposed by LTA. LTA is implementing on trial basis in Singapore from December 2018 and two companies VIA and SWAT have been awarded the contract for the same. The trial is scheduled to take place at Punggol, Joo-Koon, Marina South and Shenton Way during non-peak hours.

The main purpose of the service is to deliver better and more customized bus services, with possibly shorter wait time and travel time to the commuters. Instead of being able to alight only at a bus stop along a predetermined, fixed route, the commuters can alight at any bus stop in the operating area, making the commute more seamless and convenient than regular bus service.

Using the GQM method (PCA) we identified the Goals, Question and Metrics for the service from the commuter and LTA perspective and identified that waiting time is the most important metrics for commuters and no-show and distance for the LTA. Once the goals were identified the monitoring and evaluation framework was created to identify the various steps and data required to carry out the service evaluation. The monitoring and evaluation framework covers the current value of the goals, the expected values, the mode of measurement, the frequency of measurement, the challenges and the recommendation to improve the process.

We have used simulation for waiting time, no shows, distance travelled by bus and also calculated the running costs for the on-demand bus services using the Joo Koon area and comparing the it with service 255 serviced by SBS Transit. It was seen that the on-demand bus service would have a significantly reduced waiting time, no-shows and distance travelled by the bus as compared to the regular bus service. The running costs were also found to be lower compared to regular service.

Parameter	Current System	Proposed System
Bus Stop	Fixed	Dynamic
No Shows	6	2
Av. Distance travelled/ Customer	~5 Km	2.16 Km
Fuel Cost	S$8	S$5
Operating Cost	S$9	S$6
Manpower Cost	S$6	S$5
Waiting Time	8.193 min	4.323 min
Bus Frequency	6 buses/hour	As per the location of commuter's demand

Table 1: Parameter comparison between current and proposed system(simulated)

Then, we simulated the customer survey for the comfort level and simplicity of the app for the commuter and customer satisfaction for the LTA. The commuters were seen to be 60% satisfied with the services.

INTRODUCTION

LTA is planning to introduce the on-demand bus service on the island. The trial of this bus service is to be run during the off-peak hours in Punggol, Joo Koon, Marina Way and Shenton way for a period of 6 months from December 2018 onwards. An initial tender of $460,000 for Algorithm development and another tender for trial of value $2.26 million and has been awarded to two companies, VIA and SWAT. VIA is running a similar on demand bus service in Chicago and New York and bring an experience of the service on board for the project. SWAT by Ministry of movement is a local Singapore based company and has already been running on demand bus services in areas in Singapore. These companies have already developed the application for the system in February 2018.

As a part of the deliverables the companies were supposed to provide the following:

- develop a Mobile App for the commuters and the bus captains
- train the bus drivers and the support staff
- develop a performance monitoring system
- develop a system for the maintenance and operation
- on-demand service that runs on cloud system and machine learning

Currently, fixed buses are scheduled to a fixed route based on fixed frequency. However, the demand is not always fixed. Some areas face very high demand during peak hours causing shortage of buses and overcrowding and sometimes low demand during non-peak hours causing low ridership. This mismatch in demand-supply is affecting the commuters as well as LTA, which is facing tough competition from private ventures like Grab Shuttle. Thus, it is imperative for LTA to optimize its resources to better serve its customer's needs.

BUSINESS OBJECTIVE

LTA is in the process of implementing the trial-phase of on-demand bus service in Singapore. In order to understand the impact of their on-demand bus service, a monitoring and evaluation framework needs to be built for LTA.

GOALS - QUESTIONS – METRICS

Joo Koon area was proposed by LTA to conduct a pilot of the "On Demand Bus Service" since it has a poor occupancy rate over the off-peak hours. Hence, it is vital to optimize the resources of LTA and also provide service to commuters in the best possible way without burning a hole in LTA's pocket. Though it is a trade-off between two highly interdependent and sensitive parameters, we use analytics to understand how effectively an On-Demand Public Bus Service could be implemented on of the routes: 255.

The goal of the proposed solution is to identify an evaluation framework that measures the KPI's such as waiting time of a commuter, the distance travelled by the bus, the number of no-shows, the resource utilization, the operating costs, bus-ride charges etc. A mobile application for both commuters and the bus captains is also being implemented for booking a ride, accepting a ride etc. Using the Goal-Question-Metric (GQM) methodology, the questions that must be addressed are outlined below. Using Paired Comparison Analysis, the relative importance of these questions is identified and the performance measures for the proposed solution are defined.

The goals are divided into 2 aspects: Commuter's aspect and LTA's aspect

1) GQM from a Commuter's point of view

- Decrease waiting time
- Decrease travelling time
- Increase bus availability
- Decrease cost
- Increase comfort (survey simulation)
- Increase UI simplicity (survey simulation)

Below is the priority list derived from the total score obtained after the Paired comparison analysis.

	Waiting Time	Travelling Time	Bus Availability	Cost	Comfort	UI
Waiting Time		W_3	W_3	W_2	W_3	U_2
Travelling Time			A_2	T_3	T_3	T_3
Availability				A_2	A_2	A_2
Cost					Cs_3	Cs_3
Comfort						UI_3
UI						

Table 2: PCA on Goals (Commuters)

Prioritising the Commuter's Goal	
Goals	**Score**
Waiting Time	11
Travelling time	9
Availability	8
Cost	6
UI	3
Comfort	0

Sl. No	***Goals***	***Questions***	***Metrics***
1	Decrease waiting time	1) How long commuter must wait for bus to arrive	Average waiting minutes.
2	Decrease travelling time	1) How much is the usual time travel different from the optimised	Average time for usual route and optimised route
3	Increase bus availability	1) What is the coverage? 2) How much time commuter needs to wait for the next bus if he misses the one he booked	Density of stop points in the specific stops Frequency
4	Decrease cost	What is the dynamic pricing and how much is the % increase compared to the actual one?	Calculated through an algorithm
5	Increase comfort	1)How comfortable is the commuter using on-demand service?	Analysing the survey via App
6	Increase UI simplicity	1) Is the user app simple and user-friendly?	Analysing the survey via App

Table 3: GQM for Commuters

2) GQM from LTA point of view:

- Decrease Operating & Maintenance costs (infrastructure, assets, application)
- Increase user base
- Increase bookings
- Decrease no-shows
- Increase resource utilization (send for regular service if no/less demand as per forecast for next n hours)
- Increase customer satisfaction (survey simulation)

Below is the priority list derived from the total score obtained after the Paired comparison analysis.

	O & M Cost	User Base	Bookings	No shows	Resource	Satisfaction
O & M Cost		C_2	B_3	C_2	C_2	S_2
User Base			B_2	N_3	R_3	S_3
Bookings				N_3	R_3	S_3
No shows					R_3	N_3
Resource						R_2
Satisfaction						

Table 4: PCA on Goals (LTA)

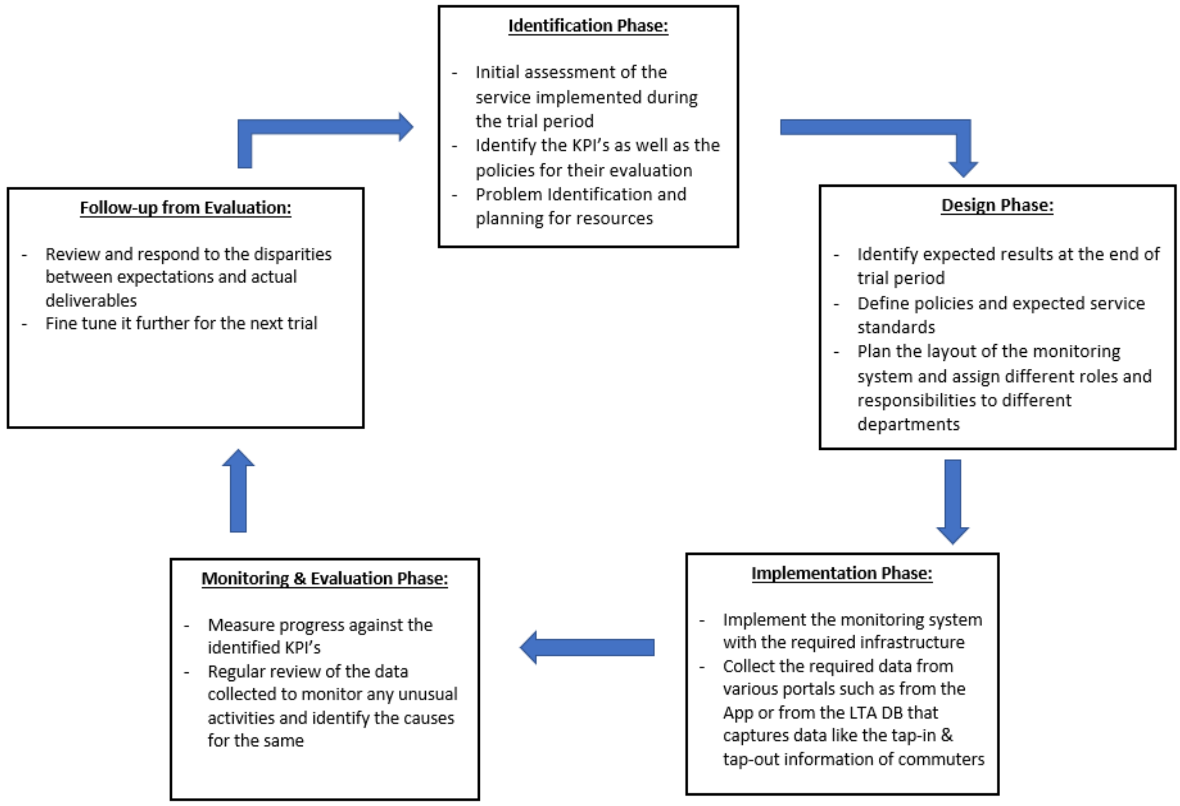
Prioritising the LTA's Goal	
Goals	Score
Resource	11
No-shows	9
Satisfaction	8
O & M Cost	6
Bookings	5
User Base	0

Sl. No	*Goals*	*Questions*	*Metrices*
1	Decrease operating and maintenance cost	1)How much the occupancy rate has decreased? 2) What is the number of buses per service? 3)What is the earning to spend ratio?	Calculated through an Algorithm
2	Increase User base	What is the increase in number of new users installing the app	Percentage increase in new users over past 1 month
3	Increase booking	What is the number of requested pick-ups / drop-offs for each location	Number of requests made in last 1 hour
4	Decrease no-shows	How many customers not opting after booking the ride?	Difference between schedule pickups and actual swipe- ins.
5	Increase resource utilisation	1) How many buses allocated for the service 2) Number of drivers	Number of buses used
6	Increase customer satisfaction	How well are the customers satisfied with the on-demand service?	Survey feedback from App

Table 5: GQM for LTA

MONITORING AND EVALUATION FRAMEWORK:

Monitoring & Evaluation phases through the Trial period:



Identification Phase: The stakeholders involved in the implementation process identify the objectives they plan to achieve through the proposed phases. For this purpose, implementers need to make sure they have the necessary information available to them in order to be able to make decisions about how to allocate money and effort in order to meet the identified objectives.

Design phase: A new architecture may be designed or an already existing one may be revised to meet the objectives identified in the earlier phase. In this stage, the strategy or plan to be used for execution should be finalised.

Implementation phase: During this stage the staff members operationalize the planning. They adapt the necessary settings, resolve problems that arise, and get the entire loop to a point where it is running smoothly. To monitor the implementation, there must be a constant check on the service being implemented. Information describing how the program is operating and how the program can be improved is needed: To what extent has the proposal been implemented as designed? How much does implementation vary from assured SLAs? How can the trial period (in our case) become more efficient or productive?

Monitoring & Evaluation Phase: Data with respect to all the aspects of the service needs to be collected at regular intervals for analysis purposes. This phase includes the evaluation of the KPI's based on the data collected. This would help identify any anomalies early in time and identify measures to tackle them. Sometimes, a mid-term evaluation is conducted to explain an unusual event. For example, during the trial period there might be an increasing number of no-shows which may affect the operational cost. Based on the mid-term evaluation, design restructuring can be carried out to nullify these kinds of scenarios. The restructuring would also address the changes required in the current processes to address the increased number of no-show cases.

Follow-up from Evaluation: This will be an iterative process to monitor the changes suggested and implemented during the evaluation phase.

RECOMMENDATIONS FOR IMPLEMENTNG THE FRAMEWORK:

Following table provides the policies as well as the recommendations for implementing the framework:

Goals	DEFINITION	BASELINE	TARGET	DATA SOURCE	FREQUENCY	RISK	RECOMMENDATIONS
	How is it calculated?	What is the current value?	What is the target value?	From where will it be measured?	How often will it be measured?	What might go wrong/challenge?	How it needs to tune it further?
Reduce Waiting and Travelling Time	1) WT- Ratio of Distance to the nearest location of the bus to the speed of the bus 2) TT - Ratio of optimised distance from origin-destination to the speed of the bus	WT- 10-20 mins TT - N/A	WT- 5-15 mins TT - 25% less than the current value On-demand bus service won't stop at all bus stops	App LTA DB	Every booking	Multiple requests from the same location but different destination via different routes, hence different buses will be allocated for different routes although from the same location.	Shorter routes with On-Demand bus services to serve short distances with high demand using Dynamic Matching and Routing algorithm
Maximize resource utilization	Calculated using Minimum Cost Flow Analysis	Approximately 1 bus every 15 minutes	Deploy the buses only at demand locations	LTA DB	Daily	Bus bunching	Accurate and timely communicaton between bus captains and Bus managing portal
Reduce Cost of on-demand commute for customer	Calculated based on the distance travelled and at what time of the day	Adult- $2.80 to $9.00(Grab Shuttle Plus on-demand service)	Taking into consideration competitor's rate, service will be offered in a range of $1.50 to $4.00 per ride.	Will be measured based on the distance and time of day by the App	Revised Quarterly	Commuters may find regular bus services, competitor bus and shared-cab services as well as bicycle services more pocket-friendly	Set prices for the ride with the constraint that the cost of travel will never exceed the competitor price or 1.5* regular bus ride cost
App UI usability	Time taken to open the App and book a ride, general user-friendliness of the App, Different UI for the bus drivers to accept the bookings.	N/A	1) Easy App interation 2) Run-time updates on the App 3) Multi-Language support 4) Flexible vehicle options 5) Automated E-receipt	App: User experience with App feedback	Every booking	1) Commuters may not find the App to be user-friendly 2) Commuters may not give ratings at the end of trip	Identify the problem areas based on the feedback received and improve further
Reduce No-shows	Difference between schedule pickups and actual swipe- ins.	5% of total booking/day	Reduce the No-shows to the minimum	LTA DB	Weekly	Increase in the number of No-shows would lead to loss of both capital and time	Penalise the commuter on the next trip if they cancel a ride more than once in a week
Increase Bookings	Calculate occupancy rate	N/A	Weekdays- Increase by 20% Weekends- Increase by 10%	From 3rd party App	Weekly	Competition from MyBusSG, Grabshuttle and Grabshuttle plus & other private players which already operate	By strictly serving and complying with the assured facilities and services
Increase Customer Satisfaction	Calculate using Net Promoter Scale (NPS)	N/A	Excellent(4-5/5)	From 3rd party App	Weekly	Commuter might not give ratings at the end of trip	Improve the service and cater to commuter's individual issues based on their feedback
Decrease Operations & Maintainance Cost	Calculated via algorithm	N/A	Minimizing it by 10%	LTA DB	Monthly	Over usage of bus deployments might lead to wear-out of the buses causing shortage of supply sometimes.	Needs planned calculation and execution
Operational Performance	Keep track of breakdowns, performance incidents, fuel consumptions and earn-to-spend ratio	N/A	Keep the number of incidents and the maintenance time for every breakdown/repair to minimum	Based on the call logs from the bus captains maintained by company's DB	Weekly	Too many buses off road due to breakdown incidents causing incovenience to commuters, Loss of revenue due to inability to serve demand	Ensure incident maintenance time is less than 2 hours. Maintain a few extra buses in case of breakdowns as well to handle peak-demand areas.
Data Collection	Collect and maintain vital data from all the sources	Current LTA Data	Maintain detailed data obtained from App as well as LTA DB	3rd party App and LTA DB	Hourly(as per the demand)	Data loss, DB connection issues etc.	Archiving/Backing up the data at regular intervals(daily)

Table 6: Policies and recommendations for framework implementation

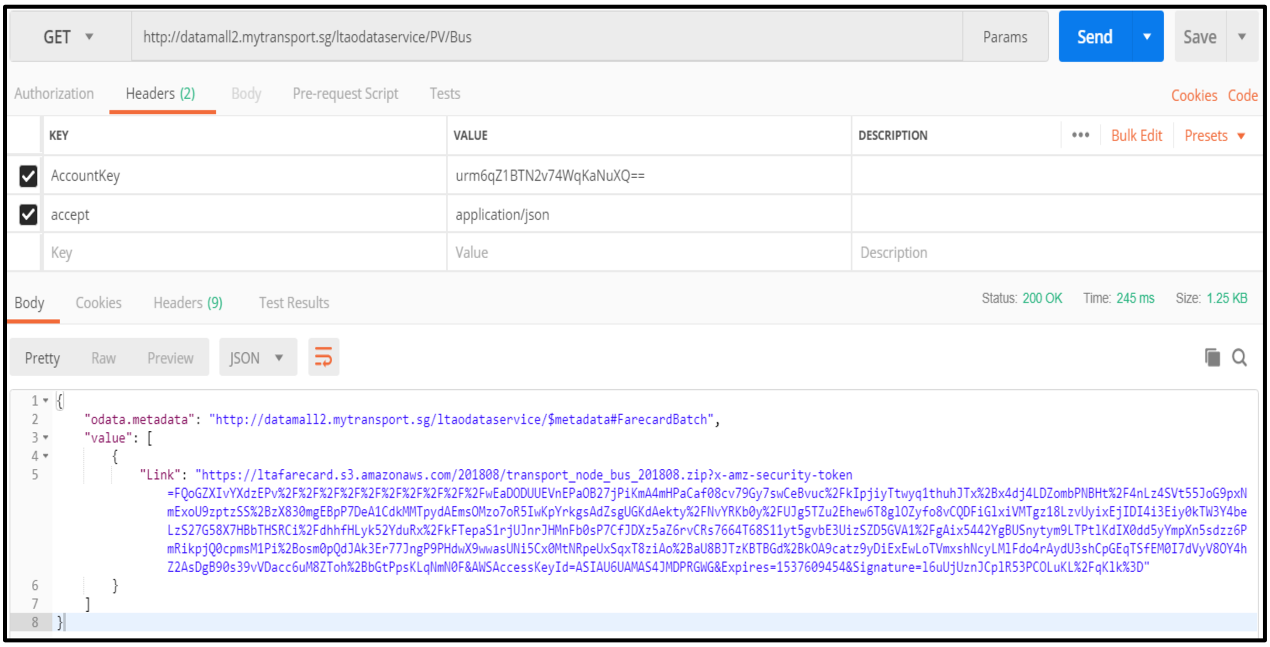
DATA EXTRACTION AND PRE-PROCESSING

DEMAND FORECASTING:

Based on the GQM and Framework defined above, we are planning to simulate the on-demand bus service for Bus Number 255 in Joo Koon area. In order to do that, we need to forecast the passenger demand data at each of the bus stops covered by Bus 255. So, we used a Demand Forecasting technique to predict the passenger demand at each bus stops by analysing the August 2018 passenger volume data.

DATA EXTRACTION:

To predict the passenger demand at each of the bus stops, we extracted the Passenger Volume by bus stops data i.e. the Tap In/Tap Out data of the passengers from LTA DataMall website. API calls and Data Extraction were done using Postman and Python respectively. We used Postman app to make an API Call to the LTA website and obtained the JSON file with the zip download link.



Python was used to extract the zipped folder containing the Passenger volume data.

<u>Python code:</u>

```
url = "https://ltafarecard.s3.amazonaws.com/201808/transport_node_bus_201808.zip?x-amz-security-token=FQoGZXIvYXdzEPv%2F%2F%2F%2F
target_path = 'H:\Service Analytics\API\lta.zip'
response = requests.get(url, stream=True)
handle = open(target_path, "wb")
for chunk in response.iter_content(chunk_size=512):
    if chunk:  # filter out keep-alive new chunks
        handle.write(chunk)
handle.close()
```

The dataset contains the tap in/tap out volume for each hour for weekdays, weekends and public holidays for the month of August 2018.

A small sample of our dataset:

YEAR_MONTH	DAY_TYPE	TIME_PER_HOUR	PT_TYPE	PT_CODE	TOTAL_TAP_IN_VOLUME	TOTAL_TAP_OUT_VOLUME
2018-08	WEEKENDS/HOLIDAY	13	BUS	24259	2	46
2018-08	WEEKDAY	13	BUS	24259	5	113
2018-08	WEEKDAY	21	BUS	24631	42	2
2018-08	WEEKENDS/HOLIDAY	21	BUS	24631	6	0
2018-08	WEEKENDS/HOLIDAY	19	BUS	24289	19	17

DATA PREPARATION:

As our study is focussed on Joo Koon area for Bus Service Number 255, we compiled a list of all the bus stop codes covered by Bus 255 from https://www.transitlink.com.sg.

24009	24209	24089	23519	24199	24299
24639	24189	24289	24259	24179	24279
24249	24169	24269	24239	24301	24631
24229	24641	23371	24219	24651	24009

Currently, 23 bus stop codes are being covered by Bus Number 255. We then created a subset of data containing only these bus stop codes and their corresponding tap in/tap out passenger volume data for each hour for weekdays, weekends and public holidays.

FORECASTING IN R:

A Generalized Linear Model with Negative Binomial distribution was built using the subset data containing the 23 bus stop codes. The Package **MASS** provides the function **negative.binomial()** that can be directly plugged into **glm()** function. We then use the values of the fitted model to predict the demand of passengers at each of the bus stops at a particular time.

R Code:

```
data_demand<-read_xlsx("H:/Service Analytics/Assignment/API/lta/Bus_255.xlsx")
View(data_demand)

data_demand$DAY_TYPE<-as.factor(data_demand$DAY_TYPE)
data_demand$TIME_PER_HOUR<-as.factor(data_demand$TIME_PER_HOUR)
data_demand$PT_TYPE<-as.factor(data_demand$PT_TYPE)
data_demand$PT_CODE<-as.factor(data_demand$PT_CODE)

p_load(MASS)

neg_bin_reg<-glm.nb(TOTAL_TAP_IN_VOLUME~.,data = data_demand[,c(2,3,5,6,7)])

summary(neg_bin_reg)

predictions<-round(neg_bin_reg$fitted.values)
```

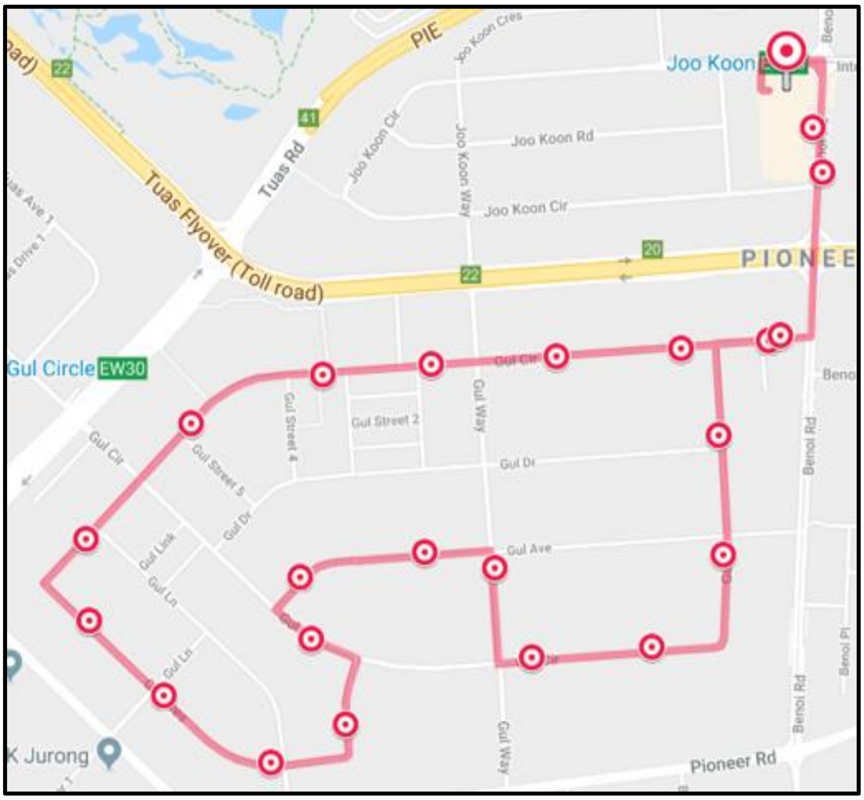
Predicting the average demand at each bus stop:

For our simulation purposes, we are planning to calculate the average passenger demand per bus at each of the bus stop at 2 pm. In order to do that, we are assuming that, for an hour, the number of buses arriving at each bus stop is 5. Using this, we can calculate the passenger demand per hour and per minute for all the bus stops.

On taking an average, we can say that approximately **3 passengers** ask for on-demand service per minute at all the bus stops along the route of Bus Number 255.

PROOF OF CONCEPT / SIMULATION

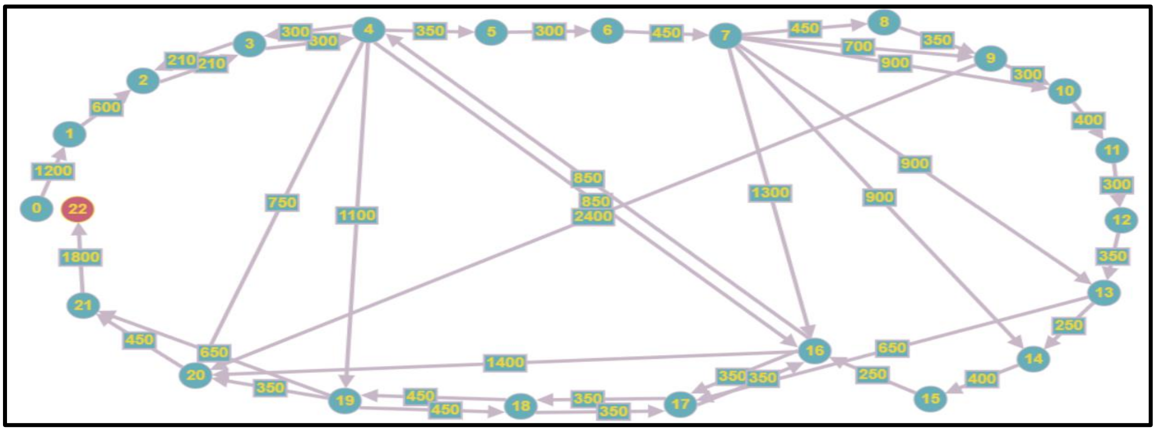
1)Distance covered



For measuring the KPI of distance covered via Dynamic Routing Service, we need to first lay down a Geofence and then calculate the total distance covered by all the bus services via dynamic routing in that Geofence. This measurement of distance travelled by a bus within a pre-designated Geofence can be easily accomplished by several GIS plugins within the GPS systems that will be employed to guide the driver on the route he/she needs to follow. For the sake of illustration, we have simulated the dynamic routing service within the Geofence of bus service 255. The path/Geofence is as below. It is a closed network.

We make use of Python libraries Google ortools and numpy.random to simulate demand(pick-up and drop), optimal routes and distance covered in a simulation. We assume the simulation frequency to be per minute. We make use of the arrival time across the geofence calculated per min from the forecasting step earlier to set up a Poisson arrival process at rate 3 per min.

First, the resulting route converted to a graph is as below.



Each simulation iteration consists of:

1) Setting up the demand (source-sink vector).
2) Supplying the graph.
3) Solving the resulting graph – demand optimization problem of minimum cost flow.

A typical output example of this simulation is as below.

Optimal Distance travelled for service: 6100 metres
This demand is better served with dynamic routing
Demand: [0, 0, 0, 0, 0, 0, 4, 3, -1, 1, -5, -1, -1, 5, -1, 2, -3, 1, 1, -1, -3, -1, 0]

Arc	Flow / Capacity	Distance
0 -> 1	0 / 96	0
1 -> 2	0 / 96	0
2 -> 3	0 / 96	0
3 -> 2	0 / 96	0
3 -> 4	0 / 96	0
4 -> 3	0 / 96	0
4 -> 5	0 / 96	0
5 -> 6	0 / 96	0
6 -> 7	4 / 96	450
7 -> 13	0 / 96	0
7 -> 14	0 / 96	0
7 -> 16	0 / 96	0
7 -> 9	0 / 96	0
7 -> 10	6 / 96	900
7 -> 8	1 / 96	450
8 -> 9	0 / 96	0
9 -> 10	1 / 96	300
10 -> 11	2 / 96	400
11 -> 12	1 / 96	300
12 -> 13	0 / 96	0
13 -> 17	3 / 96	650
13 -> 14	2 / 96	250
14 -> 15	1 / 96	400
15 -> 16	3 / 96	250
4 -> 16	0 / 96	0
16 -> 4	0 / 96	0
16 -> 17	0 / 96	0
17 -> 16	0 / 96	0
17 -> 18	4 / 96	350
18 -> 17	0 / 96	0
16 -> 20	0 / 96	0
18 -> 19	5 / 96	450
19 -> 18	0 / 96	0
19 -> 20	3 / 96	350
20 -> 21	0 / 96	0
19 -> 21	1 / 96	600
21 -> 22	0 / 96	0
4 -> 19	0 / 96	0
4 -> 20	0 / 96	0
9 -> 20	0 / 96	022 -> 0 0 / 96 0

Statistics:

Travel Distance due to service: 6.1 km
Default travel distance: 10.21 km
Number of buses deployed to satisfy service: 5
Number of via travels: 2

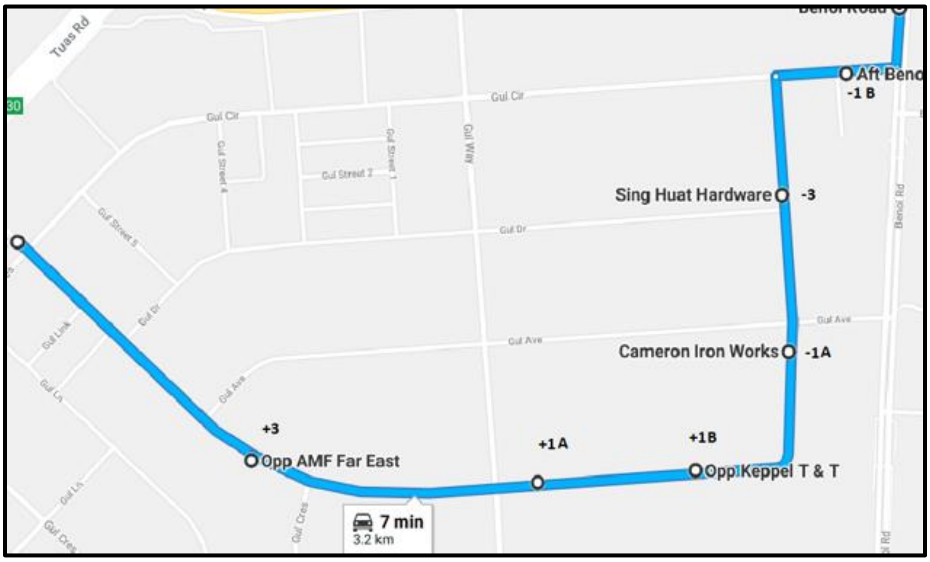
Thus, as proved by the simulation, it is possible to effectively use the metrics of Distance covered and number of buses (and also number of via travels needed) utilized within a Geofence to measure, as per a trade-off, the performance of service.

Explanation above the output: The following have been visualized using BusRouter.sg and Google Maps.

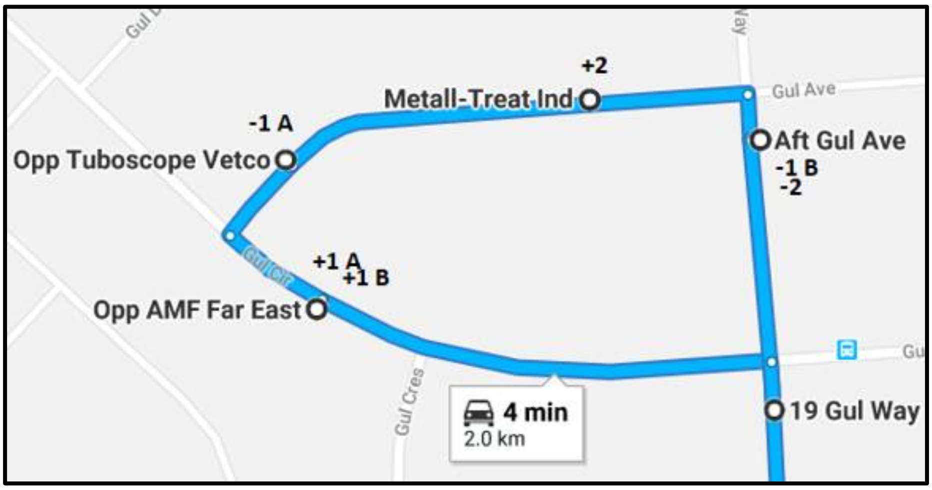
Bus 1 Route:

Demands: There are a total of 5 demands generated at SNL Logistics. 1 of them want to go to Aft Gul Avenue, 1 of them want to go to W Atelier/Opp Tuboscope Vecto and 3 of them want to go to Sing Huat Hardware.

Other Demands generated are: One person at Aft Gul Way want to go to Cameron Iron Works Another person at Opp Keppel T & T wants to go to Aft Benoi Rd.



The resulting bus 1 enters GeoFence via Gul Crescent drive, services the demands, and leaves the graphed GeoFence. This is shown in the figure on the left.

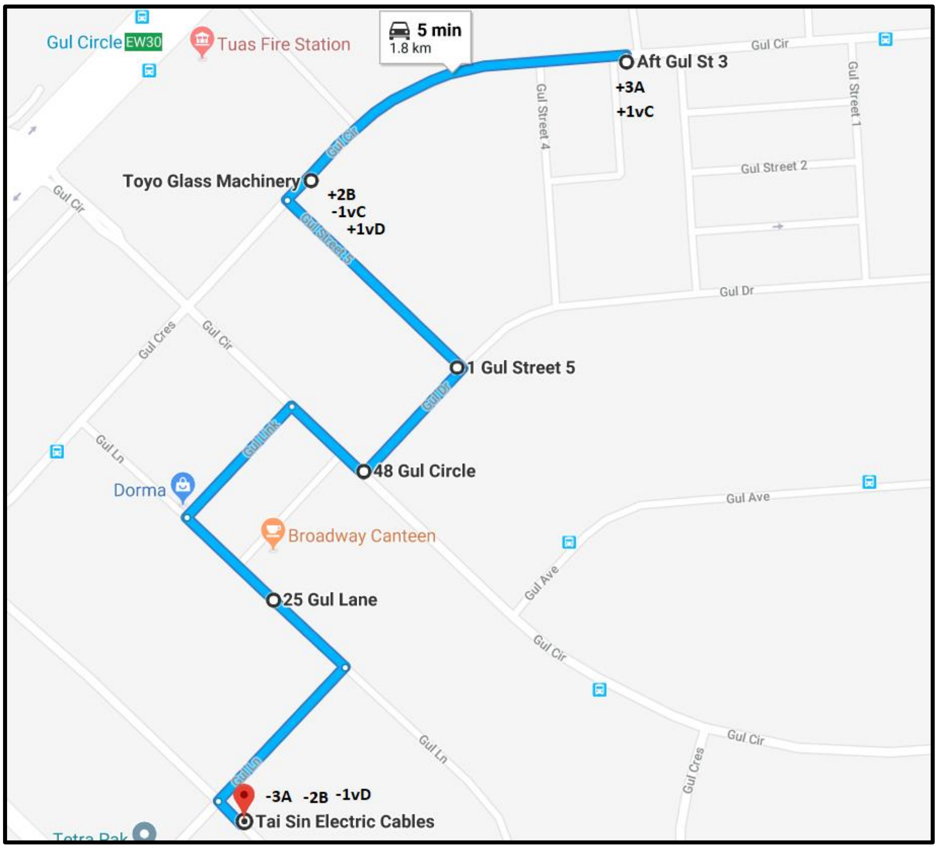


Bus 2 route:

Other Demands generated: 2 people get in at Metall Treat Ind and want to get down at Aft Gul Ave. So, second bus comes in through 19 Gul Way, serves 4 customers and goes back through 19 Gul Way and out of the GeoFence.

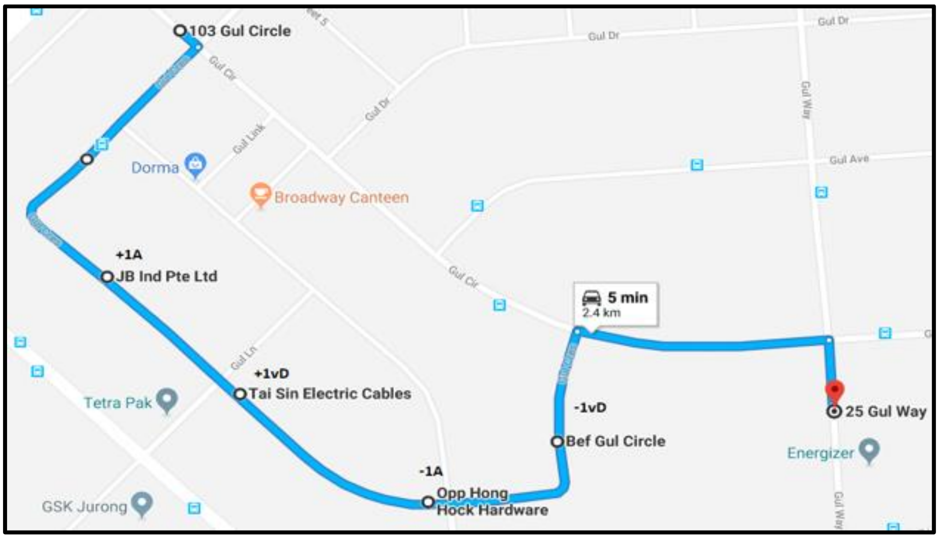
Bus 3 Route:

Demands: 4 people are there at Aft Gul St 3 of which want to go to Tai Sin Electric Cables and 1 want to go to Aft Gul Lane. 3 people at Precision Products, 2 want to go to Tai Sin Electric Cables and 1 want to go to Bef Gul



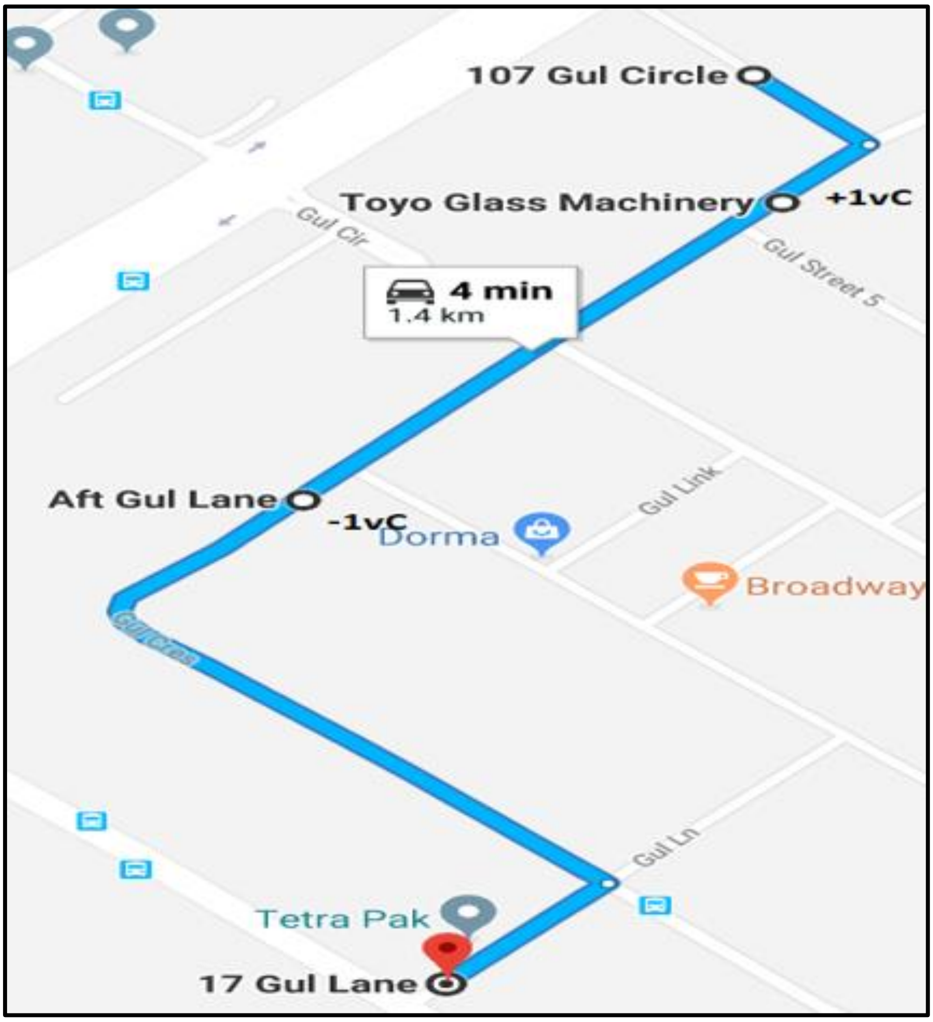
Concept of via Travels:

2 via travels are set-up by bus 3. One person is taken to stop Toyo Glass Machinery, and other to Tai Sin Electric Cables. This is represented by -1vC and -1vD in the figure on the left. Rest are regular demands.



Bus 4 Route:

Other Demands: There is 1 person at JB Industries Pvt Ltd who wants to go to Opp Hong Hock Hardware. A new bus comes into the Geofence via Gul Circle 103 Lane. This bus services the via D person and this additional demand and leaves the Geofence to service other demands.



Bus 5 Route:

The Final via Demand via C from Bus 3 is serviced now. A new bus arrives from Tuas Rd and services this request and leaves the Geofence.

2)Waiting Time and No-Shows:

The KPI of commuter waiting time is an important KPI since it is directly linked to another KPI of number of no-shows, which LTA would like to keep as low as possible. The waiting time can be easily measured as time between the booking of a travel request via the mobile app and person's verification at the time of boarding the bus. If the number of verified boarders is less than the number of assigned demands at the bus stop for a bus, then there is a loss/no-show observed.

<u>The Simulation Environment:</u>

- We have simulated for the bus stop 24009 i.e. Joo Koon Int on a weekend at 14:00 hrs., where we have calculated from the demand data that per min demand is roughly 2. This is the arrival rate for the Poisson Process.
- Now, as per the news, the service policy for on demand bus routing was found to be 5-15 mins, for any bus stop.
- Next, we have taken the fixed schedule bus interval to be one bus every 12 mins on a weekend at 14:00 hrs., as per the available frequency data by LTA.

We made use of the packages 'simpy' and 'random' in Python to set up the simulation.

The environment generated a customer as per Poisson arrival rate of 2 per min. Each generated customer is assigned two characteristics:

(A) Patience – uniform random U(5,15) in mins
(B) Bus Arrival for Service – Expo-variate as per U(5,15) in mins with Max from the expo-variate <= 15mins (terms of service/policy)
(C) Bus Arrival for Non-Service – Expo-variate as per constant 12 in mins

Cases:

(A) If Patience > Bus Arrival: Customer boards the bus, then waiting time is calculated.
(B) If Patience < Bus Arrival: Customer reneges or is lost to Grab. Waiting time is then the time customer waited or Patience.

Two cases of the 30 min simulations were run. The outputs are as below.

CASE 1: As per the on-demand routing service:

```
Bus Stop Simulation - On Demand
 0.0000 Customer_01: Arrives at Bus Stop
 0.2640 Customer_02: Arrives at Bus Stop
 0.5706 Customer_03: Arrives at Bus Stop
 0.7614 Customer_02: Boards Bus after waiting for  0.497
 0.8273 Customer_03: Boards Bus after waiting for  0.257
 1.3694 Customer_01: Boards Bus after waiting for  1.369
 3.2510 Customer_04: Arrives at Bus Stop
 5.1595 Customer_05: Arrives at Bus Stop
 5.5211 Customer_05: Boards Bus after waiting for  0.362
 6.2583 Customer_04: Boards Bus after waiting for  3.007
 8.0373 Customer_06: Arrives at Bus Stop
 9.8311 Customer_07: Arrives at Bus Stop
10.2976 Customer_06: Boards Bus after waiting for  2.260
10.4375 Customer_08: Arrives at Bus Stop
11.3635 Customer_09: Arrives at Bus Stop
12.7119 Customer_10: Arrives at Bus Stop
13.8790 Customer_07: Boards Bus after waiting for  4.048
14.1907 Customer_10: Boards Bus after waiting for  0.312
15.9895 Customer_09: Boards Bus after waiting for  4.626
18.3775 Customer_11: Arrives at Bus Stop
19.4155 Customer_12: Arrives at Bus Stop
19.9104 Customer_13: Arrives at Bus Stop
22.6810 Customer_12: Boards Bus after waiting for  3.266
23.5022 Customer_14: Arrives at Bus Stop
23.9791 Customer_15: Arrives at Bus Stop
24.8031 Customer_16: Arrives at Bus Stop
25.2786 Customer_08: Boards Bus after waiting for 14.841
25.8156 Customer_17: Arrives at Bus Stop
27.4535 Customer_11: Boards Bus after waiting for  9.076
28.0266 Customer_18: Arrives at Bus Stop
```

CASE 2: As per the Regular fixed service:

```
Bus Stop Simulation - Deterministic
 0.0000 Customer_01: Arrives at Bus Stop
 4.3543 Customer_02: Arrives at Bus Stop
 4.7402 Customer_03: Arrives at Bus Stop
 5.9708 Customer_04: Arrives at Bus Stop
 6.5430 Customer_05: Arrives at Bus Stop
 8.8839 Customer_03: Boards Bus after waiting for  4.144
 8.9415 Customer_06: Arrives at Bus Stop
11.3026 Customer_07: Arrives at Bus Stop
11.9283 Customer_05: RENEGED(I am taking a Grab!!!)/Lost after  5.385
13.2516 Customer_08: Arrives at Bus Stop
14.5460 Customer_04: Boards Bus after waiting for  5.662
15.4549 Customer_09: Arrives at Bus Stop
16.1379 Customer_10: Arrives at Bus Stop
16.3659 Customer_11: Arrives at Bus Stop
16.9644 Customer_12: Arrives at Bus Stop
18.4162 Customer_13: Arrives at Bus Stop
18.7026 Customer_07: RENEGED(I am taking a Grab!!!)/Lost after  7.400
21.4281 Customer_01: Boards Bus after waiting for 21.428
22.5438 Customer_14: Arrives at Bus Stop
22.8696 Customer_15: Arrives at Bus Stop
23.2620 Customer_16: Arrives at Bus Stop
23.5512 Customer_17: Arrives at Bus Stop
24.5234 Customer_18: Arrives at Bus Stop
25.3246 Customer_19: Arrives at Bus Stop
25.6607 Customer_20: Arrives at Bus Stop
26.1339 Customer_21: Arrives at Bus Stop
26.4907 Customer_22: Arrives at Bus Stop
27.2030 Customer_13: RENEGED(I am taking a Grab!!!)/Lost after  8.787
27.2972 Customer_23: Arrives at Bus Stop
28.8782 Customer_10: RENEGED(I am taking a Grab!!!)/Lost after 12.740
29.1307 Customer_24: Arrives at Bus Stop
29.1943 Customer_11: RENEGED(I am taking a Grab!!!)/Lost after 12.828
29.4968 Customer_09: RENEGED(I am taking a Grab!!!)/Lost after 14.042
29.6217 Customer_18: RENEGED(I am taking a Grab!!!)/Lost after  5.098
```

Results:
After over 15 simulations, below were the results:

1) Avg. waiting time is lesser in case of the service (4.323 mins vs 8.193 mins.)
2) Number of customers that renege is lesser in case of service (2 vs 6)

Thus, with the help of the mobile application, we can measure these metrics.

As proved by the simulation, we can effectively use these KPI to measure the achievement of these specific goals of our service.

SERVICE QUALITY METRICS

In order to understand the quality level of the services being implemented, following metrics need to be used:

- Access – On demand facility to ensure door to door transportation with minimal time to walk
- Aesthetics – The buses need to be in good condition and the bus captains need to provide better service.
- Attentiveness/ Helpfulness- Bus captain's performance will be based on how approachable to the bus commuters and assist them with patience in case customer have issues. Also, the way they help the senior citizens and children and take special care of them
- Comfort- The company will ensure the bus captains drive safely and follow the traffic rules as well as maintain good quality buses
- Commitment- The on-demand buses will try and maintain the promised time lines such as waiting time less than 15 mins
- Communication- The app will be user friendly and information will be accurate and updated about the ride information and the information should be in sync with the bus captain app.
- Competence/Courtesy- The bus captains hired have profession bus driving experience and groomed to serve the customers in best way possible and the companies to also provide training for the same
- Functionality/Flexibility-The customers will be served using the Dynamic routing algorithms to minimise the distance that the customer needs to travel and the routes will be optimised as per the request received
- Integrity- The customers will be made aware of the fare they are going to be charged, the waiting time and the travel time at the time of booking
- Reliability- The KPI as set will be maintained 95% of the time such as the buses will arrive at the time promised etc.
- Security- The security of the customers will be ensured and the buses will be safe enough for the children and senior citizens.

CUSTOMER SURVEY SIMULATION

As per the Goals, Questions and Metrics defined earlier, we have designed and simulated three customer surveys – two from commuter's POV and one from LTA's POV.

- From Commuter's POV
  - Rating the comfort level of the passengers
  - Rating the simplicity of the user app
- From LTA's POV
  - Rating the customer satisfaction

We designed one question for each of the three categories and simulated the responses of the passengers. We took a sample size of 1000 passengers and used **rbinom()** function in R to simulate the responses. For all the three surveys, we used **Net Promoter Score** (NPS) method and the scoring for each answer is on a 1 to 5 scale.

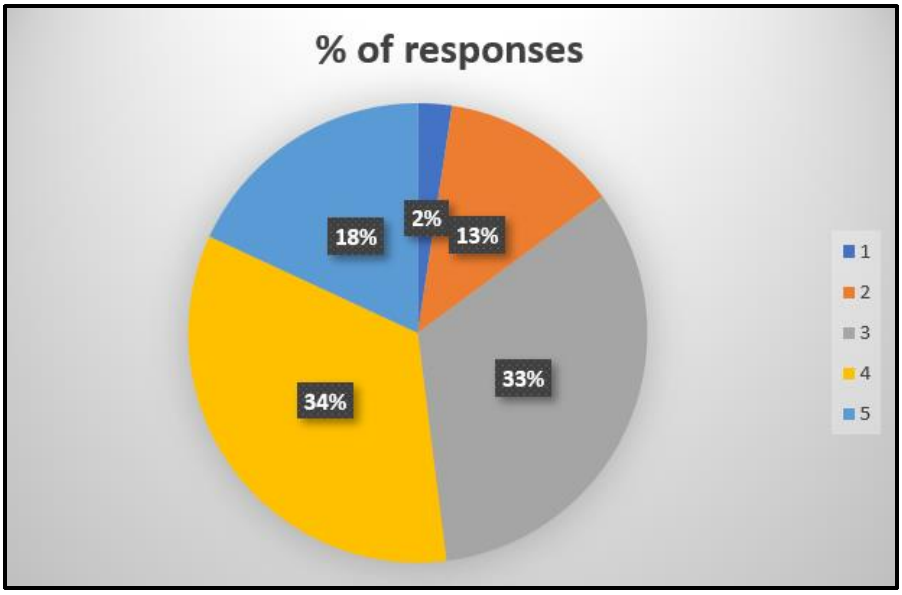
Simulation 1 – Rating the comfort level of the passengers:

This survey is simulated to gauge the comfort level of the passengers who are using the on-demand bus services.

Question: How comfortable are you with in using the on-demand service?

Extremely Uncomfortable	*Uncomfortable*	*Neutral*	*Comfortable*	*Extremely Comfortable*
1	*2*	*3*	*4*	*5*

Once the responses have been simulated, we visually analysed to check the percentage of responses for each of the response category. More than 60% of the passengers are comfortable with the on-demand services and around 15% of the passengers are uncomfortable.



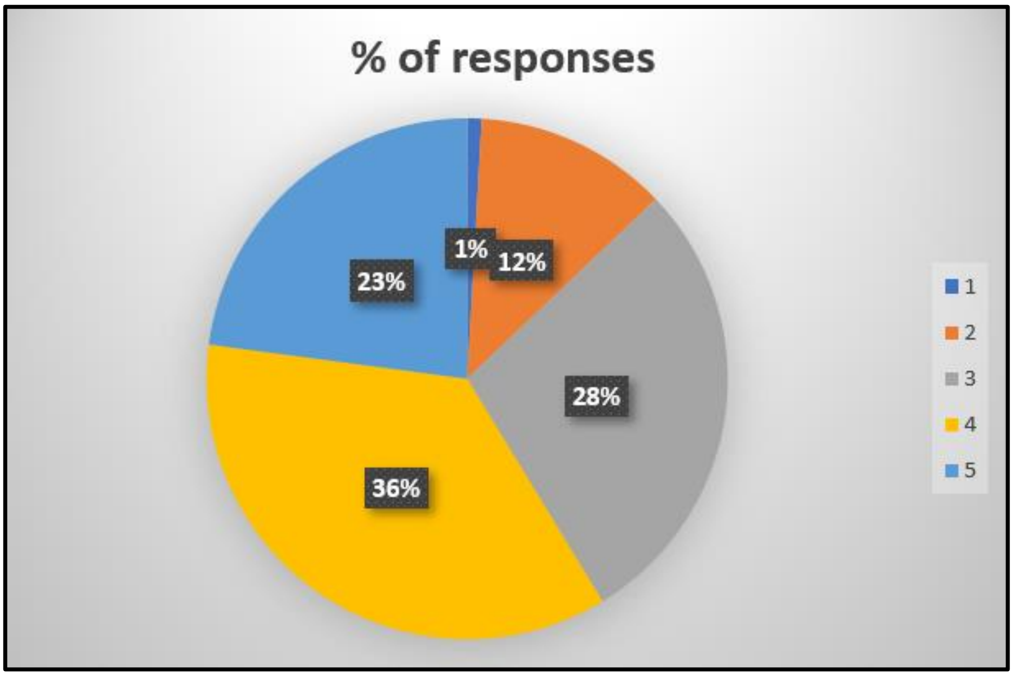
Simulation 2 – Rating the simplicity of the user app:

This survey is done to measure the simplicity of the UI interface of the on-demand service app and how user-friendly it is for the passengers to book an on-demand service bus.

Question: Is the on-demand service user app simple and user-friendly?

Strongly Disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*
1	*2*	*3*	*4*	*5*

Upon analysing the responses, we figured that around 59% of the passengers agree that the app is very simple and user-friendly to use and 1% of the passengers found it difficult to navigate their way around the app.



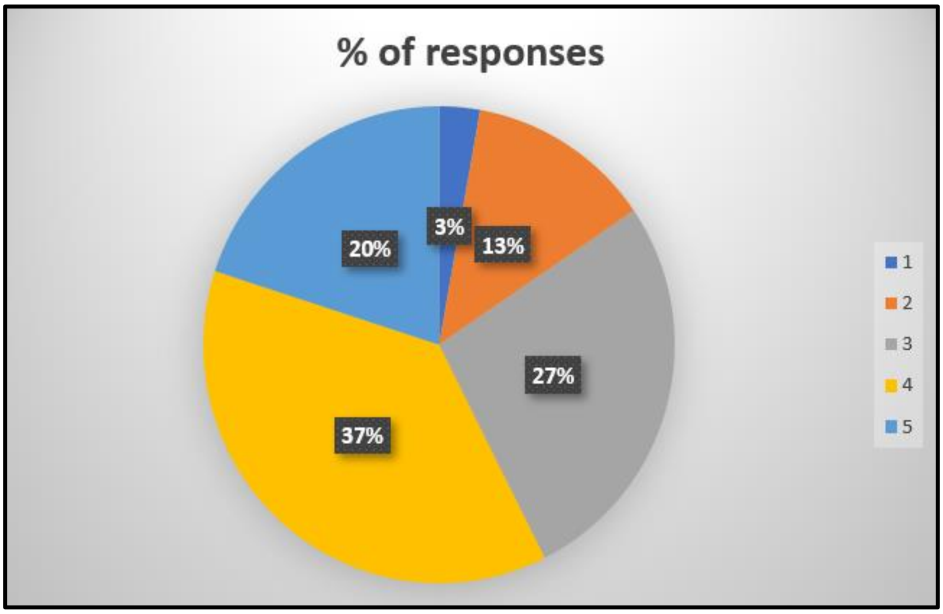
Simulation 3 – Rating the customer satisfaction of the service:

The purpose of this survey is to determine satisfaction level of the passengers who are using the on-demand bus services as LTA will want to know how their new services are being perceived by the passengers.

Question: How satisfied are you with the on-demand service?

Highly Dissatisfied	*Dissatisfied*	*Neutral*	*Satisfied*	*Highly Satisfied*
1	*2*	*3*	*4*	*5*

On analysing the survey results, we found that over 57% of passengers are completely satisfied with the on-demand services and around 15% of the passengers are not completely satisfied with the services.



COST BASED EVALUATION

Following is the cost analysis performed using the simulation for bus 255 route:

Fuel Cost: As per Mercedes Citaro mileage of 2.5 km per diesel liter and diesel price of 1.85 SGD

Manpower Cost: As per article $SGD 8 per hour --> converted to $SGD 0.2 per min --> calculated for all buses and average of 5 minutes per bus in above simulation.

Operating Cost: Assuming this to be half of the fuel cost i.e. 0.9 per km

From the calculation shown below, it is observed that the running cost for dynamic routing is less than the regular running cost even after deploying 5 buses.

WITHIN GEOFENCE	Fuel Cost	Manpower Cost	Operation Cost(A/C)
Dynamic Routing	5 S$	5 S$	6 S$
Usual Operating	8 S$	6 S$	9 S$

Source for mileage of Mercedes Benz Citaro.

Source for driver salary.

CONCLUSION

Based on simulation results we could infer that the proposed system will optimize the bus services in Joo Koon Area (255 routing) and fulfil almost all the KPIs/parameters. We observed the key KPI i.e. "Average Distance travelled per customer" reduces by almost 25-50% as per our simulation. On the other hand, we could not deliver on "Bus frequency" as there was lot of discrepancy between the location of the commuters and the volume of demand at a particular time which in fact does not give a concrete idea regarding the frequency. Our recommendation would be awareness of the above-mentioned issue on LTA's part and collaborate with a 3rd party bus fleet provider for providing the buses during dynamic demand. On a long run, this could further be replicated in subsequent areas.

Parameter	Current System	Proposed System	Up/Down
Bus Stop	Fixed	Dynamic	↑
No Shows	6	2	↑
Av. Distance travelled/ Customer	~5 Km	2.16 Km	↑
Fuel Cost	S$8	S$5	↑
Operating Cost	S$9	S$6	↑
Manpower Cost	S$6	S$5	↑
Waiting Time	8.193 min	4.323 min	↑
Bus Frequency	6 buses/hour	As per the location of commuter's demand	↓

Table 7: Performance parameters comparison with Simulated results for Bus 255 routing