Preliminary Study of Transport Pattern and Demand in Singapore for Future Urban Air Mobility

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This paper aims to present the preliminary feasibility study of future urban air mobility (UAM), by means of flying taxis, based on the existing transportation demands in Singapore. Some cities such as Dallas, Los Angeles and Melbourne have already investigated the trends of urban air mobility and planned to launch its eVTOL in 2023. The consideration behind flying taxis in Singapore serves to smoothen traffic congestions in the central and industrial areas due to occasional traffic jams caused by road works or accidents, providing greater transportation convenience in a cosmopolitan city. Firstly, the research focused on the demand in terms of cost, travel time and the travel distance for various modes of conventional transport across Singapore. Eight reference mission scenarios were analysed in line with real-time traffic and fare-time patterns were studied to understand how passengers could benefit from it, in terms of time and cost savings. Secondly, the research was narrowed down to the Central Business District (CBD) and focused on tourists' transport demands using statistics provided by the Singapore Tourism Board (STB). The goal is to determine which districts had the most in-demand and how tourists could benefit by taking a flying taxi. The objective of this preliminary study is also to gather baseline data so as to further investigate on whether flying taxis in Singapore is viable and determine how to optimise that from different perspectives of various stakeholders, including the efficiency of flying taxis.

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I. Background and Introduction

In recent years, many aviation companies such as Airbus Acubed, Volocopter 2X, Aurora Flight Science have been working on flying taxis based on the concept of UAM (Urban Air Mobility) [1]. These can be applied to cosmopolitans such as London, Los Angeles, Dubai et cetera. Several studies with eVTOLs have also been conducted in distinct cities, for example, Lilium (Germany), Flyer (Kitty-Hawk), eHang 184 (Guangzhou).

In Seoul, the concept of on-demand mobility has been carried out based on the commuting population data by distinct districts. Three commuting routes were selected from the densest areas for the experiment and it was found out the travel time by personal air vehicle was relatively small compared with the total travel time. The number of Vertiports have been obtained using the K-mean clustering algorithm [2]. However, there are problems that remain unsolved such as noise and community acceptance.

UAM represents on-demand and fully automated cargo or passenger air transportation services without any pilot on board [3]. Presently, UAM does not exist in Singapore largely due to airspace constraints, lack of airworthiness regulations and air traffic management procedures governing the use of UAM vehicles.

Having discussed a series of challenges for drone operations and studied what other countries had been doing about on-demand mobility, it is questionable whether flying taxis will become a reality in Singapore. As one of the most innovative country (2017 Global Innovation Index) [4], Singapore is also the second-best city for technology companies (Colliers International) [5] in Asia. The very first step to address the question earlier is to understand the demand and determine which districts in Singapore have potential for Vertiport sites. In 2nd quarter of 2020, Airbus and CAAS have signed a Memorandum of Understanding (MOU) to enable UAM in Singapore [6]. The purpose is to leverage on a safe UAS in dense and low altitude airspace, so that it can tackle the congested ground traffic and enhance the country's regional connectivity.

II. Statistics and Analysis

The population in Singapore is becoming denser in recent years due to reasons such as better health care, increased in migrants and immigrants. In 2025 and 2030, the population in Singapore will hit approximately 6.07 million and 6.4 million respectively, based on Worldometer forecast [7].

It would be optimal if flying taxis can not only shorten end-to-end travel time but also have reasonable fares. It is expected the fares for flying taxi are relatively high at launch [8]. With the aim of optimising the usage of flying taxis, studying the demand and how users will benefit from them are mandatory. In the near term, the fares will be comparable to the cost of JustGrab and most importantly, the fares would become economical in the long term because the technology will be more mature [9].

The journey in Singapore will take a considerable time if people travel all the way from the east region (such as Changi Airport) to the west region (such as Nanyang Technological University) using conventional mode of tranpsort. Studies have found that much time is spent on the road due to traffic conditions. For instance, residents in Sydney and Los Angeles are spending seven working weeks each year commuting [9]. The question on how commuters can benefit from this new mode of transport in terms of travel time, fares and travel distance compared with Grab (JustGrab), ComfortDelGro (a local taxi provider) and public transport (such as Mass Rapid Transit, MRT) is of particular interest in this paper.

Initially, ten different locations were selected across Singapore (see **Fig 1.**) and one of the considerations behind the selection was based on the data obtained from Grab [10] shown in **Fig. 2** which shows high demand during a certain period in the Central Business District (CBD), Tampines, Bedok and Northern regions.

In order to select the locations evenly across the entire country, few locations in the west region have also been included. Consequently, Table 1 shows the results of eight reference mission scenario which consist of three short routes (up to 10 km), three medium routes (greater than 10km but less than 30km) and two long routes (greater than 30km). The fare-distance-time comparison covered various modes of passenger transport, including the estimated values for the flying taxi.

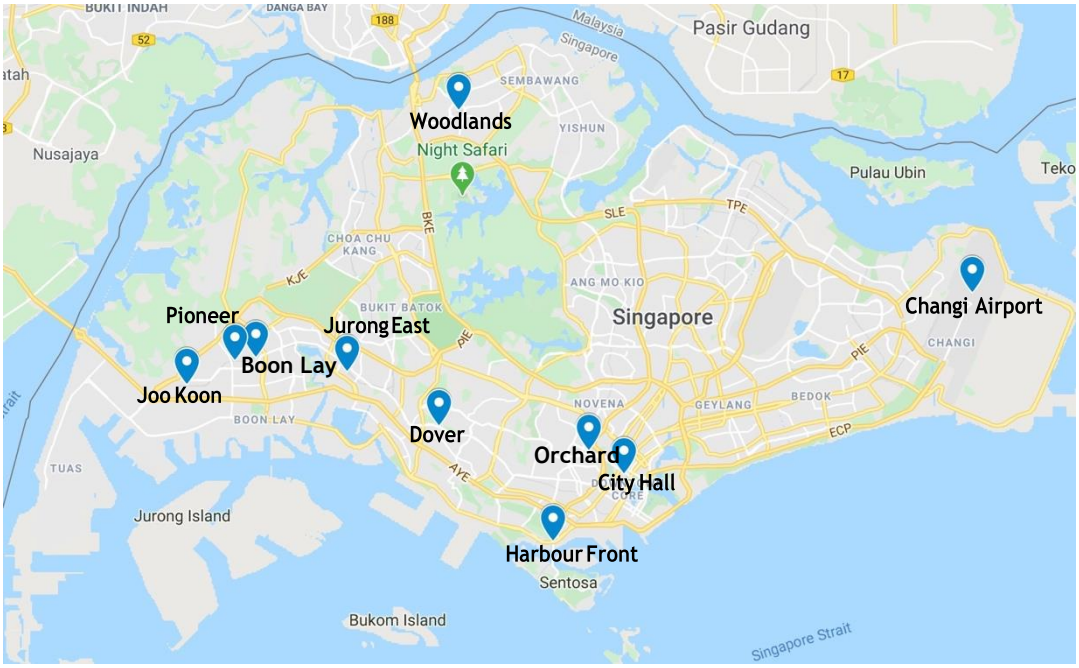

Fig. 1 Ten selected locations across Singapore

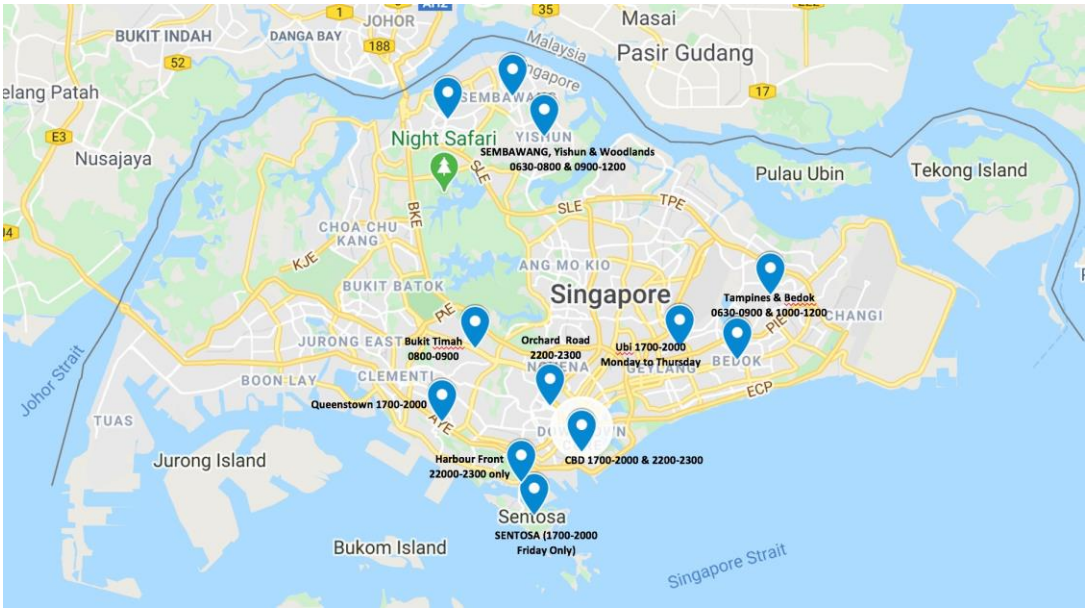

Fig. 2 High demand Pick-up points

Table 1. Fares comparison amongst different modes of transportation based on real-time traffic

	Route	MRT (Peak & Off Peak)	JustGrab (Peak)	JustGrab (Off Peak)	ComfortDelGro (Peak) [11]	*Flying Taxi*
Short Route (up to 10 km)	**1. Jurong East to Boon Lay**	S$1.10 4.7km 7 minutes	S$10-14 5.9km 20.5 minutes	S$7-8 5.9km 14.3min	S$8.50 5.9km 20.5 minutes	S$50 ($34.60)[#] 4.12km 2.5 minutes
	2. Harbour Front (Tourist Attraction) to Orchard (Shopping District)	S$1.30 7.1km 29 minutes	S$15-16 7.15km 32.5 minutes	S$13 6.26km 11.3 minutes	S$12.30 7.15km 32.5 minutes	$50 (S$36.50)[#] 4.34km 2.6 minutes
	3. Boon Lay to Dover	S$1.50 10km 18 minutes	S$12-13 11.86km 26.3 minutes	S$11 11.86km 16mins	S$12.70 11.86km 26.3 minutes	S$72.80 8.67km 5.2 minutes
Medium Route (greater than 10km, less than 30km**)**	**4. Pioneer (NTU) to City Hall**	S$1.90 20.7km 40 minutes	S$22-27 25.4km 40.8 minutes	S$18-19 25.4km 30 minutes	S$26.60 25.4km 40.8 minutes	S$144.10 17.16km 10.3 minutes
	5. Woodlands to City Hall	S$2.00 25.4km 44 minutes	S$20-29 27km 43 minutes	S$20 27km 29.7 minutes	S$34.95 27km 43 minutes	S$148.30 17.65km 10.6 minutes
	6. Orchard (Shopping District) to Changi Airport	S$1.90 21.1km 61 minutes	S$20-27 19.8km 30.5 minutes	S$20 19.8km 22.7 minutes	S$25.25 19.8km 30.5 minutes	S$149.80 17.83km 10.7 minutes
Long Route (greater than 30km)	**7. Pioneer (NTU) to Changi Airport**	S$2.15[Δ] 38.3km 84 minutes	S$32-41 41km 43.3 minutes	S$32 41km 34 minutes	S$39.10[Δ] 41km 43.3 minutes	S$275.50[Δ] 32.8km 19.7 minutes
	8. Changi Airport to Joo Koon (West Industrial Zone)	S$2.20 40km 88 minutes	S$35 43.4km 50 minutes	S$35 43.4km 35mins	S$41 43.4 km 50 minutes	S$293.50 34.94km 20.9 minutes

Δ Fare calculation see Table 2

USD $1 = SGD$1.36

[#] In order to ensure profit, a reference rate of S$50 is assumed and taken as the minimum fare for every trip. For example, for the trip of 4.12 km and 4.34 km, the meter-rate is $34.60 and $36.50, respectively. The final charge for these two trips by Flying Taxi is $50.

To avoid undesired time spent during traffic jams, commuters can consider taking flying taxis during peak hour when this facility exists in the future. The comparison of fares and travel time for all types of transports (MRT, JustGrab and ComfortDelGro) was also conducted during peak hour (as the demand is higher compared to off-peak hour). The travel distance in every mode of transport varies due to the different pathway albeit having the same origin - destination pair. The seventh route, i.e., one of the longest routes (from NTU to Changi Airport), would be used as a case study. Table 2 presents an example of how the total fare is calculated for different transport modes.

The peak hour MRT ride from Pioneer station to Changi Airport (38.3km distance) costs S$2.15 in 84 minutes. Fare for MRT was extracted from the LTA (Land Transport Authority) website. With respect to JustGrab, the fares, routes and travel time were obtained based on real-time traffic. The only difference compared with ComfortDelGro is that the fare of ComfortDelGro was computed by breaking down metered fare shown in Table 2. In respect of flying taxi, S$8.4 per km was used and the cruising speed is assumed to be 100km/h due to the crammed infrastructure in Singapore (CitiGroup) [12]. Therefore, the total fare is $275.50 in approximately 20 minutes from Pioneer to Changi Airport.

Table 2. Example of how the fares were obtained

Breakdown of fares from Pioneer to Changi Airport	ComfortDelGro/JustGrab (41km) ◊	*Flying Taxi* (32.8km) - Point to Point direct route (Straight Line)	MRT (38.3km)
Flag down	S$3.6 *	N.A.	N.A.
Waiting fee	S$0.88 (assuming four times of waiting time in this journey) §	Ride-hailing company may charge those who are late to arrive the pick-up location	N.A.
Distance fee	S$4.95 (the first 1000m) + S$19.50 (31km and S$0.22 per every 350m) ǂ	S$8.40/km [12]	N.A.
Metered fares	S$28.90	N.A.	N.A.
Peak hour surcharges	(25% of metered fare) = S$36 ✦	TBC (depending on Ride-hailing company)	N.A.
Location surcharges	S$3 ‡	N.A.	N.A.
Total fares	S$39	S$275.50 (= 32.80x8.40)	S$2.15

* Flag down fare is from S$3.2 to S$3.9 depending on the types of the car so that average price would be taken
§ S$0.22 (every 45 seconds or less)
ǂ S$ 0.22 for every 400m thereafter or less up to 10km, and every 350m thereafter or less after 10km✦ Peak hour surcharges applied to overall fares (25% of the metered fare) ‡ Location surcharges (S$3 in Changi Airport)
Peak time: 0600-0929 & 1800-1159; Off peak: 0930-1759
Electronic Road Pricing (ERP) may need to be applied depending on the route between the two locations.
◊ Since there are different pathways to Changi Airport from Pioneer, different routes would be taken (via Kranji Expressway and Pan Island Expressway or East Coast Parkway or Ayer Rajah Expressway and Pan Island Expressway) so that the average distance and average travel time were obtained

A. Fare-Time Analysis

For any mode of transport, the distance undertaken by the vehicle, the fare applicable for the journey and time taken are factors used to determine the suitability of the final mode of transport by commuters. It is not only the in-vehicle time, but also out-vehicle time ¶ [13]. Distance, fare and time are directly proportional to each other where the longer the distance travelled, the relatively higher the fare and time taken will be. Since fare and distance are directly proportional to each other, distance travelled can be represented by fare and hence, by establishing a fare-time diagram for a particular mode of transport as shown below, fare and time have an exponential relationship.

Any particular point on the exponential graph represents a corresponding distance travelled and its associated fare to travel that distance. If an analysis is carried out at a particular point on the graph, a fare-time ratio can be calculated and a conclusion on the relative time savings can be generated by comparing the fare-time ratio of two different distances travelled.

The fare-time ratio for a mode of transport is the ratio between the instantaneous fare increment against the instantaneous time increment at a particular distance travelled/fare of interest. By comparing the ratios of two different journeys using the same mode of transport, we can determine the relative time savings between them.

The fare of JustGrab and ComfortDelGro is approximately ten times higher than public transport, but it saves half the time for travelling a long distance. Having calculated different fares and travel time in different modes of transport during peak hour, 8-routes scenarios were plotted and shown in **Fig. 3** in the fare-time diagram. Diagram can show that the curve of flying taxi considerably steep whilst the other modes of transport (MRT, JustGrab and ComfortDelGro) are relatively flat. It stands for some point of view that passengers taking a flying taxi can save a large amount of time for travel no matter short, medium or long journey albeit exorbitant fares. This scenario can be applied for some businessmen and those who would like to arrive in a certain destination from the original location within a short amount of time, but the prerequisite is that users are willing to pay more. On the other hand, regarding the other modes of transport, passengers spend plenty of travel time in relatively affordable fares. The survey found out that users are willing to pay around four times higher than the taxi fare for eVTOL technology by travel time reduction [14] [15].

¶ In-vehicle time stands for time of transport; out-vehicle time represents journey preparation such as walking to the pick-up location, waiting for the vehicle and walking to the final destination from stop

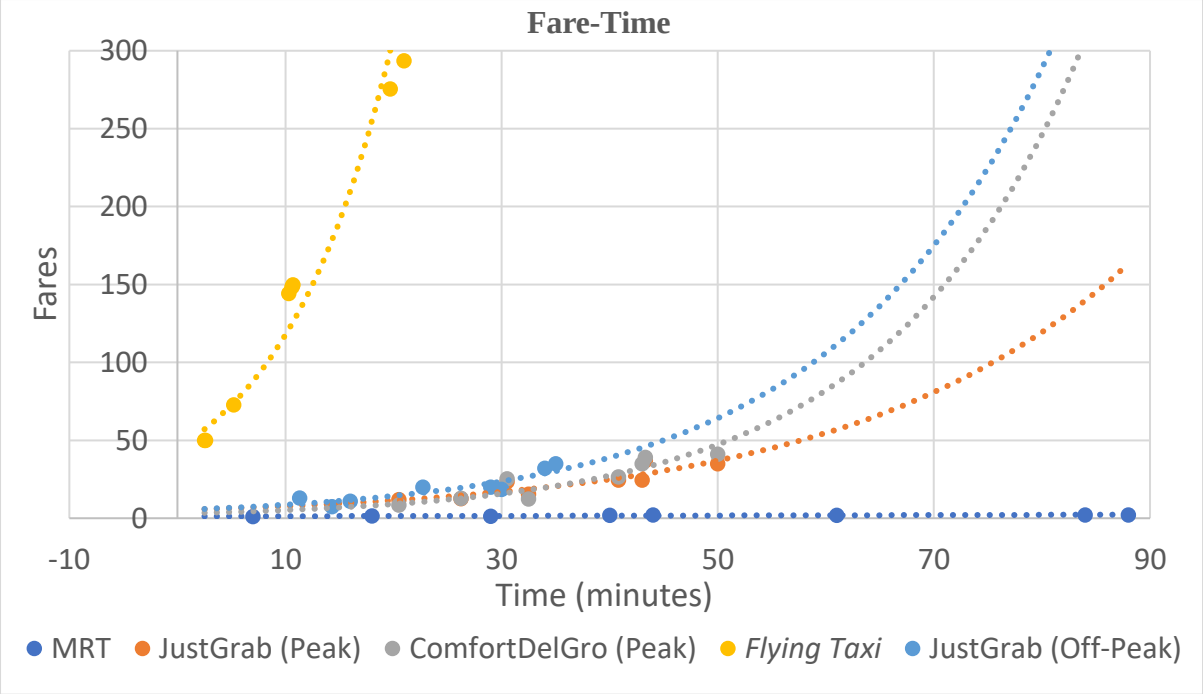

Fig. 3 Results amongst different modes of transportation

The slope in the fare-time diagram shown in **Fig. 3** would ascertain how much time passengers could benefit from travelling between any two locations and whether or not the fares are economical by taking different modes of transportation. The slope on MRT seems to be flat but it is not. It demonstrates that the fares are significantly affordable compared with other modes of transportation no matter peak or off-peak. During peak time, traffic jam, notoriously, does exist so that the fares and travel time of ComforDelGro and JustGrab take longer time and more expensive than off peak.

The conclusions between different modes of transport are as follows:

- *Flying taxis*: less travel time but the fares are higher (Avoiding traffic jam experienced by land transport modes);
- Other modes of transport: Relatively affordable but it takes a large amount of time.

III. Potential Demand for Flying Taxis in Central Business District (CBD) Area based on Tourism Statistics

Flying taxis apart from providing more convenient to residents in the whole country, they may also be particularly beneficial to tourists. There has been an increase in public transport ridership over the past few years falling in line with the number of visitors [16] contributed to public transport ridership numbers. In order to figure out which regions may have the large demand for flying taxis, the most popular attractions sites, which are mostly located in the central area, were selected between 2009 and 2018 regardless of free access or paid access based on the Singapore Tourism Board (STB) shown in **Fig. 4** and **Fig. 5** [17].

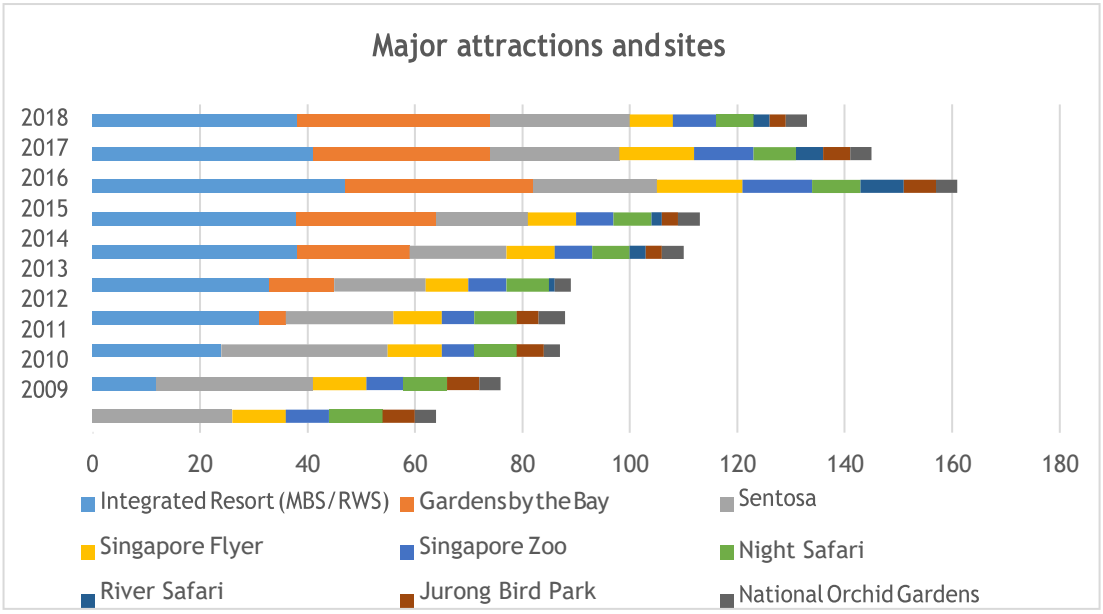

Fig. 4 Major attractions and sites (not free of charge) in Singapore from 2009 to 2018

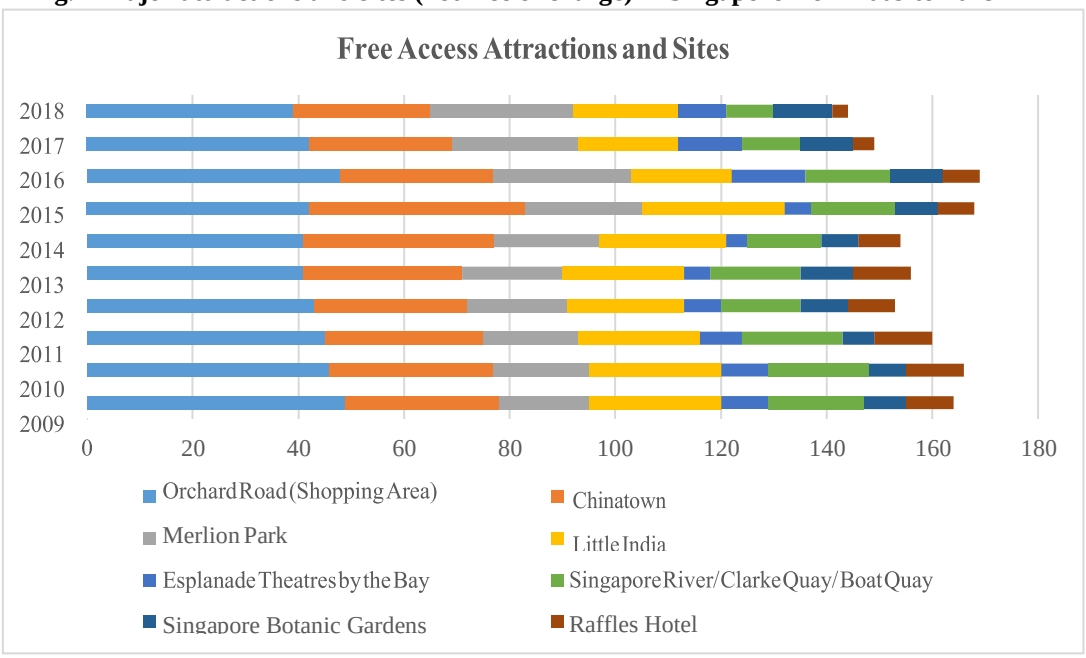

Fig. 5 Free access attractions and sites in Singapore from 2009 to 2018

To summarise the results shown in **Fig. 4** and **Fig. 5**, the three top popular sites for both major and free access attractions (see **Fig. 6**) where tourists mainly visited were Integrated Resort (MBS, RWS), Gardens by the Bay, Sentosa, Orchard Road, Chinatown and Merlion Park.

Table 3 lists the results between different modes of public transports and flying taxis in tourists' areas during peak hours. The hypothesis is that commuters travel from origin to destination with the minimum walking required - in other words, they exceedingly rely on public transport. Furthermore, since the distance from Marina Bay Sand to Gardens by the Bay and to Merlion Park are remarkably close, there is limited public transport option between those two routes and commuters can travel by foot. Therefore, N.A. was applied in some of the cells as shown in Table 3.

Fig. 6 The most population top three free access and major attractions and sites

Table 3. Fares, time and distance comparison amongst different modes of transportation based on real-time traffic

Start Point/ End Point	Orchard Road (Orchard Station)	Chinatown (Chinatown Station)	Merlion Park (Raffles Place Station)	Marina Bay Sand (Bayfront Station)	Gardens by the Bay Station	Sentosa (Resorts World Station)
Orchard Road (Orchard Station)		**Refer to Result A**	**Refer to Result B**	**Refer to Result C**	**Refer to Result D**	**Refer to Result E**
Chinatown (Chinatown Station)	**Result A** S$1.02, 3.8km 18 minutes S$7, 3.2km 8 minutes S$ 9.60, 3.2km 8 minutes S$51.30, 2.54km 1.52 minutes		**Refer to Result F**	**Refer to Result G**	**Refer to Result H**	**Refer to Result I**
Merlion Park (Raffles Place Station)	**Result B** S$1.02, 4.4km 24 minutes S$7, 5km 12 minutes S$10.80, 5km 12 minutes S$56.50, 3.15km 1.89 minutes	**Result F** S$0.92, 3.5km 15 minutes S$8, 2.7km 6 minutes S$9.20, 2.7km 6 minutes S$37.20, 0.86km 0.52 minutes		**N.A.**	**Refer to Result J**	**Refer to Result K**
Marina Bay Sand (Bayfront Station)	**Result C** S$1.12, 5.2km 26 minutes S$8, 6km 13 minutes S$11.50, 6km 13 minutes S$62.60, 3.88km 2.33 minutes	**Result G** S$0.92, 2km 22 minutes S$7, 3.9km 9 minutes S$10, 3.9km 9 minutes S$44.70, 1.75km 1.05 minutes	**N.A.**		**N.A.**	**Refer to Result L**
Gardens by the Bay Station	**Result D** S$1.22, 6.1km 13 minutes S$9, 6.2km 13 minutes S$11.60, 6.2km 13 minutes S$66.60, 4.36km 2.61 minutes	**Result H** S$0.92, 3.42km 29 minutes S$7, 3.2km 7 minutes S$9.60, 3.2km 7 minutes S$49.30, 2.30km 1.38 minutes	**Result J** - S$6, 2.1km 4 minutes S$8.80, 2.1km 4 minutes S$40.20, 1.22km 0.73 minutes	**N.A.**		**Refer to Result M**
Sentosa (Resorts World Station)	**Result E** S$5.31 [+], 8.6km 45 minutes S$10, 9km 19 minutes S$16.70 [|], 9km 19 minutes S$76.45, 5.53km 3.32 minutes	**Result I** S$5.02 [+], 4.9km 26 minutes S$9, 7.9km 17 minutes S$17.20 [|], 7.9km 17 minutes S$74.40, 4.09km 2.45 minutes	**Result K** S$5.12 [+], 6.8km 29 minutes S$8, 8.6km 15 minutes S$16.30 [|], 8.6km 15 minutes S$72.80, 5.10km 3.06 minutes	**Result L** S$5.22 [+], 6.9km 38 minutes S$9, 10.4km 19.3 minutes S$17.50 [|], 10.4km 19.3 minutes S$76.00, 5.47km 3.28 minutes	**Result M** S$5.22 [+], 8.22km 34 minutes S$9, 8km 11.5 minutes S$15.90 [|], 8km 11.5 minutes S$76.60, 5.55km 3.33 minutes	

SMRT
JustGrab
ComfortDelGro
Flying Taxi [ω]

[|]**:** Including Location Surcharges for Resorts World Sentosa: S$3
[+] : Additional S$4 for Sentosa Express from Harbour Front MRT Station
ω: Since all the pick-up points are in CBD areas or located in tourists' attractions, an assumption of S$30 would be considered and added to the distance-based fare. For example, the final and total charge is $51.30 for the meter-fare of $21.30 (Result A).
(Note: There are four different sets of data in each cell in Table 3. They are SMRT, JustGrab, ComfortDelGro and *Flying Taxi* respectively.)

Table 4. Fare-Time Analysis based on Table 3 (Tourist regions)

<table>
<tr><th>Straight line distance between two places/Modes of Transport</th><th>Flying Taxi</th><th>JustGrab</th><th>ComfortDelGro</th><th>MRT</th></tr>
<tr><td>Distance < 2km</td><td>Fares are 4-5 times higher than JustGrab / ComfortDelGro. Most importantly, commuters could save a large amount of travel time</td><td colspan="2" rowspan="3">Both fares are almost the same. The external factors are waiting time; it is because JustGrab does not have any external charges for waiting time. Nonetheless, the reason why taking ComfortDelGro to Sentosa is slightly higher is because of the location surcharges for Resorts World Sentosa.</td><td rowspan="3">S$0.92 – S$1.22 (S$4 for Sentosa Express)

Time is directly proportional with distance</td></tr>
<tr><td>5km > Distance > 2km</td><td>Fares are approximately 5.5 - 6.5 times higher than JustGrab / ComfortDelGro whilst travel time is 5-7 times less than JustGrab / ComfortDelGro</td></tr>
<tr><td>Distance > 5km</td><td>Although fares are 6 times higher than JustGrab / ComfortDelGro, travel time is 4-6 times less than grab/ ComfortDelGro</td></tr>
</table>

According to the analysis tabulated in Table 4, for trips of less than 2km, taking a Flying Taxi is only 4-5 times higher than JustGrab and ComfortDelGro in terms of fares. More importantly, commuters could save a large amount of travel time. Several examples would be between Merlion Park and Chinatown, between Chinatown and Marina Bay Sand, between Merlion Park and Gardens by the Bay. The fares of flying taxi are approximately 6 times more than JustGrab or ComfortDelGro for straight-line distance more than 2km. Nonetheless, tourists can reach the destination within approximately 2 minutes and 3 minutes for a journey of around 3 km and 5km respectively, rather than 10-20 minutes.

IV. Conclusion and Future Works

This paper has presented a preliminary feasibility study of transport by flying taxis in entire Singapore and tourist attractions based purely on the existing transportation demand using different factors, i.e., cost, travel time and travel distance between different modes of transportation. In addition, a concept of fare-time ratio has been presented to demonstrate the effect of travel time and fares on the optimum efficiency. CBD, which has the densest land use, is certainly having the most in-demand as it is the commercial business centre of a city and the top three of free access and major attractions and sites are also located in those areas. More importantly, when a threshold (the straight-line distance) is less 2 km, it is worth taking a flying taxi to arrive at the destination within a very short time.

Having demonstrated that there is a potential demand for flying taxis in Singapore, particularly in tourist areas, and how users can benefit from it, there is an urgent need to create the infrastructure and systems necessary for the use of UAM safely in Singapore. Future research can concentrate more on airworthiness, risk analysis [18], airspace management [19] in the short-term, Detect and Avoid (DAA), ground infrastructure, community acceptance in the mid-term and cybersecurity in the long-term. As the present study focuses mainly on fares and times spent for the trips, other factors should be considered, like the phases of the flying path, suitable sites of take-off and landing, technology and safety requirements for the whole operation including pre-, post-, and cruising of the drone's flying.

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