URBAN AIR TRANSPORTATION JOURNEY TIME COMPARISON FOR MELBOURNE METROPOLITAN AREA

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Abstract

The advent of small, all electric aircraft has opened the opportunity for air transportation services in urban areas. The success of such a service will depend on its competitiveness with other modes of transport in terms of travel time, cost and general convenience. This will depend on individual city design, road network and transport services. This project compares air taxi services with bicycle, road and public transport for Melbourne, Australia, based on journey time from selected suburbs to the city centre. Public perception on noise and community benefit are also been addressed. Future research in this project aims at developing a realistic business model for urban air transportation in Melbourne with recommendations on landing pad locations. It is expected that this model can be used for other capital cities in Australia.

1 Introduction

The advent of small, all electric aircraft has opened the opportunity for Urban Air Transportation services. These vehicles, currently under development, have VTOL capability and a low noise footprint.

In 2007, UN figures showed that more than a half of the world's population lived in urban areas. That proportion is set to rise to 60% by 2030 and 67% by 2050. This will be accompanied by a massive growth in the number of individual journeys taken on daily basis. Today, 64% of all travel kilometers are made in urban environments but the number of urban kilometers travelled is expected to treble by 2050. Such an explosion in the growth of urban mobility systems will present new challenges (Figure1) [1].

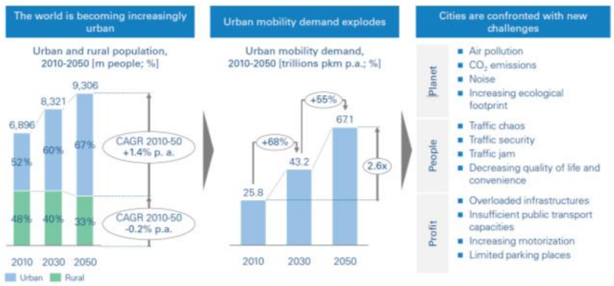


Fig. 1. Urban population and mobility demand trends [1].

Uber Elevate is developing new business venture by offering on-demand urban air transportation or air taxi service. "On-demand aviation has the potential to radically improve urban mobility, giving people back time lost in their daily commutes" [2]. In addition, urban air transport does not require the complex and expensive infrastructure, ie. roads, tunnels and bridges. The concept is based on an air taxi service model, where passengers fly between *vertiports*, for example on top of shopping centre carparks, high-rise buildings or purpose build. Such a service can save significant travel time, but it will depend on local circumstances in terms of road network, traffic congestion, public transport services, etc.

The aim of this research is to determine the competitiveness of urban air transportation with bicycle, road and public transport, in terms of travel time for Melbourne, Australia. Each transportation mode has its advantages and disadvantages. Driving allows comfortable, point-to-point travel, but can be stressful, expensive and it is polluting. Bicycle travel is only feasible for relatively short distances and can be dangerous on shared roads. Public transport allows the commuter to do other things on the way, but it is not point to point and may require the use of other transport modes to get to the stop or station. Public transport can also be crowded during peak times.

This paper presents the results of part of an investigation into the feasibility of an urban air transportation for the Melbourne metropolitan area by mapping networks of available transport modes and comparing average journey time.

2 Problem Modelling

Melbourne is the second largest city in Australia, behind Sydney, with a population of 5 million. The largest part of the population lives within a 20 km radius of the city centre, the Central Business District (CBD) or City. Most people live East and South East of the city, with the highest population density within 5km of the CBD, as shown in Figure 1 [3].

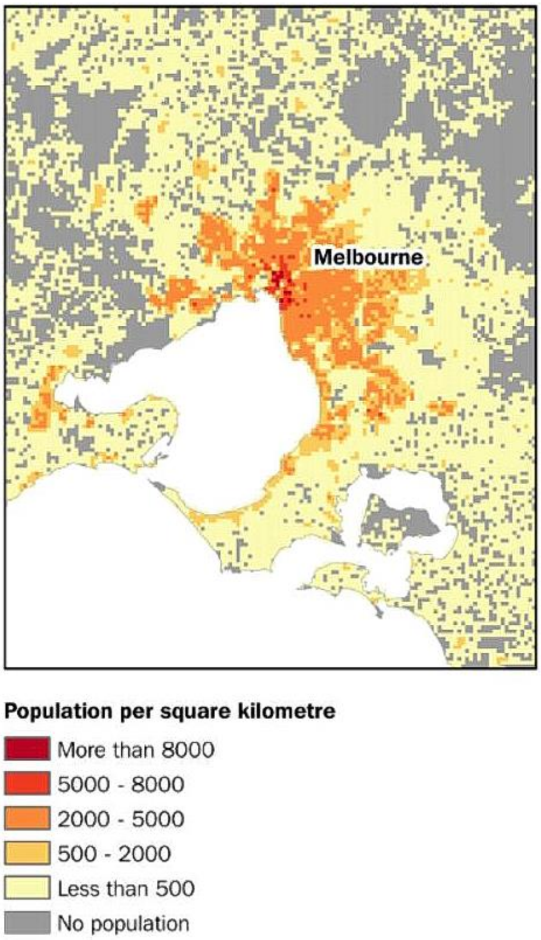


Fig. 1. Population density distribution for Melbourne [3].

Figures 2 and 3 show the main roads and public transport train/metro network respectively. The metro network is as a hub-spoke system with main lines running from the suburbs to the CBD. Suburb to suburb travel requires transvers or the use of a car. In fact, 80% use cars as their preferred method of transportation for their daily commute [4].

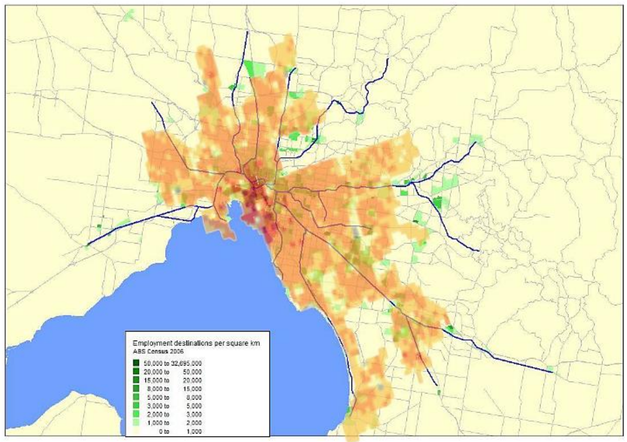


Fig. 2. Major roads in overlaid with population density.

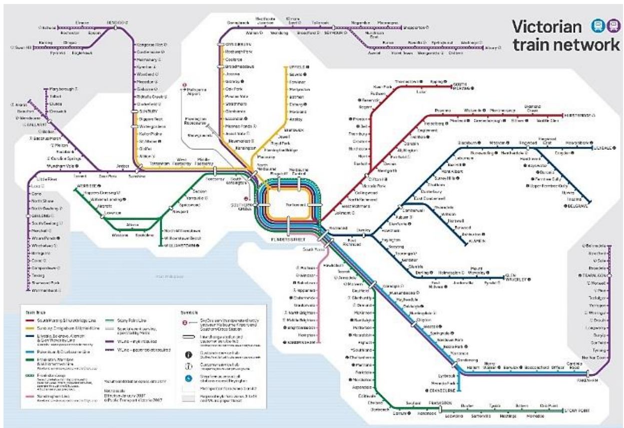


Fig. 3. Public transport network (train and metro).

Figure 4 shows the typical directional trends for daily commute by car (a), public transport (b) and bicycle (c). The thicker lines are representative of a higher portion of the population using the road. In the case of private vehicle usage, the most heavily used roads are the Monash Freeway, Eastern Freeway and Burwood Highway.

The public transport trend lines all point in the direction of the city, this is because the public transport system is setup as a hub-spoke network. Bicycles are the most sporadic of all the destinations however there are still large trend lines in the direction of the CBD.

Table 1 shows the top suburbs visited by 10% of people in their daily commute.

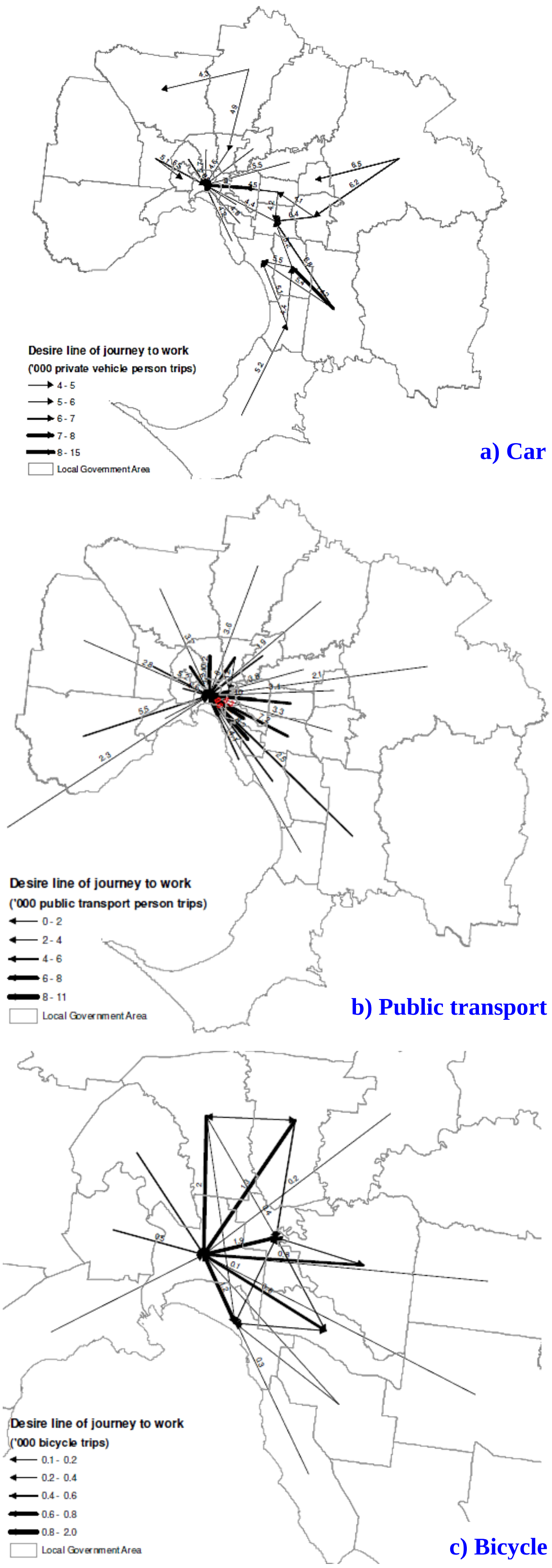


Fig. 4. Directional commute trend lines.

Table 1 Population daily commute destinations.

Destination	1996	2001	2006	2011
CBD (City)	220,774	240,943	262,916	320,255
Monash	67,657	71,407	76,249	78,178
Greater Dandenong	55,029	59,547	66,536	69,306
Greater Geelong	51,593	54,580	61,101	65,531
Hume	43,200	49,275	55,906	62,943
Yarra	47,235	46,924	49,545	58,841
Kingston	56,330	57,951	58,236	57,921
Port Phillip	50,016	55,030	58,343	57,921
Whitehorse	41,107	47,413	49,734	51,649
Boroondara	44,094	44,332	48,022	51,293

This commuting data for location and direction clearly shows that Melbourne's CBD gives a good representation of the major direction of travel.

3. Model Design

Collins Street in the CBD was used as the destination for the model for road, public transport, bicycle and urban air transportation. Additional routes in directions or to destinations other than the CBD is only representative for specific cases. The main CBD entry points are shown in Figure 5.

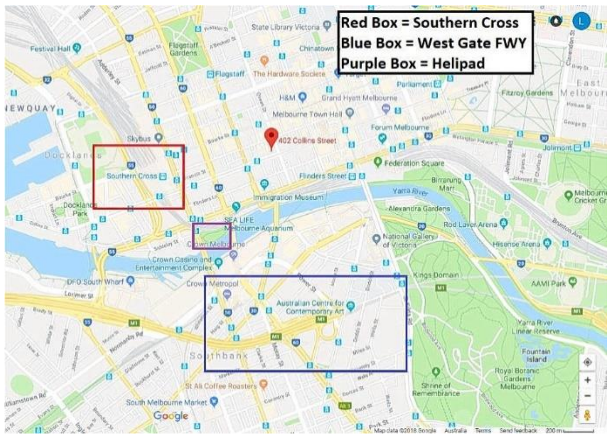


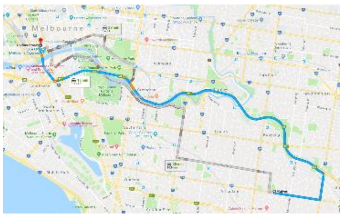
Fig. 5. CBD major access points.

The roads from the Eastern Suburbs and bicycle routes can access this part of the city. However, these routes were not added to this figure because they are too numerous. The model uses major corridors that can be accessed by all three surface transport modes, so that their maximum potential is represented. The suburbs were chosen based on the direction of travel trend lines (Table 2).

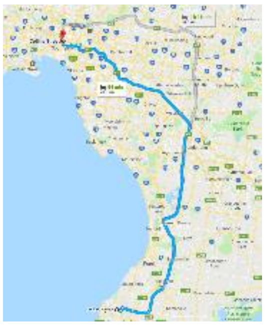
Table 2 Selected suburbs and available transport modes.

Suburb	Road	Public Transport
Malvern	Monash Freeway	Tram/Train
Mornington	St Kilda Road	Bus/Train
Box Hill	Canterbury Road/ Eastern Freeway	Express Train
Geelong	Princess Freeway	Regional Train
Bundoora	Plenty Road	Tram
Airport	Tullamarine Freeway	Express Bus

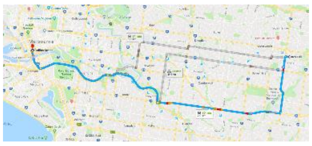
Each typical route from each suburb to the CBD is shown in Figure 6.



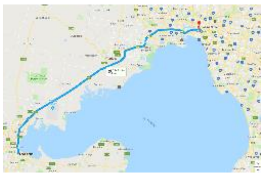
(a) Malvern - City



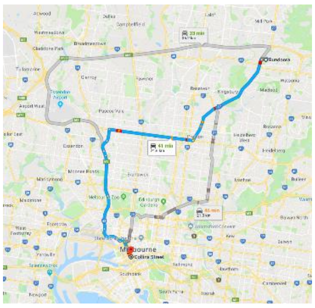
(b) Mornington - City



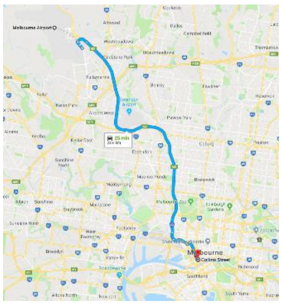
(c) Box Hill - City



(d) Geelong - City



(e) Bundoora - City



(f) Airport - City

Fig. 6. Typical roads from selected suburbs to the City.

To illustrate the model, Malvern to City travel is used in this paper as an example.

4 Case Study

This case study compares travel time for the following transport modes:

- Car
- Public Transport
- Bicycle
- Urban Air Transportation

4.1 Car

Road traffic in the metropolitan area becomes progressively busier throughout the day with two large spikes between 7 - 9am and 3 - 7pm. Figure 7 shows the hourly progression of traffic density from 6am to 9am.

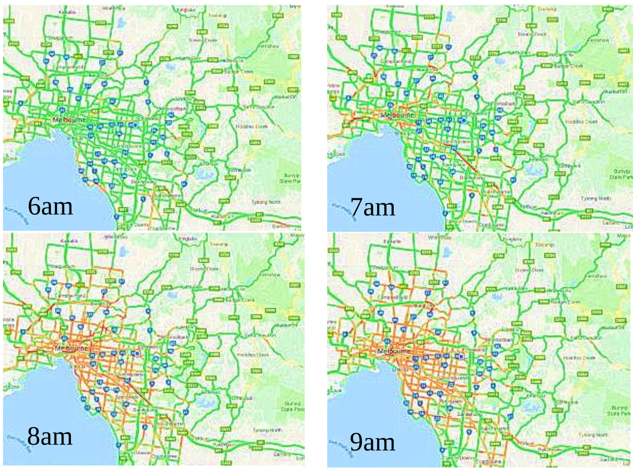


Fig. 7. Progression of traffic density from 6am to 9am.

High traffic density affects all routes and does not entirely subside throughout the day, with midday traffic within 25% of the peak traffic. For example, Figure 4a shows the Malvern to City route using the Monash Freeway. The average trip time was determined by including all roads, including toll roads, this meant that the trip taken should be the quickest. Inbound and outbound data was taken every 15 minutes throughout the day. The maximum time was used for calculations because this is the value that is more likely to be used by commuters in their time planning.

The data demonstrates that the busiest times are in the morning around 8am and around 4:30pm in the afternoon. For the Malvern to City example, the data shows an increase of 275% in travel time as compared to the shortest journey time of the day. The average time that it takes to complete this journey during a 7am – 7pm work day is about 41 minutes. The average time to travel to work is 225% less than a trip without traffic.

Table 3 shows car travel times from selected suburbs to the CBD.

For each mode of transport, the travel time includes some walking, for example to public transport and then from the final stop to the destination. An example is shown in Figure 7 for Malvern to the City. In this case the walking adds an additional 25 minutes to the journey. Hence, the time on the train is actually 12 min.

Table 3 Minimum, maximum and average travel time by car between selected suburbs and the city.

	Malvern	Mornington	Box Hill	Geelong	Bundoora	Airport
Inbound minimum (mins)	20	120	30	65	40	30
Inbound maximum (mins)	50	65	85	120	70	55
Outbound minimum (mins)	18	60	30	65	35	30
Outbound maximum (mins)	50	120	75	110	100	75
Average journey time (mins)	41	87	66	95	66	53

4.2 Public Transport

The process to determine average journey time by public transport was similar to the one used for travel by car. Table 4 shows the journey times from the selected suburbs to the City.

Table 4 Average travel time by public transport from selected suburbs to the City.

Suburb	Travel Method	Travel Time (mins)
Malvern	Tram/Train	35
Mornington	Bus/Train	127
Box Hill	Train	43
Geelong	Regional Train	88
Bundoora	Tram	76
Airport	Express Bus	41

Fig. 7. Typical journey from Malvern to the City by public transport.

Not factored into the analysis are things such as people missing trains, crowded trains resulting in longer travel times due to loading/unloading or public transport services not interlinking as they should. Each of these factors are prevalent in every day public transport usage, however cannot be accounted for unless statistically dependable.

4.3 Bicycle

The same method from driving has been applied to bicycle trips to work. A typical bicycle route from Malvern to the City is shown in Figure 8.

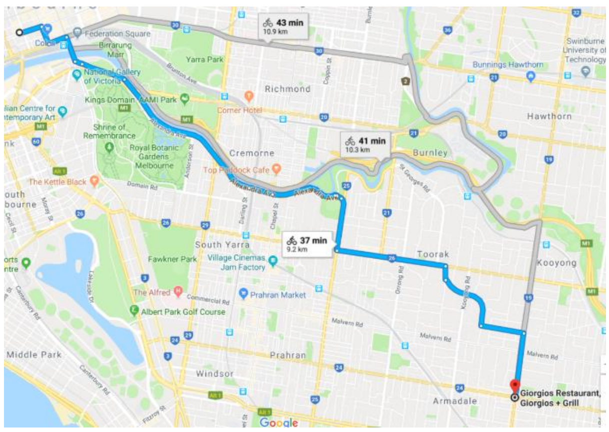


Fig. 8. Typical bicycle route from Malvern to the City.

Bicycle commute is not practical for all the model journeys that are analysed in this paper. However, it is very practical for an inner suburb such as Malvern. The bicycle commute data for each of the six suburbs is shown in Table 5.

Table 5 Average travel time by bicycle from selected suburbs to the City.

Suburb	Travel Time (mins)
Malvern	37
Mornington	203
Box Hill	59
Geelong	234
Bundoora	74
Airport	85

Bicycle time did not vary much throughout the day as they are typically unaffected by heavy traffic. Bicycles also have the benefit of being able to choose from different routes. This model does not include the time taken to lock bike or shower/get changed after the commute. This has been excluded because it is subjective based on the commuters needs and presentation requirements.

4.4 Urban Air Transportation Commute

4.4.1 Vertiport Placement

The placement of vertiports is very important, to ensure the greatest number of people have access to the urban air transport service. However, obtaining approval to build new vertiports is not trivial as they are subject approval by local government. For example, a recent application to build a helipad on top of a, yet to be build, high-rise apartment building in the City of Stonnington, was rejected. Some of the arguments were:

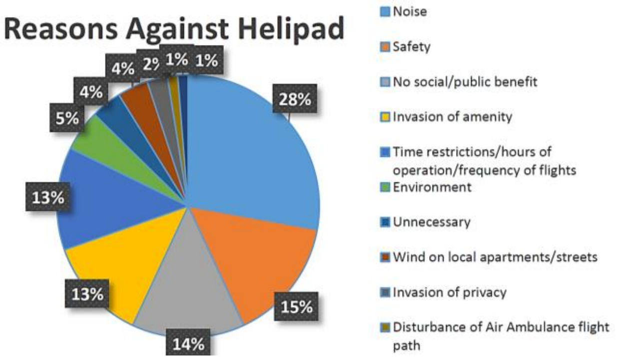


Fig. 9. Typical perceived public concerns for helipad.

Most of the concerns (28%) is related to noise, while safety is also a concern (15%) indicating that there is a perception in the community that the use of a high-rise helipad in a highly populated area is not safe. Although this application refers to a helipad, some of the concerns are still valid for vertiports.

Some of the typical vehicles considered for urban air transportation are the Joby S2 and the Airbus A^3 Vahana. Both are all electric power driven multi-rotor vehicles. The Joby S2 is a 2-seater, while the Airbus A^3 Vahana is a single seat, autonomous vehicle (Table 6).

Table 6 Performance of typical air taxi designs.

	Joby S2	Airbus A^3 *Vahana*
		
Max. weight (kg)	907	725
Cruise speed (km/hr)	322	175
Range (km)	322	100

4.4.2 Noise requirements

With respect to noise requirements, Uber Elevate states the following guidelines [2]:

- VTOL vehicles operating from vertiports/stops should ultimately approach noise levels half that of a truck traveling on a residential road (75-80 dB(A) at 50 feet): approximately 62 dB L_{Amax} at 500 ft altitude (Figure 10). This is also about 25% as loud as the smallest four-seat helicopter currently on the market.

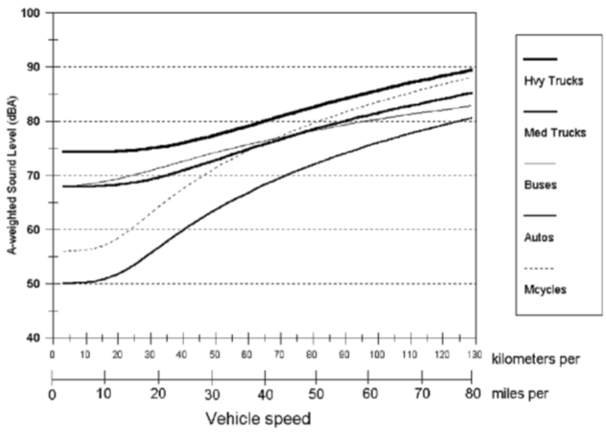


Fig. 10. Noise emissions for typical road transports.

- VTOL vehicle operations at vertiports and vertistops should not contribute long-term annoyance that exceeds the smallest change in noise background that a person can detect, about 1 dB increase in the Day Night Level (DNL) indicator. The DNL is the average sound pressure level for a 24 hr period and is currently at a level of 70dB during daytime and 60dB at night. Long term annoyance expressed using Miedema's day night level (DNL) annoyance index [9]. The index uses two equations to determine an acceptable level for DNL:

  Road: $\%HA = 0.24(DNL\ 42) + 0.0277(DNL - 42)^2$ (1)

  Rail: $\%HA = 0.28(DNL - 42) + 0.0085(DNL - 42)^2$ (2)

  Using equation 1 and 2, one can use an iterative process to define what percentage of the population will be highly annoyed (%HA) with certain DNL levels. For instance, a DNL of 55dB would cause 7.8% of the population would be highly affected for road and 5.1% for rail.

- VTOL vehicle operations should not exceed a maximum 5% increase in nighttime awakenings in their surrounding communities. Single noise events are the typical method of analysing noise disturbance. According to the Federal Aviation Authority (FAA), practical considerations for noise disturbances are as follows [10]:
  - Speech interference
  - Sleep disturbance
  - Task interference
  - Impairment of classroom learning
  - Non-auditory health effects
  - Aversive effects on emotion and tranquillity.

  These values are used in a multivariate equation: [10]

  $$R = (m_1, m_2, m_3, \ldots, m_x) \quad (3)$$

  Where m_1 to m_x represents the listed variables above and similar additions based on the use of the equation, and f is a function of the Schultz curve, shown in Figure 11.

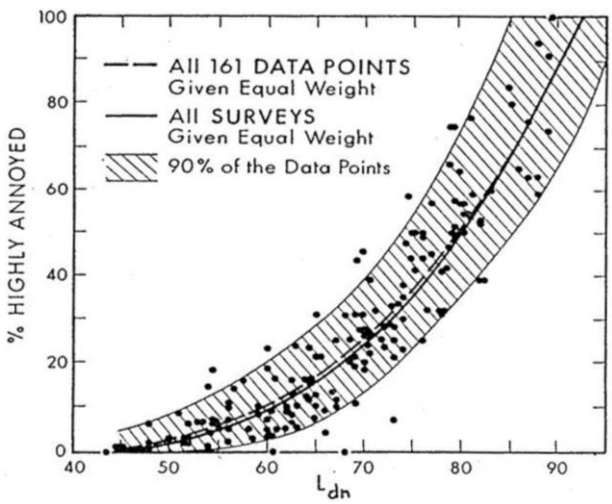


Fig. 11. The Schlutz curve.

- VTOL operations should be measured continuously on an individual site basis to establish actual Day-Evening-Night background sound levels.

For helicopters the level of public acceptance can be a function of both acoustic (direct) noise and a non-acoustic element, termed virtual noise [12]. The magnitude of the virtual noise component is not directly related to either the absolute level or to the character of the noise generated by helicopters, but it is triggered by the acoustic signal. The magnitude of virtual noise is dependent on numerous factors including:

- Fear of accidents.
- Lack of appreciation of need and positive impact on local economy.
- General feeling that public concerns about noise (and safety) are ignored.
- Feeling that there is no control of rotorcraft when flying. This is partly a result of the fact that fixed routes are not used.
- Virtual Noise is adverse reaction disproportionate to the measured or calculated helicopter noise levels.
- Virtual noise is triggered by the sound heard as helicopter approaches, flies by or flyover.

Response dependent on 'character of sound'. On helicopters 'impulsive main rotor noise' (HSI/BVI), thickness noise, TRI and high tail rotor noise provokes highest response.

- Virtual noise is dependent on a wide range of inputs but is triggered initially by any distinctive feature of the acoustic signature and, to a far lesser extent, the absolute noise.
- Virtual noise impact is much lower if triggered by sound without pronounced impulsive or tonal characteristics; this occurs on rotorcraft with low levels of impulsive main rotor noise HSI/BVI, TRI and/or tail rotor noise. These noise sources are also less pronounced on all rotorcraft in the "10 dB-down period."
- Evidence available suggests helicopters are 10 dB(A) to 15 dB(A) more annoying than other aircraft for the same or lower measured sound level.
- Irrespective of the sound level measured the sound from helicopters is generally considered annoying.
- Public acceptance is not directly related to the 'noise certification level' or 'measured levels'...... or some other part of the acoustic signal?
- A small section of the general public does not like helicopter flying overhead or near them.

4.4.3 Model Parameters

Like public transport, urban air transportation will require the passenger to and from the vertiport. Hence, for each trip 10 minutes were added to the beginning of the journey.

Currently there are no helipads in the Melbourne CBD. The closest helipad is located on the Yarra River near Batman Park (Figure 5). This was chosen as the destination vertiport for the analysis of commute time to CBD using urban air transportation. The final part of the journey is travelled on foot.

A mission profile was created from the information provided in the Vehicle Collaboration Strategy document [10]. Uber Elevate aims for a minimum cruise speed of 150 mph (242 km/h). Currently there is no infrastructure available for urban air transportation. Therefore, using current infrastructure an additional 35 minutes has been added to every journey to account for this:

- Origin to vertiport travel = 10 mins
- Vertiport to final destination travel = 10 mins
- Landing time = 5 mins
- Take-off + ground operations = 10 mins

The aircraft needs time to accelerate to cruise speed and will not maintain cruise speed for whole journey. The average speed has been assumed at 200km/h for the entire journey, approx. 82% of cruise speed. The average journey times from selected suburbs to the City using urban air transportation are shown in Table 7.

Table 7. Average travel time by urban air transportation from selected suburbs to the City.

Suburb	Distance (km)	Cruise Time (mins)	Journey Time (mins)
Malvern	7.8	2.34	37
Mornington	46.4	13.92	49
Box Hill	15	4.5	40
Geelong	63.9	19.17	54
Bundoora	18.8	5.64	41
Airport	19.4	5.805	41

5. Analysis and Recommendations

Table 8 shows the journey times for all transport modes for comparison. The green highlighted sections are where urban air transportation outperforms the other methods.

Table 8 Journey time comparison.

Suburb to City (min)				
Malvern	37	41	35	37
Mornington	49	87	127	203
Box Hill	40	66	43	59
Geelong	54	95	88	234
Bundoora	41	66	76	74
Airport	41	53	41	85

The data shows that the travel time for urban air transportation is superior in all except two cases. Urban air transportation was quicker than driving in all cases and the average saving was 24.3 minutes.

Malvern is a suburb close to Melbourne CBD so the time that it takes to travel there by any method is comparatively low. If the time taken to travel to and board the aircraft could be reduced, urban air transportation would still be superior.

As stated, if the time to board and disembark aircraft, as well as getting to and from vertiports can be reduced, the flight time in each case is actually very low when compared to other transport methods.

It is recommended that vertiports are placed in proximity to major roads and public transport areas. This will enable passengers to park cars or catch public transport to and from vertiports.

It is also recommended that the vertiports are not placed within 10km of each other based on speed requirements. It may be necessary to place several vertiports closer than 10km of each other to capture high traffic, however that is subject for further study.

An example of what a 10, 20 and 30 km radius line looks like around Melbourne CBD is shown below:

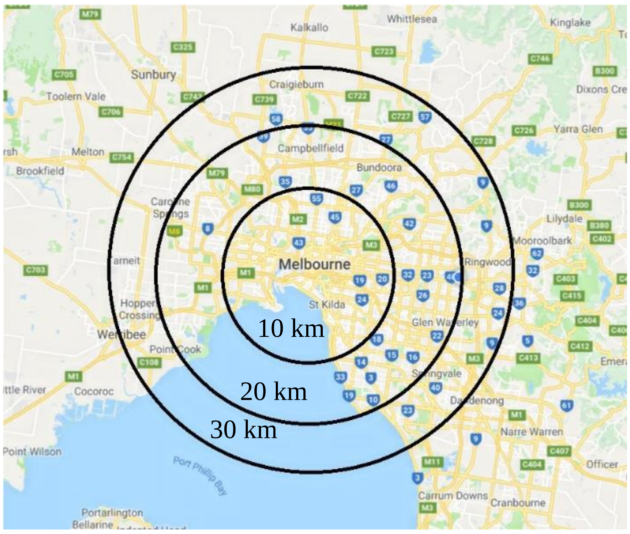


Fig. 12. Radius lines around Melbourne CBD.

The next stage of this research will be to define high traffic routes between certain suburbs create a mission around that.

6. Conclusion

The aim of this study is to determine the competitiveness of on-demand urban air transportation compared to other modes of transport in the Melbourne metropolitan area.

The findings of this study indicated that most commuters travel to the Melbourne CBD for work. On-demand urban air transportation should be targeted towards getting people to and from the city with options to travel elsewhere if needed. The current desired travel routes are typically along major roads and freeways. Approximately 80% of all Australians use cars as their desired transport method, and by doing so the travel times due to congestion during peak times can be as high as 283%. Therefore, on-demand urban air transportation would have the most market exposure when competing with the most heavily congested roads.

By comparing the travel time of on-demand urban air transportation against 3 other of the most common transport methods, on-demand urban air transportation was found to be the quickest transport method in 88% of all cases. The only occasion where on-demand urban air transportation was comparable in terms of speed was when the destination was within 10km of the origin. The greatest difference came in at a nearly 3 hour benefit. Urban air transportation was quicker than driving in all cases. The biggest difference between driving and urban air transportation was 40 minutes.

The public perception of urban air transportation is cautious, mainly to expected noise levels and safety. Vehicle manufacturers will need to reduce noise as much as possible, but even current electric aircraft may still be too noisy in some circumstances, particularly for vertiports located close to residential areas.

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