Design of a Rapid, Reliable Urban Mobility System for the DC Region

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***Abstract*— The Washington D.C. region is ranked 5th in the U.S. by GDP per capita and 3rd worst for traffic congestion causing friction in the local economy. A confluence of technological advances enables Urban Air Mobility (UAM) transportation systems to bypass road congestion and transport passengers in electric Vertical Takeoff and Landing vehicles. Analysis of travel demand profiles have identified the initial phase of a Rapid, Reliable Urban Mobility System (RRUMS) for the D.C. Region servicing private jet owners and first-class passengers from local airports to and from central business districts, assuming relaxed aerial vehicle and FAA restrictions. A stochastic simulation with random variables for vehicle speed, boarding times, vertiport operation times, and passenger inter-arrival times identified the need for a 5 node network with 70 vehicles, 3 landing pads, and 2 UAM vehicle parking space at the business Vertiports, servicing 369 flights per day. A Return on Investment of 122% can be achieved with a break-even in 2 years on an investment of $160M.**

Keywords—Urban Air Mobility, Stochastic Simulation, eVTOL, Vertiport

I. Introduction

Surface transportation is a problem in the Washington, D.C. area. For example, unimpeded travel times for the route from Dulles Airport to Capitol Hill Washington, D.C. is 42 minutes; but peak travel time is 85 minutes - this is an increase of 100%. Mass transit has an on-time reliability of 80%, resulting in the Planning Travel Index (or PTI) of 1.6. This delays the annual 1.8M high-value passengers using the regions airports who have time sensitive schedules.

This paper describes the design of a Rapid, Reliable Urban Mobility Transportation System (RRUMS) system to transport high-value passengers efficiently from the airports to business locations in the region by flying over congested roads using aerial vehicles.

This paper describes the analysis conducted to determine the:

- Travel demand (inter-arrival times and willingness-to-pay)
- Number and location of Vertiports
- Throughput Capacity and UAM Vehicle Parking Spaces at the Vertiports
- Number of Vehicles
- Number of Spare Batteries for Battery Swaps

II. Context Analysis

A. Washington, D.C. Metropolitan Statistics

Washington, D.C, the nation's Capital is a hub for corporate business. The metropolitan GDP in 2018 was $540,648M that includes 6.1 Million people in the region [1]. High-value business neighborhoods have been identified in the following areas:

(1) Capitol Hill and K Street Washington, D.C.
(2) Ronald Regan Washington National Airport (DCA) / Crystal City
(3) Bethesda, Maryland
(4) Tysons Corner, McLean, Virginia
(5) Dulles International Airport (IAD) / Reston.

In addition to its residents, Washington, D.C. also welcomes 24 Million visitors per year [2].

Forty-nine million (48.7 million) passengers arrive and depart from the regions to airports: DCA and IAD. 46,768 passengers arrive on private jets [3] and 1.84 million passengers arrive first class on commercial airliners [4].

B. Transportation Statistics and Performance Evaluation

Once arrived in the DC region, passengers disburse to the desired destination using roadways and metro rails (Table 1). For example, 25% of passengers arriving at Dulles airport (IAD) travel to the government/business district around Union Station, 25% to the Crystal City/Alexandria area, 25% to Tysons Corner, and 25% to Bethesda.

Table 1: Probability of Commuters Traveling from Origin or Destination Region [5]

Probability of Travel Throughout DC Region					
	Union Station	DCA / Crystal City	IAD	Tysons	Bethesda
Union Station	0%	10%	30%	30%	30%
DCA / Crystal City	10%	0%	30%	30%	30%
IAD	25%	25%	0%	25%	25%
Tysons	25%	25%	25%	0%	25%
Bethesda	25%	25%	25%	25%	0%

Currently, transportation methods to and from airport regions in the Washington D.C. area consist of Metro, VRE, personal vehicles, limos, and ride-sharing platforms (Uber, Lyft). With these transportation methods, high value travelers are subject to road congestion and slow mass transit with low on-time reliability.

The major roadways within Washington, D.C. exhibit congestion during peak hours. The busiest roads experience as much as 220,750 cars per day [6]. This creates bottlenecks along the I-66 corridor and the west side of the I-495 beltway. Local railways also experience delays. The Washington Metro's on-time performance is 70% and passengers wait an average of 19 minutes [7]. The VRE has an on-time performance rate of 90%; however, passengers wait up to 22 minutes for their train to arrive [8].

As an example, consider the route from Union Station in Washington, D.C. to IAD. The route is 31 miles overall and takes 42 minutes unimpeded, giving a planning time index of 1. Under impeded conditions, the route can take 80 minutes, a 100% increase in travel time, yielding a PTI of 2. A distribution of travel time from Union Station to IAD shows a tail with travel times up to 80 minutes (Figure 1).

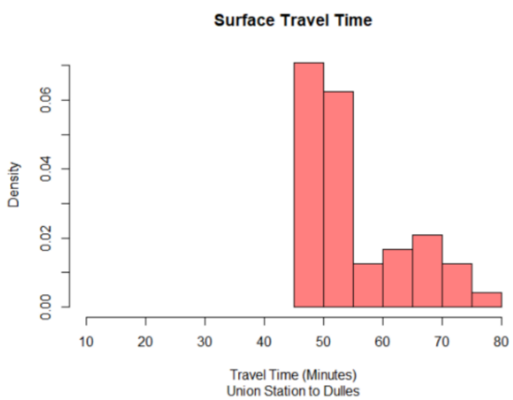

Figure 1: Distribution of Travel Time on the Route from Unions Station to IAD

Potential factors leading to congestion are traffic volume, accidents, roadwork for repairs and expansion, weather, movement of VIPs, and disabled vehicles.

C. *Future Technologies for Transportation*

Urban Air Mobility (UAM) is a concept that uses the third dimension to fly over congested surface roadways. Currently, helicopters are used for UAM systems in New York City, NY; Dallas, TX; and Los Angeles, CA. NASA and private industry funded testing is being conducted to use Electric Vertical Take-Off and Landing Vehicles (eVTOLs) as more economical solution for the UAM systems (e.g. Figure 2).

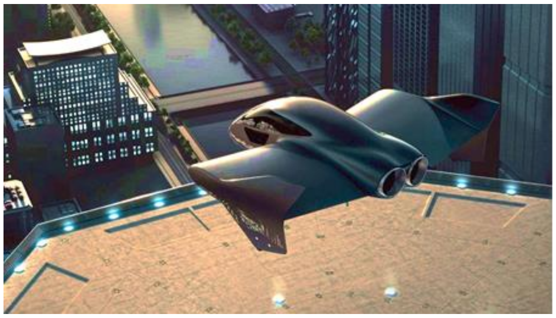
Figure 2: Electric Vertical Takeoff and Landing Vehicle (eVTOL).[9]

eVTOLs will carry 2 to 4 passengers, constrained by the weight of passengers and luggage. VTOLs have cruise speeds that can be up to 150 mph, operates up to an altitude of 3000 ft Above Sea Level, and emits less than 65db of noise per vehicle, enough to disturb the surrounding community. eVTOLs can operate from a hybrid fuel solution or rechargeable batteries that can provide about 150 miles of flight [10].

Navigation, communication, and surveillance for eVTOLs will integrate newly formed systems with current Air Traffic Management. Navigation will be predetermined between nodes for the system. It will follow current helicopter paths, major roadways, and waterways for routing. Communication will be rendered by a Dedicated Short Range (DSRC) and Cellular Vehicle-to-Everything (C-V2X) systems. Surveillance systems include Automatic Dependent Surveillance Broadcast (ADS-B) and Instrument Flight Rules (IFR) will be used. Detect-and-Avoid Rules will also be implemented for UAM systems given the nature of flying at lower altitudes among the buildings of an urban environment. Collision Safety for Low Altitude will be monitored by an Airborne Collision Avoidance System X (ACAS X), an adaptation from traditional aviation systems [11].

Blade Urban Air Mobility and UberElevate are two companies that are developing UAM systems in the United States. Blade connects New York City to local airports, Nantucket, and the Hamptons. It also provides charters to points around Los Angeles, CA and the Bay Area (including Napa).[12] UberElevate is developing markets around Los Angeles and Dallas, TX and will integrate within the next few years [13].

D. Enterprise Description

The Rapid, Reliable Urban Mobility System (RRUMS) is for the Washington, D.C. region. The enterprise will transport high-value passengers arriving and departing at the regions two major airports to business and government locations more reliably and rapidly than current surface transportation systems can (i.e. reduce Planning Index Time (PTI) below 1).

III. STAKEHOLDER ANALYSIS

Primary stakeholders include (1) passengers, (2) current transportation providers, (3) the community, (4) real estate developers, (5) the municipal government, and (6) Original Equipment Manufacturers (OEM).

Tensions sourced from the community regarding RRUMS is "Not In My Backyard", increased taxes, noise, and safety concerns. These are all barriers to deployment. OEM groups may also create tensions for the transportation systems with high selling prices.

IV. PROBLEM/NEED STATEMENT

A. Problem Statement

High value travelers who arrive to DC on private jets and first-class flights are subject to:

- Surface travel time experiencing a 60% increase
- Mass transportation networks with 80% on-time reliability.

B. Need Statement

High value travelers who arrive to DC on private jets and first class need rapid, reliable transportation in DC area with Travel Index =1 (I.e. Unimpeded)

- Provide rapid transportation mobility to and from DCA, Dulles IAD, Tysons, Bethesda, and Union Station.
- Reduce high traffic congestion by decreasing passengers in mass transportation.
- Acceptance of transportation method from surrounding community (NIMBY).
- Provide reliable transportation which reduces noise emissions at or below 65db.
- Reduced tax from development of new transportation method.

V. CONCEPT OF OPERATIONS

The RRUMS system will provide an alternative rapid, reliable transportation method for high value travelers to meet their demanding schedules (Figure 3).

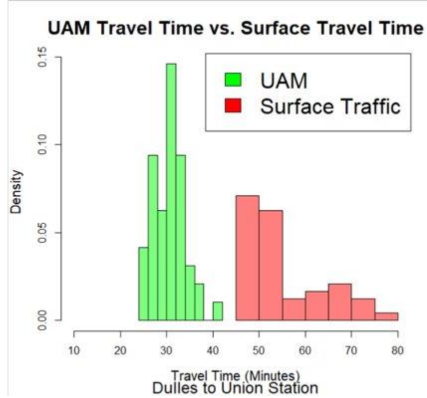

Figure 3: Comparison of Travel Time on the Route from IAD to Union Station

Analysis of travel demand identified transportation needs between the airports and the business/government districts. The RRUMS system for the DC Region consists of 10 bidirectional air-paths in a network with nodes located at Dulles International Airport (VIAD), Bethesda, Maryland (VBMD), Tysons Corner, Virginia (VTYC), Ronald Reagan Washington National Airport (VDCA), and Union Station in Washington D.C. (VWUS). The network is illustrated in Figure 4.

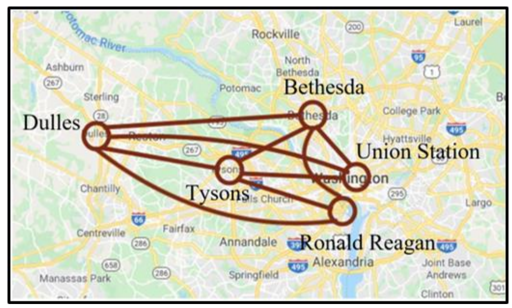

Figure 4: RRUMS Network

Ticket purchases for the RRUMS transportation service will be accessible through a mobile application for customers. Passengers entering and exiting the system can also view boarding, arrival, and departure information.

Navigation will utilize current helicopter paths, water ways, and major roadways to reduce noise to the surrounding community. The RRUMS system will also operate in air classes B, G, and E. This will yield a range from 500 ft to 3000 ft above sea level (ASL). Geofencing capabilities will be used to mark the boundary of flight paths. The transportation system shall address noise, safety, and tax-based concerns.

VI. REQUIREMENTS

The following are the mission requirements for the DC-RRUMS system.

1. The RRUMS-DC system shall provide transportation between nodes (IAD, DCA, TYS, Bethesda, Union Station).

2. The RRUMS-DC system shall provide passenger transportation with 95% of flights being within 5 minutes of expected time.
3. The RRUMS-DC system shall be faster than unimpeded surface travel times with 95% confidence interval.
4. The RRUMS-DC system shall emit Day Night Average Sound Level (DNL) less than or equal to 65 dB.
5. The RRUMS-DC system shall incorporate rechargeable air vehicles.
6. The RRUMS-DC system shall be a ride hailing operation to reduce repositioning of vehicles.
7. The RRUMS-DC system shall have passengers wait less than 20 minutes for an available vehicle.
8. The RRUMS-DC system shall limit vehicles arriving at vertiports from waiting more than 20 minutes for an available landing pad.

VII. DESIGN

To design a system to meet the mission requirements, a deterministic and stochastic simulation of the DC-RRUMS was built to determine:

- The number of vehicles
- The number of landing pads at each vertiport.
- The number of UAM Vehicle parking spaces at each vertiport
- Required number of batteries required at each vertiport
- The throughput at each vertiport.

A description of the simulation is in the appendix.

A. *Design Requirements for Deterministic System*

The simulation analysis identified that the 5-node transportation system and passengers arriving according to the demand in Figure 6 would optimally require 70 vehicles, 2 landing pads, and 2 UAM vehicle parking space. The maximum peak throughput is the maximum total arrivals and departures in a half hour. The number of batteries is assuming a single battery gets recharged 6 times during the day (Table 2).

Table 2: DC-RRUMS based on Deterministic Simulation

RRUMS Parameter	
Total Vehicles Required	70
Union Station Peak Throughput	13
Tysons Corner Peak Throughput	19
Bethesda Peak Throughput	18
DCA Peak Throughput	20
Dulles Peak Throughput	14
Number of Batteries at Each Vertiport	10
Number of Landing Pads	2
Number of UAM Vehicle Parking Spaces	2

B. *Design Requirements for Stochastic System*

The Design Requirements were evaluated in the presence of stochasticity in the DC-RRUMS (see simulation description in Appendix).

Considering the stochasticity, the DC-RRUMS is defined by Table 3. The batteries are assumed to be charged 6 times during the day. The throughput is the total arrivals and departures at that vertiport every half hour.

Table 3: DC-RRUMS based on Stochastic Simulation

RRUMS Parameter	Mean	Std. Dev.	Max
Total Vehicles Required	70	-	-
Union Station Throughput	7.07	2.81	14
Tysons Corner Throughput	9.03	3.82	*18*
Bethesda Throughput	8.80	3.63	16
DCA Throughput	9.75	2.59	17
Dulles Throughput	9.68	2.94	17
Number of Batteries at Each Vertiport	10.09	1.129	-
Number of Landing Pads at Business Locations	3	-	-
Number of UAM Vehicle Parking Spaces at Business Locations	2	-	-

Adding stochasticity increased the number of landing pads by 1 to meet the requirements, and the peak throughput became comparable with this increase.

VIII. VERIFICATION TEST PLAN

Verification of the RRUMS-DC System will be handled through simulation and data analysis for the combinations of input conditions most notably the passenger arrival times.

IX. VALIDATION TEST PLAN

Validation of RRUMS-DC will occur when the system is deployed. Validation tests will measure service performance based on the actual demand profiles.

X. BUSINESS PLAN FOR DC-RRUMS

A. *Value Proposition*

The customer value proposition for high-valued passengers includes receiving rapid transportation with high on-time reliability. Customers will travel in comfort and spend less time waiting idly in congestion.

B. *Competition*

Competition is luxurious transportation systems like private cars and limos, elite ride sharing services like Uber: XL, Black, and Black SUV), premier bussing services, helicopters, and bus only lanes.

C. Business Plan

Costs will include Acquisition Costs and Annual Operating costs. Acquisition costs will include vehicles, batteries, and battery chargers. The infrastructure is assumed to already be in place and ready for service. Yearly Operating Costs will include 109 corporate and operations staff, government and airport fees, application development, and marketing costs.

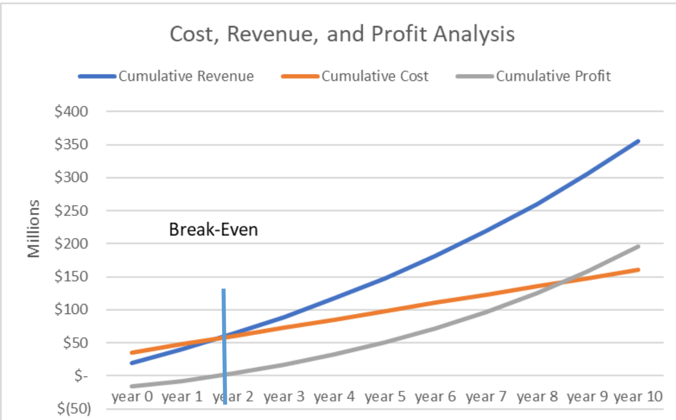

Figure 5: Break Even and Projected Revenue Analysis

Sales will be generated by passenger ticket sales at a $200 per ticket based on current UAM ticket prices. Projected revenue for the first 10 years will be produced from a 10% annual penetration for the high-value customer pool. This will result in $38.7 million for the first 10 years with an overall profit of $195M. RRUMS is anticipated to breakeven within the first 2 years with an ROI of 122%.

D. Future Work

Future work for this project will include:

- Impacts of the Atmosphere (i.e.: Temperature and Wind)
- Vehicle Reliability
- Battery Swaps per Day
- Hybrid Propulsion
- Incorporate Different Vertiport Designs
- Safety and Collision
- Incorporate Vehicle Utilization
- Vary the demand each day

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Appendix

I. SIMULATION OF THE RRUMS-DC

A. Objectives

The objectives of the simulation are to determine the number of vehicles required in the system and the number of landing pads and parking spaces at each of the business locations to meet the requirements. It will also determine the number of batteries per vertiport required and the throughput at each vertiport, the passenger wait time and queue length of the passengers waiting for their vehicles, and the wait time and queue length of the vehicles waiting for an available landing pad.

B. Inputs, Parameters, and Outputs

The inputs to the simulation are the passenger interarrival rate, the number of vehicles, the number of landing pads, and the number of UAM vehicles parking spaces. The parameters are the vehicles speed, boarding, and the vertiport operations time. For the stochastic simulation, the distributions used by each input and parameter are described in Table 4. These vertiport operations contain any small maintenance that can be done on the pad, battery swapping, and passenger disembarking. The probabilities of going to each vertiport is based on the probabilities displayed in Table 1. The outputs are the total travel time, on-time reliability, vehicles wait time and queue length, passenger wait time and queue length, number of batteries required, and the vehicle inter-arrival rate at each vertiport.

Table 4: Distributions Used for Stochastic Simulation

Parameter	Distribution
Vehicle Speed	$Normal(80, 2^2)$
Boarding Time	$Normal(7, 3^2)$
Vertiport Operations Time	$Normal(10, 2^2)$
Passenger Arrival	Poisson Distribution Based on Passenger Demand (Figure 6)

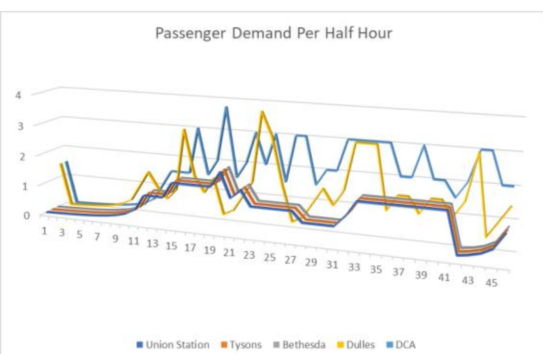

Figure 6: Passenger Demand per Half Hour by Vertiport

C. Simulation Assumptions

The simulation assumes there are perfect weather conditions. This prevents any weather from disrupting the operations of the system. The vehicles can hold up to 4 passengers and are all functioning properly. It is assumed there are enough batteries in the system, and the vehicles will have their batteries swapped instead of charging. The batteries are swapped when they get below 50% power. All the vertiports have single landing pads, although the number of these landing pads change. There are no FAA restrictions.

If a vehicle is requested from a vertiport, the first place they will come from are the airports. If a vehicle must be sent somewhere else because there is no room for it, it will be sent to a business location. This is to position the vehicles in the locations that would deplete their supply the fastest and prevent future repositioning.

II. SIMULATION VERIFICATION

To conduct the verification for the simulation, all tests were conducted with the following assumptions and parameters. All values in the simulation are deterministic. There were 5 nodes in the system that were 20 nautical miles apart. The vehicles were flying at a constant 60 miles per hour and they could hold up to 4 passengers. There were 7 minutes required for boarding and 10 minutes for vertiport operations when the vehicle lands. The interarrival rates of passengers were also constant throughout the day. The outputs of the simulation were compared to hand calculated values.

A. Verification Test : Minimum Number of Vehciles

This verification test confirmed that the simulation was able to correctly identify the minimum number of vehicles necessary to maintain a stable simulation. There are infinite landing pads and parking spaces, so the number of vehicles is the only limiting input. The simulation passed the verification test.

B. Verification Test: Minumum Number of Landing Pads

This verification test confirmed that the simulation was able to identify the number of landings pads that each node needs to maintain a stable simulation. There were infinite vehicles and parking spaces to keep the landing pads as the only limiting factor. The simulation passed this verification test.

III. ANALYSIS BY SIMULATION

The analysis was conducted with a parameter sweep of the number of vehicles, number of landing pads, and number of parking spaces. These were incremented individually until the waiting times for vehicles or passengers exceed the limits defined in the requirements.

A. Passenger Demand

The simulation demand was based on data for the airport arrivals and departures of first class and private jet arrivals, and the demand for the business locations follows the peak traffic times using BTS data [14] See Figure 6. This is used in both the deterministic and stochastic runs. Every day uses the same distribution.

B. *Deterministic Results*

The simulation was run with 5 nodes, each the geodesic distances between the vertiports. There was 7 minutes required for boarding and 10 minutes for vertiports operations when the vehicle lands. The number of vehicles in the system varied from 10 to 100 vehicles, iterating by 10. The number of landing pads and UAM vehicle parking spaces at each business location each varied from 1 to 5. The airports each had 10 landing pads and 50 UAM vehicle parking spaces.

The first system to meet the requirements when incrementing the number of vehicles, number of landing pads, and number of parking spaces had 70 vehicles, 2 landing pads, and 2 parking space at each business location (Table 5). The vehicle wait time is the time vehicles must wait for the landing pad to become available. These vehicles can either be flying or waiting for the pad to be able to take off. This is also assuming the batteries are being swapped when they get below 50% power. The number of batteries is calculated by every battery being charged 6 times during the day. Reliability is the percent of trips that were within 5 minutes of the expected travel time. The travel time includes the wait time, boarding time, and flight time.

The total travel time between each pair of vertiports is displayed in Table 6. The total travel time starts at the time the passenger arrives to their origin vertiport to the time they disembark at the destination vertiport. The variance in Table 5 is a result of averaging the travel times between each of the Vertiports in Table 6.

Table 5: Deterministic Results Based on the Travel Times Between Pairs of Vertiports shown in Table 6

Result	**Mean**	**Standard Deviation**
Reliability	97.0%	-
Vehicle Wait Time	5.085	4.252
Vehicle Queue Length	0.359	0.711
Passenger Wait Time	0.304	1.387
Passenger Queue Length	0	0
Batteries per Vertiport	9.293	1.013
Vehicle Interarrival Rate at Union Station	18.22	63.328
Vehicle Interarrival Rate at Tysons	16.519	60.627
Vehicle Interarrival Rate at Bethesda	15.383	58.485
Vehicle Interarrival Rate at DCA	21.688	64.273
Vehicle Interarrival Rate at Dulles	27.256	75.874

C. *Stochastic Results*

The simulation was also run with stochastic parameters to account for variability. The inputs and parameters are displayed in Table 5. The results are displayed in Table 8. The reliability is measured by the total travel time being within 5 minutes of the expected travel time, which includes the wait time, boarding, and flight time. The interarrival rate is the time between vehicle arrivals at the respective vertiports.

The total travel time is the time from when the passenger arrives to their origin vertiport to when they disembark at the destination (Table 7).

Table 4:Total Travel Time Means and Standard Deviations for Origin-Destination Pairs in Deterministic Simulation (Minutes)

	Union Station		Tysons		Bethesda		DCA		Dulles	
	Mean	SD	Mean	SD	Mean	SD	Mean	Sd	Mean	SD
Union Station	0	0	20.71	3.17	21.22	9.15	12.87	0.79	28.57	1.19
Tysons	22.38	4.13	0	0	16.09	3.78	20.71	1.68	17.72	3.91
Bethesda	19.60	3.17	16.52	3.33	0	0	17.63	1.90	23.79	1.95
DCA	13.36	2.23	21.63	3.54	19.30	6.12	0	0	28.71	0
Dulles	28.72	1.72	17.23	1.70	24.24	2.14	28.71	0	0	0

Table 5: Total Travel Time Means and Standard Deviations for Origin-Destination Pairs in Stochastic Simulation (Minutes)

	Union Station		Tysons		Bethesda		DCA		Dulles	
	Mean	SD	Mean	SD	Mean	SD	Mean	Sd	Mean	SD
Union Station	0	0	22.71	6.80	21.51	8.17	12.19	3.02	30.16	5.91
Tysons	22.32	6.93	0	0	18.23	8.11	21.02	6.16	17.45	4.15
Bethesda	22.43	6.74	17.94	8.41	0	0	20.24	4.07	24.57	4.71
DCA	13.92	6.31	21.76	6.33	19.29	5.16	0	0	28.85	3.29
Dulles	31.42	5.56	19.73	5.61	26.66	8.46	27.63	2.66	0	0

Table 6: Stochastic Results Based on the Travel Times Between Pairs of Vertiports Shown in Table 7

Result	Mean	Standard Deviation
Reliability	97.9%	-
Vehicle Wait Time	4.063	2.814
Vehicle Queue Length	0.476	0.715
Passenger Wait Time	0.15	0.903
Passenger Queue Length	0	0
Batteries per Vertiport	10.09	1.129
Vehicle Interarrival Rate at Union Station	17.55	59.59
Vehicle Interarrival Rate at Tysons	13.80	51.68
Vehicle Interarrival Rate at Bethesda	15.18	55.31
Vehicle Interarrival Rate at DCA	21.87	63.44
Vehicle Interarrival Rate at Dulles	24.45	72.02

D. *Sensitivity Analysis*

An analysis was conducted to evaluate the sensitivity of the results to change in (i) number of vehicles, (ii) number of landing pads, and (iii) number of parking spaces.

The number of vehicles was varied from 65 to 75. The reliability peaks at 70 vehicles and the average time passengers wait in line is the smallest when there are 70 vehicles. At 65 vehicles and 75 vehicles, the reliability is 94.21% and 97.75%. With small changes, the system is not sensitive to small changes in the number of vehicles.

Holding 70 vehicles and 2 parking spaces constant, the number of landing pads was varied from 1 to 5. The system is sensitive to the number of parking spaces. With only 1, the system is unstable (i.e. passenger and vehicle wait times grow exponentially). With 2 or more, the system becomes stable, however 2 landing pads only has 91.5% on-time reliability. Three or more landing pads meet all the requirements.

Parking spaces were varied from 1 to 5. Passenger and vehicle wait times remain stable, however only 2 and 3 meet the on-time reliability requirements and have no statistical difference. Having 4 or 5 parking spaces reduces the on-time reliability to 85% and 83% on-time reliability, respectively. This may be due to vehicles being stored at the business locations when they are needed at the airports. The vehicles would have to be repositioned, causing more flights and increased usage of the landing pads. The system is sensitive to the number of landing pads in the system.

IV. Mobile Ride Hailing Application

A. *Description of Ride Hailing Application for End-User*

The purpose of the ride hailing application is to provide a way for passengers to efficiently enter and exit the RRUMS transportation system. Passengers using iOS and Android devices can view arrival, boarding, and departure information, as well as purchase tickets. Push notifications will be used to alert passengers of their arriving air vehicle.

B. *Design Requirements for Mobile Application*

1. The ride hailing app shall display ticketing information on mobile devices containing iOS operating systems version 7 or higher.
2. The ride hailing app shall display ticketing information on mobile devices containing Android Operating system version 7.1 or higher.
3. The ride hailing app shall provide login process with one-factor authentication.
4. The ride hailing app shall provide login process through account link to Facebook.
5. The ride hailing app shall allow selection of 5 potential route destinations.
6. The ride hailing app shall display account information in the settings menu.
7. The ride hailing app shall allow credit card payment method for ticket purchases.
8. The ride hailing app shall utilize push notification to alert passengers of air vehicle arrival status.
9. The ride hailing app shall display expected passenger wait time for nearest air vehicle to destination.
10. The ride hailing app shall display expected air vehicle boarding time on interface display.
11. The ride hailing app shall display expected air vehicle departure time on interface display.

C. *Conceptual Mockup of Ride Hailing Application*

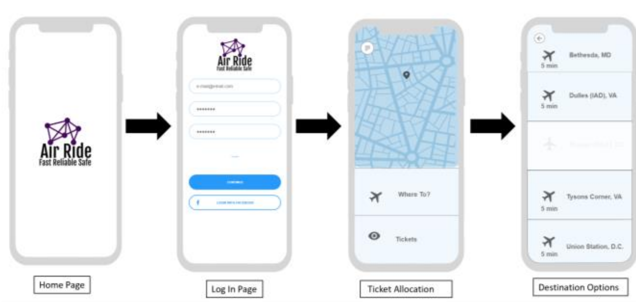

Figure 8: Ride Hailing Mobile Application for Passengers