

Breaking Through the Bottleneck

Transportation to Make Stewart a Viable New York Airport

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Abstract—The city of New York is served by the largest and busiest airport complex in the world. The three metropolitan airports, LaGuardia (LGA), Newark Liberty International (EWR), and John F. Kennedy International (JFK), are consequently plagued by flight delays. Since population density and economic feasibility prohibit further development of New York City airports, the New York New Jersey Port Authority recently leased an isolated airport 97 kilometers north of the city—Stewart International (SWF). Due to Stewart’s distance from Manhattan however, airlines are hesitant to shift operations to SWF without a noticeable transportation improvement that links it to the city. Four alternatives have been identified that evade currently congested air and ground-based traffic: High Speed Commercial Ferries (HSCF), Sky-Cat 50 airships, and two commercial helicopter models, the Eurocopter AS332 Super Puma and the Sikorsky S-92. Since the number of vessels required to move a set quantity of passengers is unknown and can vary drastically based on vessel speed and capacity, a system dynamic model was written in Python. Upon finding the number of vessels for each alternative which handles the appropriate amount of passenger traffic, each alternative’s key decision variables (including time in transit, seating capacity, cost, safety rating, etc.) were compared through tradeoff analysis and measured against operational costs. This resulted in a utility value based on each alternative’s ability to form a suitable, functional, economical system, that supports a recommendation which we can be presented to the Port Authority of New York & New Jersey as to which alternative makes SWF a more viable air travel choice to passengers and airlines alike.

Keywords - airport; simulation; transportation; trade off analysis

I. INTRODUCTION

In 2007, flight delays cost passengers, airlines and the economy of the New York metropolitan area 5 billion dollars [1]. The three airports that currently service this metroplex, LaGuardia Airport (LGA), Newark Liberty International Airport (EWR) and John F. Kennedy International Airport (JFK) are managed by the Port Authority of New York & New Jersey (PANYNJ). These three airports currently operate at peak capacity and optimistic estimates of adding a single runway would take a decade’s time. Realizing that additional airport capacity is a key contributor to decreasing flight delays, the PANYNJ obtained a 90-year lease of Stewart International Airport (SWF) located in Newburgh, New York. Currently operating at only 10% of its theoretical capacity and possessing two runways with room to grow, SWF appears to be a valuable, yet unrealized addition to the

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runway capacity of the New York metroplex. However, SWF is between 83 and 100 kilometers away (Figure 1) from the other three airports, which surround the New York City metro area. Thus, transportation method is needed to move passengers between SWF and downtown New York City. We evaluated four alternatives for this system, as discussed below.

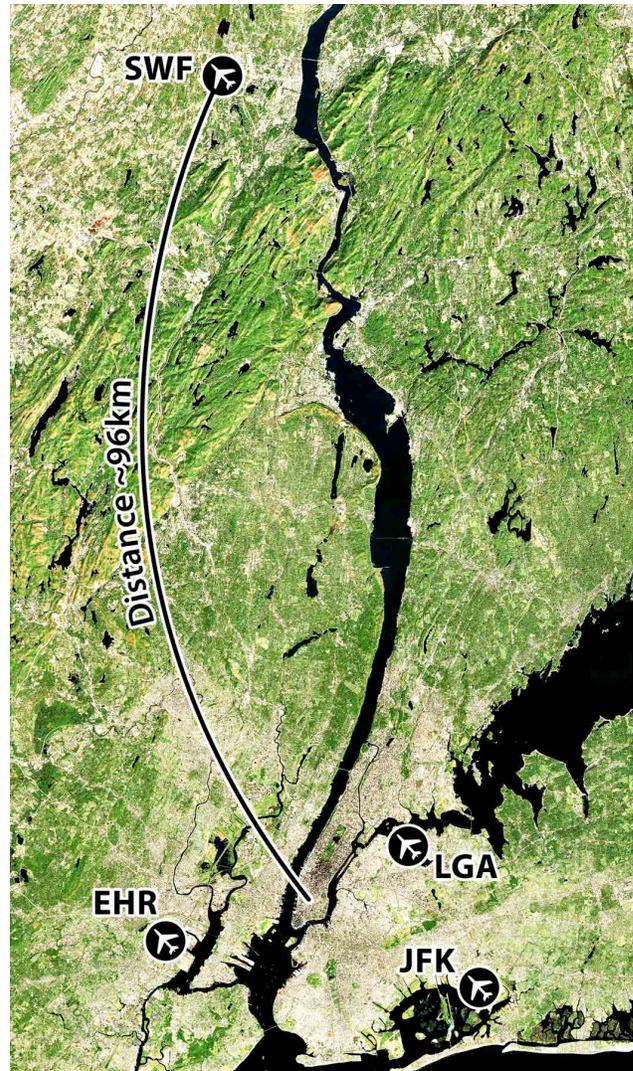


Figure 1. Map showing the location of Stewart International Airport (SWF) in relation to NYC and its airports. SWF was added to the metroplex with a 90-year lease.

One of our sponsors, The Center for Air Transportation System Research (CATSR), has asked us to evaluate this system from a macro viewpoint, taking into account all of the aspects an investor or high-level stakeholder would otherwise consider when evaluating such a transportation system. These include qualities like purchase and operational costs, safety, and emissions. This CATSR analysis is a subset of a larger, NASA sponsored research on the New York metroplex airspace. NASA rotorcraft engineers expressed a the desire to see which vessel characteristics proved most beneficial to a commercial transportation environment. Although the New York metroplex is unique in many ways, there are other major cities that would benefit from a similar linkage to a distant airport that increases overall runway capacity. As a result, the transportation simulation was constructed to account for variations in vessel characteristics and changing environments, while enabling analysis of potential tradeoffs such as speed versus turnaround time and seating capacity versus queuing time.

Many administrative issues such as permits, land rights and terminal facilities were not evaluated in this analysis. Although these are likely to play an important role on the feasibility of such a system, the main concern was to evaluate the physical characteristics of the alternatives. Initial research as to a possible location for a terminal for our system in NYC, reveal that the area around W 30th St. and 12th Ave was suitable. It neighbors the Hudson Yards Redevelopment Project along the Hudson River with 93 thousand square meters of potentially developable space for terminals and parking. We assumed that a terminal would already be available for fast loading and unloading of passengers and their baggage.

II. BACKGROUND ON CAPACITY, DELAYS AND THE DEMANDS ON THE SYSTEM

A. Airport Capacity

For the scope of this analysis, airport capacity is defined as the number of movements (an aircraft arrival or departure) an airport can handle within a given period of time. For example, if an airport was able to execute 10 arrivals and 9 departures within a given hour, that airport had a capacity of 19 movements during that time slot. An FAA agent working in the control tower sets the capacity every 15 minutes. The FAA publishes historical capacity and movement information for the four airports of this study in these 15-minute bins. Factors that contribute to the setting of the capacity include wind direction, current visibility, runway geometry, and experience. Also, the FAA has established minimum landing and take-off separation distances which airport controllers must follow.

Therefore since the capacity changes every 15 minutes, it is not feasible to simplify things and declare an airport's capacity at any given level. What we can state is the probability that an airport will be able to handle a certain capacity, given its history. This is commonly portrayed by air transportation researchers using a Capacity Coverage Chart (CCC). For example, the CCC of SWF (Figure 1) [2] shows that at least 10 movements per 15 minutes can be handled 99% of the time.

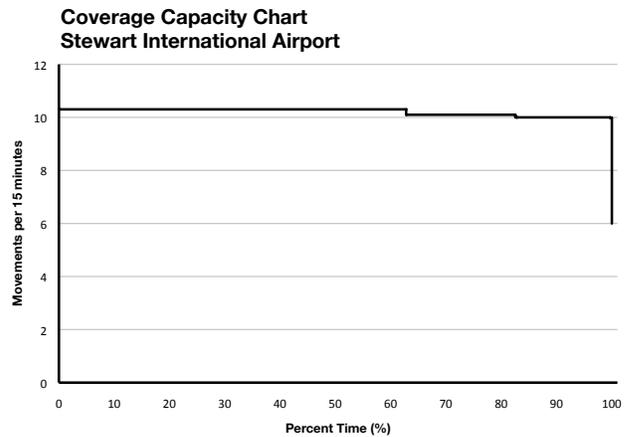


Figure 2. Capacity Coverage Chart for SWF illustrates how this airport can reliably (99%) handle 10 movements per 15 minute bin.

Despite this capacity, SWF operated an average of less than two movements per 15-minutes in all of 2007.

B. Delays

Within a queuing system, when the ratio of demand to capacity (ρ) gets high, the system will commonly begin to experience stochastic delays according to basic queuing principles. Such delays can become excessive when $\rho \geq 0.8$. In theory, it would be in everyone's best interest if airlines would schedule only enough flights into and out of an airport so as to stay at or below 80% of the airport's capacity. Those who manage airports might claim this to be too low a number because they would like to schedule as many flights as possible to obtain a higher revenue whereas passengers would like this number to be even lower, corresponding to fewer delays and less-crowded airports. Unfortunately, it will always be extremely difficult to meet the demands of both airports and passengers. Therefore, in conjunction with advisor feedback and CATSR research, it has been assumed for our base analysis that whenever a movement demand on an airport is greater than or equal to 0.8 of the capacity, it is likely to contribute to stochastic delays.

C. System Demands

1) Candidates for SWF

Applying this ρ value to the 2007 NYC (EWR, JFK, LGA) airport capacity at each 15-minute bin from 6 AM to midnight, it was calculated that on average, approximately 22,500 passengers each day exceed the 0.8 capacity in the three metroplex airports. This number was calculated by summing the average number of passengers, or aircraft gauge, on each flight (EWR: 70.9, JFK: 78.8, LGA: 59.4) [3] that exceeded a ρ of 0.8. These movements are displayed in Figure 2. The delay problem begins promptly at 6AM and continues throughout the day, fluctuating at different times for each airport.

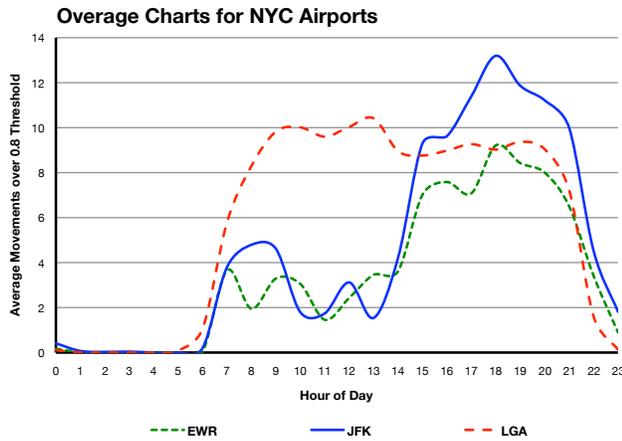


Figure 3. Illustrates at what time of day the number of movements that exceeded $\rho = 0.8$ of the declared capacity for that hour. Data shown for EWR, JFK, and LGA.

This estimation has its limitations; aircraft gauge variance is generally high, however it is a best effort given our scope.

This excess in movements and passengers has transformed the Manhattan area airports into the worst performing metroplex in the world with respect to late arrivals and departures; reaching an average of 60 minutes “time-loss” per passenger [4]. The CATSR generates an annual technical report that provides statistics for delays experienced by passengers on scheduled airline flights. In 2007, out of the 35 airports which account for approximately 75 percent of the nation’s total consumer air traffic, Newark International, LaGuardia and JFK are ranked within the 5 worst in the country (32, 33 and 35 respectively) [3] in terms of delays. Not only do these delays propagate negative effects throughout the National Airspace System (NAS), but they are also detrimental to the people and business in the New York City area. When addressing airport delays, the NYU Wagner Rudin Center for Transportation Policy & Management stated that “the City of New York believes that solving the transportation bottleneck problem is the most important item ensuring the strength of [their] economy” [5].

The Wagner Rudin Center also cites the New York Metropolitan Transportation Council, saying forecasts of temporary economic slowdown can only slightly numb the growing pains of a region that is projected to increase by 2-3 million residents by 2030.

2) Candidate Vessels

In order to find a viable solution, transportation alternatives have been chosen that evade currently congested streets and overcrowded rail systems in the New York City metro area. These alternatives are also runway independent. Since the problem of delays is ever-present and growing worse, the alternatives need to be deployable within a year or two. This is an important part to combating the current issues. The four chosen candidates are as follows:

a) Eurocopter AS332 Super Puma

The Super Puma is a twin-engine medium-weight civil helicopter. About 70% of the Super Puma fleet is operated in passenger transport to offshore oil locations. (\$13.7M; seating capacity: 19; cruise: 268 km/h) [6]

b) Sikorsky S-92

The Sikorsky is a twin-engine medium-lift helicopter built for military and civil use. CHC Helicopter Corp., the largest commercial helicopter shuttle company in the world with a fleet of 320 helicopters in 30 countries currently uses this aircraft. (\$18.9M; seating capacity: 17; cruise: 280 km/h) [6]

c) Austal High-Speed Commercial Ferry

The Hudson River runs within 3 km of SWF to New York City. Austal is the world’s leading designer and builder of customized aluminum commercial vessels. These vessels are used all over the globe to shuttle passengers to and from popular destinations. (\$14M; seating capacity: 450; cruise: 65 km/h) [7]

d) SkyCat-50 Air Vehicle

The SkyCat is capable of landing virtually anywhere on land or water without need of ground infrastructure. These “lighter-than-air” crafts resemble blimps and range in payload capacity from 18 to 200 tonnes. Currently operating in Canada as a commercial cargo vessel. (\$50M; seating capacity: 200; cruise: 148 km/h)

III. METHODOLOGY

A three part evaluation method that can accept changes in parameters, such as those related to different vessels and/or cities has been designed to evaluate each alternative’s strengths and weaknesses. The first part is our Value Hierarchy Utility Functions, which use data resulting from our Continuous Simulation and Financial Analysis.

A. Value Hierarchy

Utility functions derived from a value hierarchy are set at the highest level of our evaluation. Preliminary weights for each value in our hierarchy were obtained from close dialog with representatives of our stakeholders who are also professionals in the fields of air transportation research and design, systems engineering, and decision theory. At the highest level of the value hierarchy are Net System Cost, System Performance and Suitability. Each of these is broken down into more detailed levels, which are elaborated on in section IV (Results) of this paper. Cost will be plotted versus System Performance and Suitability.

B. Continuous Simulation

This continuous simulation was designed to accomplish two important objectives. First, a typical day has been modeled to increment the quantity of vessels one at a time until a diminishing return or decline in performance became evident (with respect to passenger service time and throughput). Second, the simulation has shown how the system responds to a limitation on passenger queue using a conditional statement to replicate real life operations. Thus, if the average passenger queue reaches a certain limit, or a

full vessel's worth of passengers are waiting when there are no vessels readily available, a vessel is created. Although outside the scope of this project, this simulation has been designed to handle hybrid transportation systems (systems comprised of two or more alternatives simultaneously), where hypothetically, smaller capacity vessels could be used to help during peak load hours. Imposing these simulation requirements, it became clear a continuous simulation model would be necessary.

The simulation was coded using Python 2.6, an open-source, object-oriented programming language. This code performed iterations each minute from 6:00 to 23:59. We also made use of an Application Program Interface (API) that allows us to upload our results to Google Visualization and Graphs. This free service plotted our results for better viewing and trend analysis.

C. Financial Analysis

The outputs from the simulation (including the time each vessel spent in transit and how many people were transported) become the input into our financial analysis. This allowed us to calculate costs related to operation, fuel and maintenance with the aid of a spreadsheet. This analysis computes equivalent cost per passenger (based on initial purchase and operational costs).

IV. RESULTS

A. Highest Values

The utility for each alternative is derived using set of equations below. Performance is comprised of safety, transit time, schedule flexibility, and passenger throughput. Suitability is comprised of emissions and noise. These values were obtained through dialog with stakeholders to determine the most important attributes of our system. Some important attributes of the alternatives, such as MTTR, MTBF, and weather (performance in wind, snow, etc.), are not included in this utility function due to lack of data.

$$U(x) = 0.76U_{Performance} + 0.24U_{Suitability}$$

$$U_{Performance} = 0.37U_{Safety} + 0.25U_{Transit\ Time} + 0.25U_{Flexibility} + 0.13U_{PAX\ Throughput}$$

$$U_{Suitability} = 0.57U_{Emissions} + 0.43U_{Noise}$$

Safety is measured in deaths per year for the overall transportation system in use. Transit time is obtained by combining both service time and queuing time. Flexibility is measured as the frequency of trips made per day. PAX throughput is the ability of system to meet our passenger demand. Emissions is calculated based on the total grams of NOX, CO₂, HC, SO₂, and particular matter produced per day. Noise is measured based on sound exposure level (SEL) for each trip. The results of this utility function for all four transportation alternatives can be found on Table 1.

Utility for Transportation Alternatives	
AS332 Super Puma	0.39
Sikorsky S-92	0.37
Austal Ferry	0.73
SkyCat-50	0.80

Table 1. Shows how well each transportation alternative measures up with our utility function.

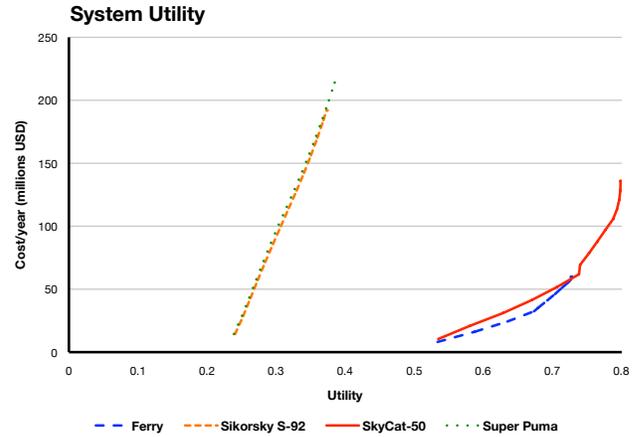


Figure 4. Illustrates the utility vs. cost of all four transportation alternatives. This shows how well each alternative measures up with our utility function.

B. Simulation

We first ran our simulation incrementing the quantity of vessels to see how many it would take to successfully move approximately 22,500 people per day, given the constraints of that particular vessel. Figure 5 shows that the Ferry and SkyCat were the only vessels to come close to the 22,500 number with $\rho = 0.8$, within one day and that the two helicopters peaked at about 10,000 passengers per day. Once the system reaches this peak, it ceases to benefit from additional vessels. Figure 6 shows us that the daily average service time experienced by passengers is always less on the higher capacity vessels on a per vessel basis, even though the helicopters have a much higher frequency of travel, which can be seen in Figure 7. One can also interpret the economies of scale in effect by observing the solid lines in Figure 5 which show rapid changes in transit times that begin to experience diminishing return when four ferries or six SkyCats are implemented.

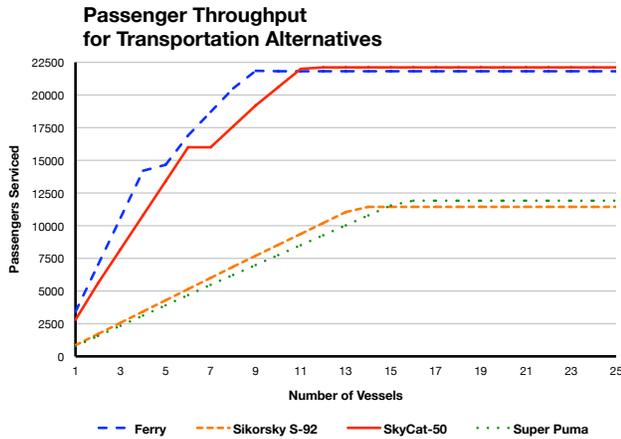


Figure 5. Compares the passenger throughput of each vessel type. The y-axis measures how many passengers are serviced by the system; the rest remain in the queue ad infinitum.

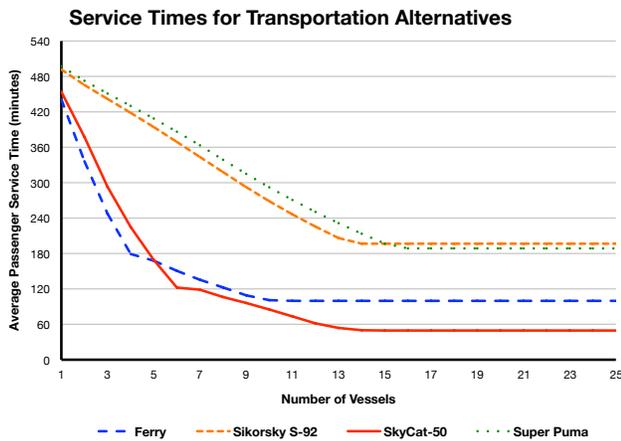


Figure 6. Compares the service times of each vessel type. The y-axis shows the passenger transit time (including queue time) as vessels are added to the system.

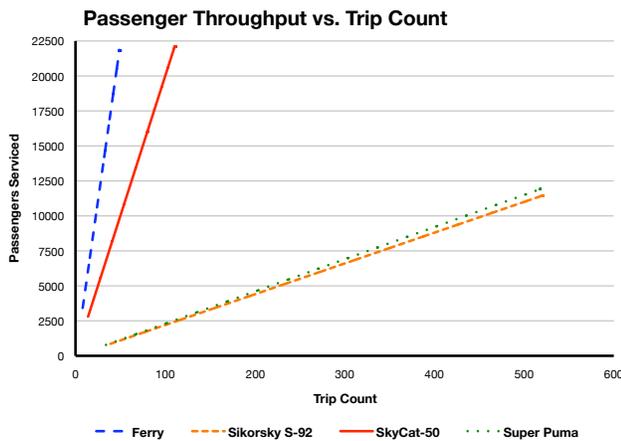


Figure 7. Compares the number of trips taken per vessel type (x-axis) in order to reach the desired passenger throughput (y-axis). This directly factors into cost, emissions and noise mitigation.

In order to determine the ideal vessel characteristics are capable of satisfying this demand, a parametric analysis was performed using these simulation data. By varying the seating capacity from 20 to 450, and the cruising speed from 65 km/h to 280 km/h, we were able to determine the effect of these factors on the average service time per passenger per day. Figure 8 illustrates the 3D surface plot of this parametric analysis.

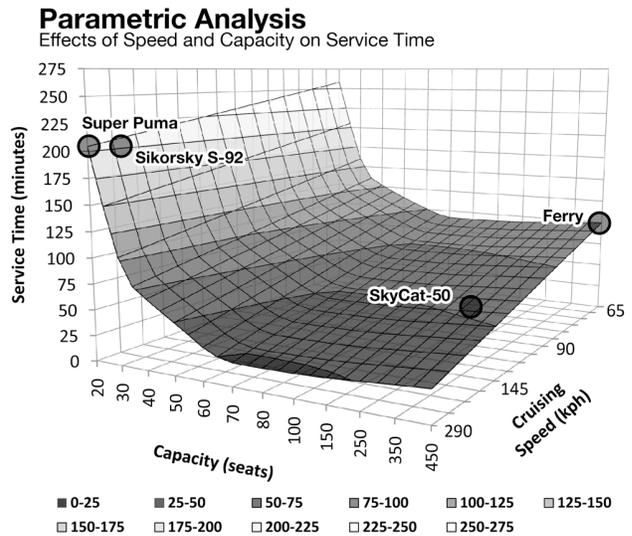


Figure 8. Illustrates the relationship between seating capacity, cruising speed, and its effect on service time. The darkest green region at the bottom of the plot shows where the passengers experienced the shortest service time.

One observation we can make from this parametric analysis is that there is a penalty if the seating capacity is beyond an optimal range. This can be attributed to the longer turnaround time (unloading, cleaning, loading, refueling, etc.) associated with larger number of passengers. Also, it is important to note that the helicopters could drastically decrease their service times if they could seat 30 or more people, as indicated by the steep drop in service time from seating capacity of only 20, to a capacity of about 30.

C. Costs Analysis

Assuming a 15 year life cycle and an interest rate of 7.5%, we calculated the costs of operating each transportation alternative. These costs include initial purchase costs, fuel, training, crew payroll, parts and maintenance, and insurance. This figure shows us the cost associated with obtaining a particular utility from each alternative. For example, to obtain a utility of 0.7 for the Ferry, it will cost an estimated \$46M per year.

Alternative	Cost/Year (\$ millions)	Cost/Passenger (\$)
Super Puma	14.47M	\$52.88
Sikorsky	14.29M	\$47.59
Ferry	8.11M	\$6.77
SkyCat	10.44M	\$10.66

Table 2. Shows the costs for each alternative per year and the cost per passenger for a one-vessel system.

V. CONCLUSIONS

Taking the results of our simulation into account, we can make predictions for the feasibility of each vessel type.

A. The “Ideal” Transport Vessel

The ideal transport vessel would combine the high speed of helicopters with the high seating capacity of the SkyCats or ferries. The major limiting factor with helicopters is their very low seating capacity of only about 20 persons. With 22,500 people to move every day, a vessel which moves only 20 persons/trip simply cannot keep up. Thus the specifications deemed ideal by this report would include a seating capacity range of 50-200 persons and a speed above 105 km/h. Keeping vessels within this range would keep customer service time (including waiting time) under 60 minutes. This range can be seen by looking at the darker region of the carpet plot in Figure 8. In one such sample simulation run with speed set to 290 km/h and seating capacity set to 80, passenger demand was met with an average service time of ~22 minutes.

B. Eurocopter AS332 Super Puma

The Super Puma was unable to satisfy the passenger demand and saturated our system with 16 units in operation. The Super Puma’s passenger service times and fuel costs were the highest when compared with the other vessels.

C. Sikorsky S-92

The Sikorsky S-92 behaved very similarly to the Super Puma in that it was unable to meet our passenger demand and saturated the system with 14 units in operation.

D. Austal High-Speed Commercial Ferry

The Ferry was able to sufficiently handle passenger demand while maintaining an average passenger queuing time of below 10 minutes. Additionally, the Ferry also made the fewest number of trips to satisfy this demand.

E. SkyCat-50 Air Vehicle

The SkyCat was also able to sufficiently handle passenger demand and maintained an average passenger queuing time of ~4.5 minutes. While the SkyCat made ~110 trips to satisfy this demand, it has the lowest fuel costs when compared to the other vessels.

Taking the results of our model and simulation into account and converting these results to the appropriate utility

values, we can rank our transportation alternatives in the following order (from most to least suitable): SkyCat 50 Air Vehicle, Austal High Speed Commercial Ferry, Sikorsky S-92, and the Eurocopter AS332 Super Puma. This ranking comes straight from our utility function shown in part A of Results. The final utility values are shown in Table 1.

VI. FUTURE WORK

There exists a strong case for utilizing a hybrid system that uses multiple transportation alternatives together in order to address this problem more effectively.

With our limited resources, we were not able to obtain significant data on Mean Time Between Failure (MTBF) or Mean Time To Repair (MTTR) for our transportation alternatives. This report recommends that MTBF and MTTR be researched extensively for any alternative to be implemented.

Weather is a factor which can significantly limit travel. Thus for any alternative to be implemented, its ability to tolerate weather-related disruptions should be studied and factored in when making preliminary system design decisions.

If a ferry system is implemented, it will be necessary to develop a shuttle service to carry passengers from their point of disembarkment on the Hudson to Stewart, a distance of about 3 kilometers.

All alternatives will require terminals, or stations where passengers buy tickets and board their vessel. Due to limited time and in an effort to maintain focus on the transportation system itself, we determined development of terminals to be outside our scope but there is still a plethora of research to be done in this area.

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