Interrelationship between Airport Enplanements and Accessibility: A Case of Three Airports in the Metropolitan Washington DC Region

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ABSTRACT

Increasingly, urbanized areas have access to multiple airports, which requires each to compete for passengers. One such location is the Washington DC metropolitan area with three international airports within a 30-mile radius, each governed by different planning authorities. A travelers' choice to fly from a particular airport depends on a number factors, chief among them is convenient accessibility to the airport. Transportation planning agencies in the area often plan for network improvements to provide the best accessibility to a single major airport, though such improvements may provide accessibility benefits to airports outside their jurisdiction. In this paper, we present an approach to estimate airport accessibility by highway and transit for both peak and off-peak hours. Further, we measure accessibility to these airports for a base year and a 20-year planning horizon. The accessibility measure presented in the paper incorporates congested travel times as obtained from a travel demand model. The results show that accessibility varies greatly for competing airports and with that variation, there appears to be a correlation with total airport enplanements. The analysis also reveals the importance of taking a multi-modal and multiple time-of-day approach to accessibility analysis.

INTRODUCTION

Until about two decades ago, the choice of airport was relatively easy for travelers. Within acceptable travel distance usually only one airport provided flights to the preferred destination. However, with a substantial growth in urbanized areas, highly developed transportation systems and increased demand for air travel many urban residents have access to multiple airports when arranging travel. Regional airports have rapidly grown over the last decade and are now providing flights to many destinations. Recently, there has been a significant rise in the rate of growth (both in terms of passengers and in number of flights) at airports in urban areas.

In an urban area when there are competing airports, a number of attributes are critical to travelers' decision-making process. One such factor is the time it takes users to pass from a ground airport access system to the airport terminal (for air passengers) and working places (for airport employees). The major time component is the surface transportation system, but small airport based people-moving systems also play a role in access time including walkways, waiting platforms, conveniently designed paths for moving baggage, escalators, spaces for short car or taxi stops to pick-up and drop-off users. Primarily, airport ground access systems are geared towards the efficient movement of air passengers, airport visitors and other commuters *(1, 2)*.

Over the past decade, structural changes in the travel and airline industry have enhanced the competition among airports. This is in part due to the rise of the Internet age and the ability of passengers to quickly and transparently find flights and prices among competing airports. This ability to easily compare prices has led to increased levels of competition and reduced the significance of price as the major factor influencing traveler choice *(3)*. Specific attributes of an airport including the number of daily flights, the range of available destinations, the airlines that service the airport and even the type of aircraft available have an influence on airport choice *(4)*. Outside the airport, a range of regional factors including access time, the total time it takes a given number of households and employees to travel to an airport are critical factors that affect airport selection *(5, 6)*.

Airport choice is highly influenced by accessibility. Enhancing access may lead to increased productivity, particularly for non-principal airports. This is of particular significance as competition requires airports to run at peak productivity *(7)*. Evidence suggests that the effects of low accessibility, especially by way of public transit, could result in a reduction in originating passengers of up to 20% for the top 10 US airports *(2)*. One study found that public transportation availability alone has a strong influence on airport ridership *(2, 8)*.

An important component in to accessibility in addition to access time is distance traveled to the airport; speed of the mode and in the case of public transit – the frequency of service. Thus, accessibility and by extension modal share of public transportation depends on primarily three factors: frequency and speed of public transportation, and distance traveled to the airport. Often shared ride and van services also play a role as they provide door to door service with reasonable prices, more convenient mode of transportation, and less waiting and no transfer time. Including all of the elements in an analysis is a necessary component of measuring regional airport accessibility.

It is important to apply accessibility tools to understanding the particular behavior of the individual taking a longer distance, multimodal, multi-segment trip. The long-distance traveler makes logical and rational economic decisions, and those decisions are different from those made in daily commuting. The longer distance traveler is making a different set of decisions from those of the metropolitan-scale traveler. These decisions are different in terms of uncertainty and lack of knowledge about the non-home end of the trip. The decisions are different because of the amount of baggage being carried by the traveler, the traveler's sense of apprehension about the reliability of the trip and arriving on time, and the total trip costs *(2)*.

The Washington DC metro region is one location with intense airport competition. The region has two competitive international airports and one national airport within a reasonable travel distance. Planning agencies, in the interest of enhancing regional accessibility, are interested in providing residents and workers better opportunities to access the major jurisdictional airport. However, in a spatially vast and modally-diverse region like Washington DC, measuring and enhancing accessibility requires a robust planning tool to capture the location of households and jobs, socio-economic and demographic characteristics of residents, characteristics of air freight related establishments, highway network characteristics, transit network characteristics, fares, and network connectivity. It has long been assumed that there is a connection between regional accessibility and airport ridership, though the evidence has been tenuous due in part to the complexity of measuring accessibility across such large areas. The objective of this paper is to develop a measure of airport accessibility that can be reflected as an attractiveness of an airport, and to demonstrate the development of the accessibility measure considering the multimodal transportation network in a metropolitan region with multiple competing major airports. The accessibility measure can be used (1) *by travelers* to assess the attractiveness of a particular airport for a given time of day and for a particular mode, (2) *by decision makers* to plan improvements to the capacity of the transportation network or by providing alternative modes of access, and (3) *by engineers and planners* to develop airport choice models in a discrete choice modeling framework to provide key performance measures that determine airport choice given the attributes of airports and characteristics of travelers and the given traveling conditions in a multimodal transportation network. To accomplish this objective we compute accessibility to each airport by major modes of travel, by two time-of-day periods, and for a base and planning horizon year. Then we discuss the impact of planned future infrastructure investments on airport accessibility.

The remainder of the paper is organized as follows. In the next section the literature review is presented followed by a description of the methodology used to compute accessibility. The next section describes the study area with an overview of the three airports and their underlying characteristics. In the results section accessibility performance for the three airports is shown. In the last section, the conclusion and discussion along with a future scope of work is presented.

RELATED LITERATURE

When considering the spatial distribution of airports in the United States, one of the more interesting characteristics of the distribution is the relatively limited level of access provided by the commercial air transportation system. Although there are nearly 20,000 airports in the US, just 139 of them account for 96.5% of all passenger enplanements *(9)*. When this spatial distribution is combined with the hierarchical nature of the airport system, the landscape of accessibility becomes even more limited. The hierarchy of airports exists because of the operational schemes implemented by airlines in 1978, post-deregulation. In an effort to maximize their available resources (e.g., equipment, crews, and maintenance) and to attain greater operating efficiencies, most carriers adopted hub-and-spoke network configurations *(10, 11)*. This operational preference among carriers has resulted in dramatic differences in overall levels of flight frequency, capacity and service between airports *(10)*. More specifically, the resulting pattern is one where a few large airport hubs dominate interaction between smaller airports, generating complex and geographically extensive network catchment areas *(12–15)*.

The accessibility of a particular geographic location (be it a household or job location) relative to the air transport system, can be difficult to capture *(16, 17)*. Entry to the commercial air network can only be gained at airport access points (and an individual's choice of which airport to access) is typically viewed in part as some function of the generalized cost of traveling to an airport *(18–20)*. A number of studies find the time to access an airport, which includes the generalized cost factors, to be one of the top considerations for individuals that have a choice among airport locations *(21–23)*.

The generalized cost is a function of in-vehicle travel time, wait time, access time, egress time, comfort of travel and convenience *(24, 25)*. An individual's access to a given airport is generally thought to increase as the generalized cost of travel decreases *(26)*. In the United States, the spatial distribution of commercial airports is somewhat skewed toward more urbanized areas, leading to levels of access that vary significantly between individuals depending on their residential or employment location *(27, 28)*. This variation is further compounded by the fact that an individual's choice of which airport will serve as the best point of origin for a particular trip is ultimately constrained by the available alternatives.

In the decision making process, the cost of airport access for a passenger negates the benefits associated with air travel. Similarly, if sufficient airport access has already been achieved, the individual need not consider more costly alternatives. For example, an individual residing in Washington, DC will not consider New York's John F. Kennedy International Airport (JFK) a feasible access point because they already have a more geographically proximate set of alternatives to select from (e.g., Washington Dulles International (IAD), Baltimore-Washington International (BWI), and Ronald Reagan Washington National (DCA)). Further, the cost of accessing JFK via car, bus or train would likely outweigh any benefits of traveling to New York City for accessing the air transport network. Hence, the spatial distribution of airports and the structure of the ground transportation system can influence both the size and quality of an individual's set of alternative access locations. Along with proximity-related costs to the air system, temporal access and quality of access are also important. For example, even if airport access from a location is relatively inexpensive, this does not necessarily mean that entry to the system is readily available. Some airports offer frequent daily flights, many available seats, extensive hours of operation, reliable service, inexpensive parking, etc., while others may offer a less robust suite of traveler options *(29, 30)*. Along with an inverse relationship with cost, the level of accessibility is also influenced by the level of service and connectivity *(31)* to the larger system available at alternative airports.

The specification of access and how system access alternatives are identified for any demand location can have a significant effect on a location's potential accessibility *(32)*. Therefore, it is important that access opportunities are represented in a flexible manner that better accounts for corresponding changes to locational accessibility. Given this context, accessibility for any location within a region is assumed to be directly proportional to the level of service maintained between connected airports and inversely proportional to the cost of using that service with respect to the access alternatives available at an individual's originating location. Within this general conceptual framework, a measure of accessibility can be formalized that reflects the mutually dependent relationship between access and accessibility of demand locations to a networked system.

Considering the importance of global air transport to larger issues of globalization and economic geography, it is not surprising that more research is needed to understand how accessibility plays a role to provide opportunities to captive riders and to provide various options to potential users *(33)*. Given the enormous number of interacting factors, summarizing these spatial relationships of transportation access to airports is challenging. What is needed is some way of organizing data into functional units for analysis. One way of representing the spatial and functional relationships between airports is to classify airports into regions where all airports within an identified region share some degree of similarity with one another with respect to a set of attributes (e.g. accessibility by mode, time of day, trip purpose etc.). Based on these measures, changes in airport access can be analyzed. There are several major challenges associated with effectively measuring accessibility. Often accessibility is estimated using travel time, distance or cost without taking congestion effect into account. Further, congestion is strongly associated with socio-economic, demographic, trip generation, destination choice, mode choice, and route choice characteristics. Without a functional travel demand model it is nearly impossible to assess true impact of accessibility. In the next section we present the data used for this analysis and describe the approach for estimating airport accessibility.

APPROACH AND DATA

To carryout the airport accessibility analysis, we use peak and off-peak network travel times derived from the Maryland Statewide Travel Model *(34)* for both auto and transit modes. From the same model a zonal system was established containing household and employment counts. Using the ArcGIS software package *(35)* service area polygons were established to measure the distance that could be traveled within a selected set of travel time isochrones by each mode. The polygons were overlaid with the zone structure to measure the proportional overlap with the zone-based housing and employment data. Using Equation (1) absolute and relative accessibility scores are derived for each destination airport by mode.

$$A_j = \sum_{t}^{n} \gamma_t \sum_{i}^{n} (\alpha H_i \text{ x } \beta E_i) \tag{1}$$

Where, j is a given airport, t is a specific isochrone represented by network travel time covering an area that can reach the destination with the given travel time range; H_i^α is the proportional number of households in zone i that can reach the destination airport weighted by a factor α; E is the proportional number of jobs in zone i that can reach the destination airport weighted by a factor β and γ_t is a given weighting factor for each increment of time (isochrone). Values for each scaling parameter are provided in Table 1. The scaling values represented in in Table 1 are offered as examples of possible weights that can be given to access by households or workers and by time. These values can be readily changed to better reflect regional priorities. A relative accessibility score is established by dividing each absolute accessibility score by the maximum accessibility score to achieve a ranking of access from 0 to 1.

<<Table 1 here>>

CASE STUDY

The metropolitan region of Washington DC is an excellent example of a location where three international airports exist within typical regional airport travel times. The three major airports are: Washington Dulles International (IAD), Baltimore-Washington International (BWI), and Ronald Reagan Washington National (DCA). Statistical highlights for each of the three airports are shown in Table 2.

DCA has the greatest number of flights per day while BWI has the lowest. However, in terms of cargo landed and number of average passengers served, BWI surpasses the other airports in the region.

<<Table 2 here>>

Figure 1 shows the number of enplanements for all three airports over the last decade. The data shows that before the recession (2007-2009), IAD had a considerably higher number of enplanements compared to other regional airports. But in last five years both BWI and IAD have been gaining originating passengers. In the last three years, BWI has surpassed IAD in the number of enplanements while DCA is approaching an equal number. It appears, from the most recent data, that there is a regional convergence in the distribution of airport enplanements. We propose that part of this convergence can be explained by changes in accessibility over the past several years.

<<Figure 1 here>>

Each of the three competing Washington DC area airports has a unique governing structure. This structure affects how regional transportation investments may be influenced to enhance airport accessibility. BWI governed by the Maryland Aviation Administration, under and umbrella of the Maryland Department of Transportation while and DCA and IAD fall under the jurisdiction of the Metropolitan Washington Airports Authority. Both of these governing agencies have an overarching goal of improving the number of annual enplanements and aim to provide higher standards of travel both by auto and transit.

RESULTS

Accessibility can be measured in a variety of ways. The most prominent feature of either measure is typically a visualization of the analysis displaying distance traveled within a set boundary of times or isochrones. Figures 2 through 5 provide just such maps. What clearly stands out is the scale of the isochrones for each of the three airports when the travel mode is by auto (Figures 2-3). This scale when combined with the number of households or employees that can access the airport in the same amount of time provides an important measure of regional airport accessibility.

In terms of reach, Dulles International (IAD) has the farthest auto-shed with over 127 square miles covered within 90 minutes. This is followed by the similarly expansive reach of BWI's 111 square miles and DCA's 103 miles (Table 3a). IAD also captures the largest Peak hour transit service area at 48 miles, compared to BWI's 37 and DCA's 27 square miles. This auto-shed figure is directly correlated with the observed enplanements in each of the three Washington DC Metropolitan Airports, they do not tell the whole story with regard to accessibility.

Incorporating an accessibility based measure presents a better picture of market capture and the access established households and employment have to each of the airports by mode. Applying Equation (1) to the auto and transit sheds of each airport we find that by auto, DCA is most accessible with the top two accessibility scores. Nearly 240,000 households and workers from over 800,000 jobs can reach the airport during peak travel times by vehicle in less than 15 minutes. The accessibility score in the far right column of Table 3a confirms the high level of access for DCA. By contrast, a mere 71,625 households and 213,229 workers can reach IAD in the same amount of time, with even fewer household and workers, 64,471 and 115,370, respectively have access to BWI in this timeframe.

When we separate accessibility by mode, DCA easily emerges as the highest accessibility airport across both transit and personal vehicle. DCA is geographically proximate to large the dense Washington DC population and can be easily accessed by both rail and bus. By contrast, IAD which has the lowest peak hour vehicle accessibility score and the second lowest off-peak score, is located a substantial distance from the DC and Baltimore area population. It is also only reachable for transit riders by bus, thus its transit accessibility score is lowest among the three airports.

Peak hours have a significant impact on accessibility to the three airports by auto, while there is a very limited impact on the transit accessibility. The number of households that can travel to each of the three airports by auto within 15 minutes is reduced by 170,984 (about 31.3%) during peak hours compared to off-peak hours. Employment accessibility is reduced by 232,381 (about 16.7%). This reduction can be attributed to peak hour congestion in the Washington DC metro area. Yet the number of households that can reach the three airports by transit within 15 minutes during peak hours increased by 2,046 due to the shorter headways of bus and pa rail during peak hours. Transit accessibility is expected to be higher as the frequency of transit service is high during peak hours.

Figure 6 provides a map of planned highway and transit investments in the study area to be completed by the year 2030. The improvements include the expansion of the Washington Metro (subway) to the Dulles (IAD) airport called the Silver Line, a new light rail line on the outskirts of DC called the Purple Line and a new light rail line in Baltimore called the Red Line. Several road improvements are planned or have recently come online for the region's highway network. The Inter-County Connector (ICC) is a toll facility connecting several major radial interstate and highway routes near DC. The facility started operation in 2012. More toll projects are planned along the highly congested I-270 corridor and to the north of Baltimore on I-95.

<<Figure 2 here>>

<<Figure 3 here>>

<<Figure 4here>>

<<Figure 5 here>>

<<Table 3a here>>

<<Table 3b here>>

<<Figure 6 here>>

Table 3(b) makes it clear that planned transit and highway improvements will substantially alter regional accessibility. A significant increase in population and employment is forecast for the DC region. With the growth comes a greater number of vehicles and higher levels of congestion. The increase in congestion will significantly increase the time required to reach each airport, in the region, shrinking the auto-shed of each airport by a large margin. Here, examining only measures of mobility, planners and policy makers get an incomplete view of the region. Using the accessibility measure presented in Equation (1), despite a more limited range, accessibility is substantially enhanced throughout the region. Accessibility by transit (Table 3b) to the IAD notably increases by a large margin. In 2007 the airport was the least accessible by transit, but with the construction of the Silver Line, which brings access by rail to many DC residents, IAD becomes the most accessible airport by transit during the peak period. DCA remains the most accessible in the off-peak period by transit, while accessibility increases for BWI but lags behind the rest of the region. Auto sheds are reduced for all airports as congestion limits the distance drivers can travel in 2030 (Table 3b), but accessibly increases as a result of population and employment growth within these reduced auto-sheds. Almost all the relative accessibility scores increased in 2030, indicating a more balanced accessibility across different modes, locations, and times of day, resulting from the great population and employment growth in the center area which make the difference of sheds in peripheral areas more marginal.

DISCUSSION AND CONCLUSION

The demand for air travel and the number of international, national and regional airports in the US has grown substantially over the past several decades. This has resulted in the availability of multiple airports serving the same region and creating a need to understand how travelers choose between several competing airports in the same region. The travelers to airports need to make logical and rational economic decisions for the long-distance, multimodal, multi-segment trips, which is quite different from the daily commuting trip. Estimating the flight ridership for different airports in the same region also requires better understanding about how people choose between the airports. Accessibility across different transportation modes and during different times of the day to the airports plays a significant role in influencing travelers’ choice of airports, along with fare, parking, convenience, and other factors. Measuring accessibility enables planners and policy makers to estimate the location and number of potential airport users. Measuring access time and catchment areas offers new insight on how future transportation investments may enhance regional airport accessibility.

This study developed a tractable accessibility measure specifically for airports by either automobile or public transit. The measure also captures variability between peak and off-peak hours. The analysis was applied to the Washington DC metropolitan region with two competing international airports (BWI and IAD) and national airport (DCA), all within a reasonable travel time for most regional household and workers. Additionally, the accessibility measures are presented for both a base year and a 20-year planning horizon. The planning horizon year is unique in that the regional transportation network includes all planned interstate and transit improvements as described by multiple planning agencies in their long range transportation plans. The accessibility measure employs peak and off-peak network travel times from the Maryland Statewide Transportation Model for both auto and transit modes. The accessibility calculation includes the number of households and workers covered within several isochrones from each of the three airports. Absolute and relative accessibility scores were derived for each airport by the two modes and by peak/off-peak hours.

The application of network travel times from a travel demand model to measure accessibility rendered the estimation of the area covered by the isochrones more accurate and allowed a more detailed estimation of travel distances by different transportation modes and different time of day than cannot be achieved through traditional methods. Examining the number of households and workers covered by the isochrones reflects the possible number of activities and trips within a given amount of time for all three airports. This approach provides the opportunity to estimate potential accessibility affects from changes in development patterns and transport investments.

The findings of this study suggest that accessibility levels for airports vary a great deal between auto and transit modes, with significant changes largely depending on the transit level of service.

Accessibility by transit is on average less than auto access. However a number of factors affect how accessible an airport is by transit including whether the transit service covers high-density areas, frequency of the transit service, and the number of transfers required to reach an airport. The factors play a large role in determining regional airport accessibility and appear to influence airport ridership and enplanements. Ronald Reagan Washington National (DCA) is located in close proximity to high-density areas of Washington DC and is highly accessible by both rail and bus, this it's accessibility score by transit is much higher compared to the other two other competing airports.

Comparing the two modes, peak hour congestion has a much greater impact on auto accessibility than transit accessibility. The number of households and workers that can access an airport within a reasonable travel time by auto significantly decreases during peak hour. However, accessibility generally increases for transit during peak periods as a result of better headways and in the case of rail, separation of highway congestion. The results show the necessity to measure accessibility by different modes and at multiple periods of time. Further, the significant difference in accessibility between peak and off peak periods by auto and transit shows the potential transit investments may have in enhancing airport accessibility and thus attracting higher rates of ridership.

There are multiple potential benefits of applying an accessibility measure like the one used in this study. These benefits include 1) an estimation of the potential riders and cargo activity at each airport, and related roadway traffic; 2) an assessment of transportation-related policies or investments in terms of planning for better multi-modal coordination and connectivity to encourage mode shifts; 3) developing more effective transit and flight schedules according to the different accessibility levels by different times of the day, so as to utilize the capacity of transit more efficiently; and 4) guiding future land use and density planning for more balanced and robust urban systems. Future research will incorporate revealed and stated preference surveys to better understand the airport choice of travelers. Integration of accessibility measures to an airport choice in the framework of a discrete choice model is a natural extension of the paper. To develop a choice model, disaggregate data on airport (considered as alternatives) attributes and characteristics (socio-economic, demographic, travel demand) of travelers needs to be collected.

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TABLE 1 Descriptions and values for scaling parameters

Parameter	Description	Assigned
α (Alpha)	The relative importance of households within each zone	0.75
β (Beta)	The relative importance of jobs within each zone	0.25
γ_t (Gamma)	The relative importance of each isochrone, for increments	
	0 – 15 minutes	0.40
	15 – 30 minutes	0.30
	30 – 45 minutes	0.20
	45 – 90 minutes	0.10
	> 90 minutes	0.00

TABLE 2 Highlights of three airports in the Metropolitan Washington DC area, 2013

Airport	Year Established	Number of Flights Served per day	Cargo Landed (million pound)	Avg. Passengers Served (1,000/day)	Public Transportation
IAD	1962	355	477.67	28.97	Moderate
BWI	1973	301	493.7	30.54	High
DCA	1941	387	< 100	26.88	High

Source: USDOT Bureau of Transportation Statistics (36)

TABLE-3a: Summary of airport accessibility by all modes-2010

			Isochrones (travel time by minutes)												Accessibility Score	
			0-15			15-30			30-45			45-90				
Airport	***Mode***	***Period***	*Area*	*Households*	*Employment*	*Area*	*Households*	*Employment*	*Area*	*Households*	*Employment*	*Area*	*Households*	*Employment*	*Absolute*	*Relative*
BWI	Transit	Off-Peak	30	15,520	59,313	293	284,936	544,249	706	622,335	766,842	3,555	1,700,081	2,876,831	446,636	0.6202
BWI	Transit	Peak	37	22,143	70,012	319	303,321	548,436	745	623,010	772,920	3,715	1,738,546	2,945,209	459,142	0.6376
BWI	Veh	Peak	76	64,471	115,370	432	417,331	663,672	869	515,712	588,903	6,726	1,997,840	3,256,123	512,596	0.7118
BWI	Veh	Off-Peak	111	90,400	161,041	600	548,373	810,598	1,077	586,460	672,584	8,597	2,103,186	3,409,552	591,979	0.8221
DCA	Transit	Off-Peak	29	105,740	590,271	260	533,749	847,614	659	604,580	1,079,893	3,943	1,458,199	1,812,309	573,768	0.7968
DCA	Transit	Peak	27	96,478	535,380	274	552,654	922,216	727	663,526	1,148,364	4,156	1,413,199	1,760,499	582,944	0.8095
DCA	Veh	Peak	58	238,559	827,294	462	639,311	958,889	918	583,503	914,791	7,353	1,373,223	1,721,370	649,350	0.9017
DCA	Veh	Off-Peak	103	349,177	959,618	549	677,058	1,062,074	1,235	626,886	942,544	9,250	1,379,317	1,711,988	720,117	1.0000
IAD	Transit	Off-Peak	42	30,433	127,531	236	186,227	389,251	502	528,887	1,343,454	3,727	1,634,616	2,133,642	415,421	0.5769
IAD	Transit	Peak	48	35,119	135,852	277	222,028	457,618	568	625,354	1,496,415	3,946	1,545,721	1,965,449	442,087	0.6139
IAD	Veh	Peak	86	71,625	213,229	419	278,665	505,267	819	586,568	1,367,280	6,352	1,599,971	2,048,461	470,964	0.6540
IAD	Veh	Off-Peak	127	106,062	267,515	532	346,611	615,963	1,107	731,499	1,505,741	8,104	1,730,363	2,156,984	551,468	0.7658

TABLE-3b: Summary of airport accessibility by all modes - 2030

			Isochrone (travel time by minutes)												Accessibility Score	
			0-15			15-30			30-45			45-90				
Airport	***Mode***	***Period***	*Area*	*Households*	*Employment*	*Area*	*Households*	*Employment*	*Area*	*Households*	*Employment*	*Area*	*Households*	*Employment*	*Absolute*	*Relative*
BWI	Transit	Off-Peak	28	53,879	48,592	280	453,094	523,836	714	1,180,419	797,934	3,465	6,994,197	2,591,975	968,581	0.6731
BWI	Transit	Peak	38	67,645	64,963	326	470,809	480,861	782	1,193,983	741,448	3,724	7,785,924	2,620,520	1,034,414	0.7188
BWI	Veh	Peak	78	103,606	129,964	416	533,408	629,709	860	1,089,956	565,423	6,367	10,526,195	2,230,115	1,248,305	0.8675
BWI	Veh	Off-Peak	87	113,862	135,325	486	634,708	710,035	959	1,362,695	545,541	5,191	10,034,916	2,105,638	1,280,694	0.8900
DCA	Transit	Off-Peak	29	68,724	254,101	250	534,391	776,699	725	1,744,202	1,280,716	3,938	9,016,566	2,048,931	1,277,649	0.8879
DCA	Transit	Peak	26	61,311	231,263	275	556,678	787,037	786	1,771,954	1,144,520	4,149	10,024,673	2,084,924	1,352,793	0.9401
DCA	Veh	Peak	58	117,129	313,563	375	618,454	700,498	848	1,968,485	1,126,080	6,557	9,103,771	1,651,539	1,333,832	0.9269
DCA	Veh	Off-Peak	69	131,869	343,165	361	617,742	714,211	786	1,934,723	1,179,315	5,754	9,240,818	1,682,880	1,350,742	0.9387
IAD	Transit	Off-Peak	49	242,256	219,130	264	918,416	556,518	560	1,439,255	1,049,366	3,922	8,673,196	2,209,671	1,317,060	0.9153
IAD	Transit	Peak	55	255,064	224,939	306	1,174,559	667,601	592	1,570,423	1,080,077	4,135	9,163,125	1,953,531	1,438,999	1.0000
IAD	Veh	Peak	74	255,803	231,098	335	955,096	593,909	777	1,561,500	770,573	5,780	9,117,097	1,839,364	1,361,811	0.9464
IAD	Veh	Off-Peak	79	299,834	251,309	310	843,326	557,633	689	1,611,548	909,580	4,998	9,123,324	1,790,076	1,362,864	0.9471

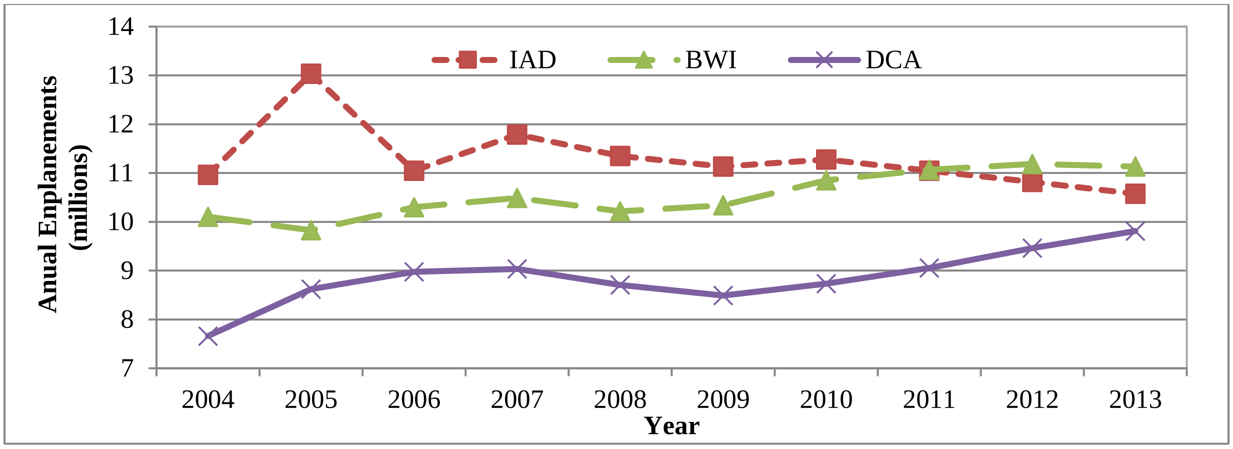

FIGURE 1 Enplanements in Washington DC Metropolitan Airports, 2013
Source: USDOT Bureau of Transportation Statistics (36)

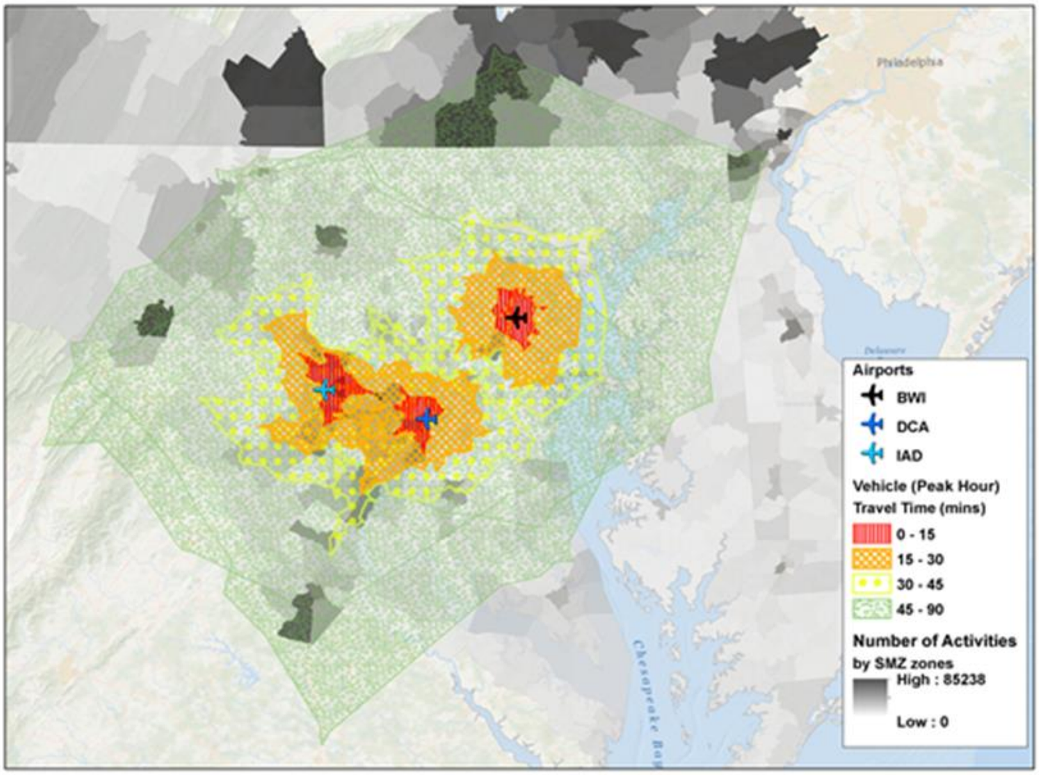

FIGURE 2. Peak hour accessibility by auto-DCA/BWI/IAD airport

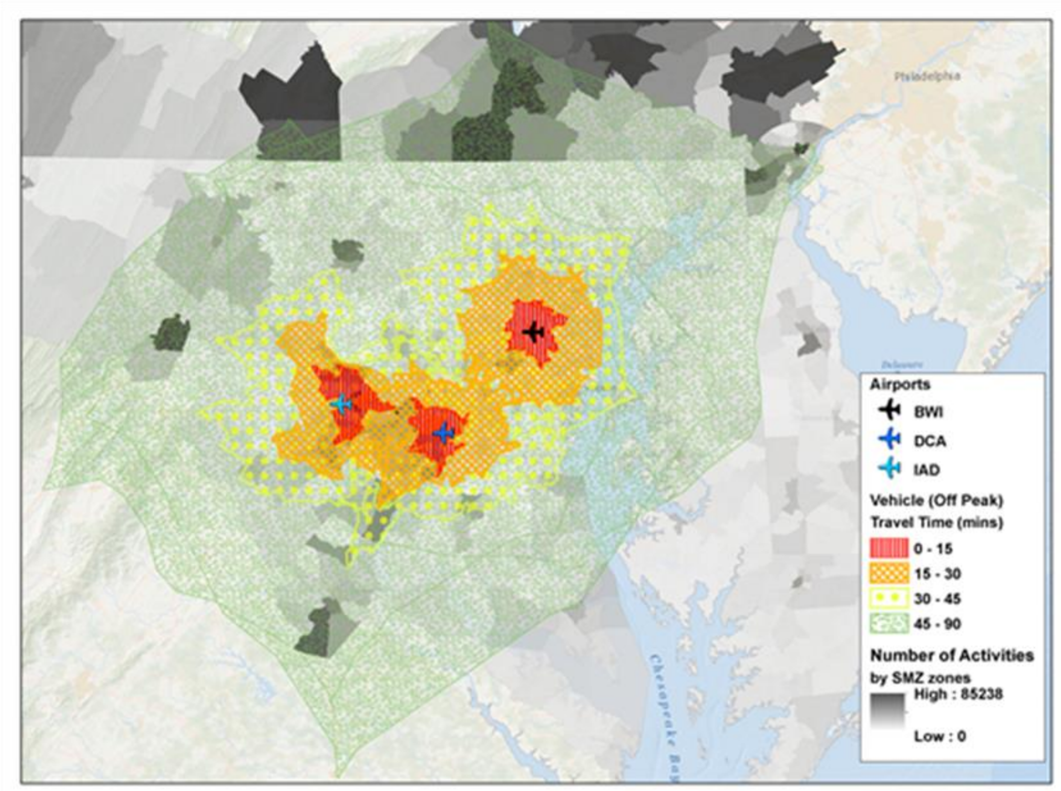

FIGURE 3. Off-peak hour accessibility by car- DCA/BWI/IAD airport

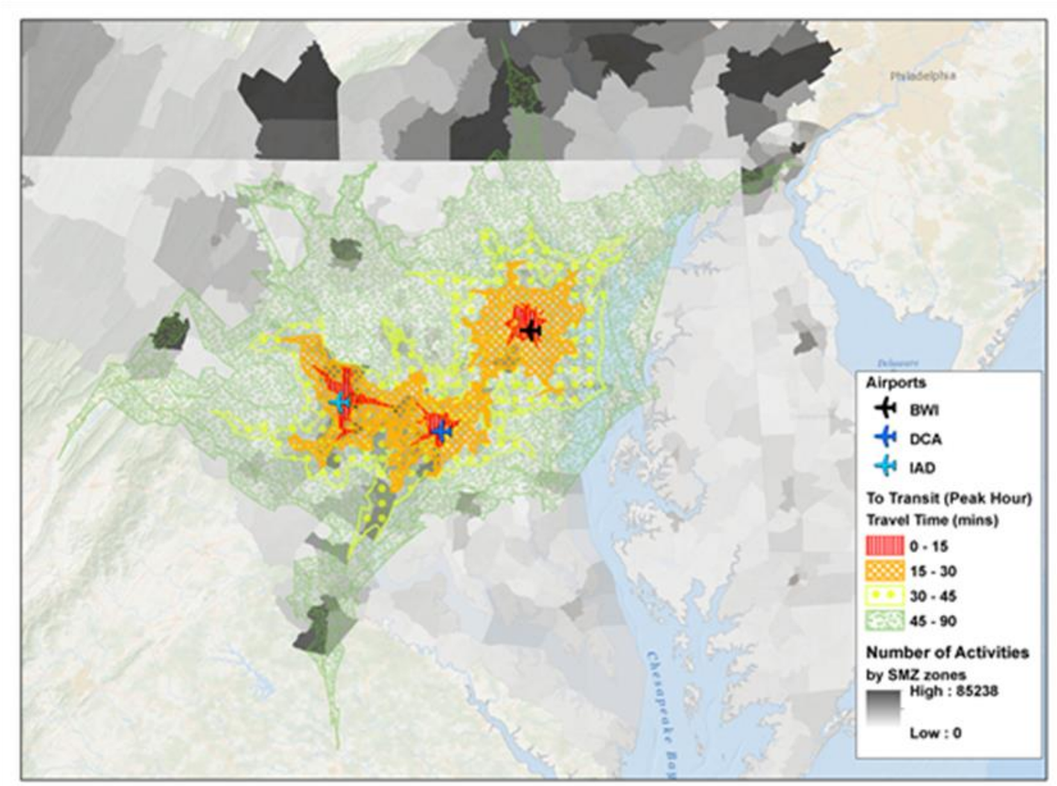

FIGURE 4. Peak hour accessibility by transit-DCA/BWI/IAD airport

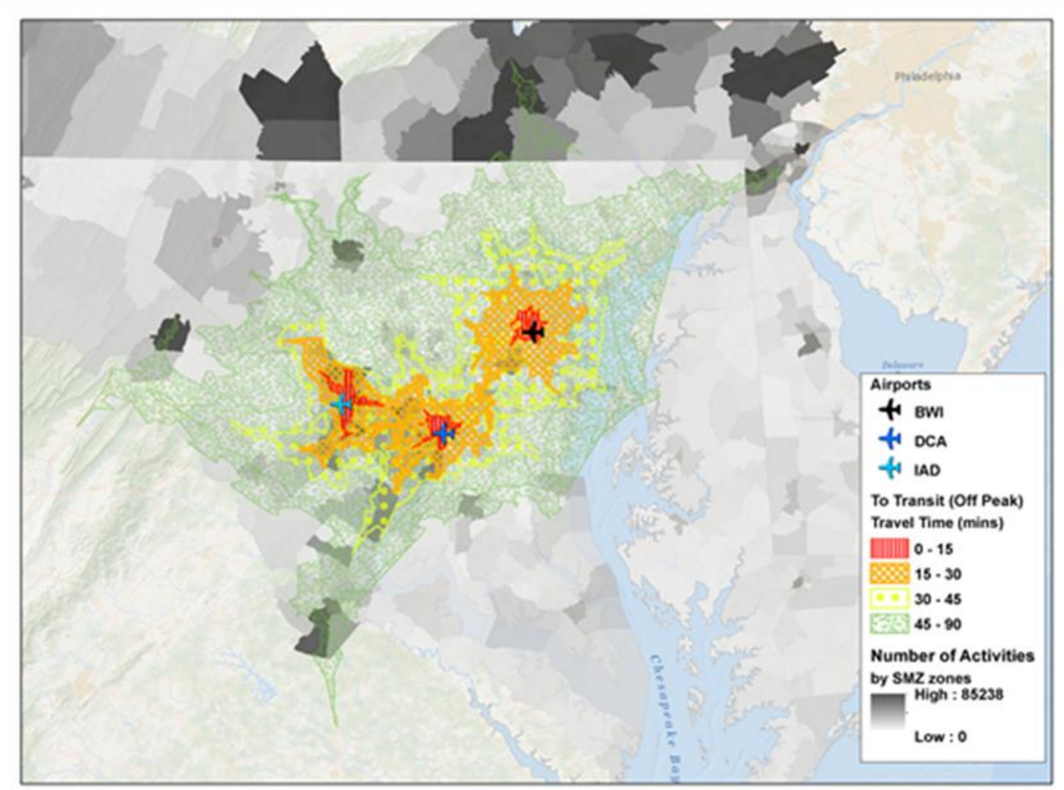

FIGURE 5. Off-peak hour accessibility by transit- DCA/BWI/IAD airport

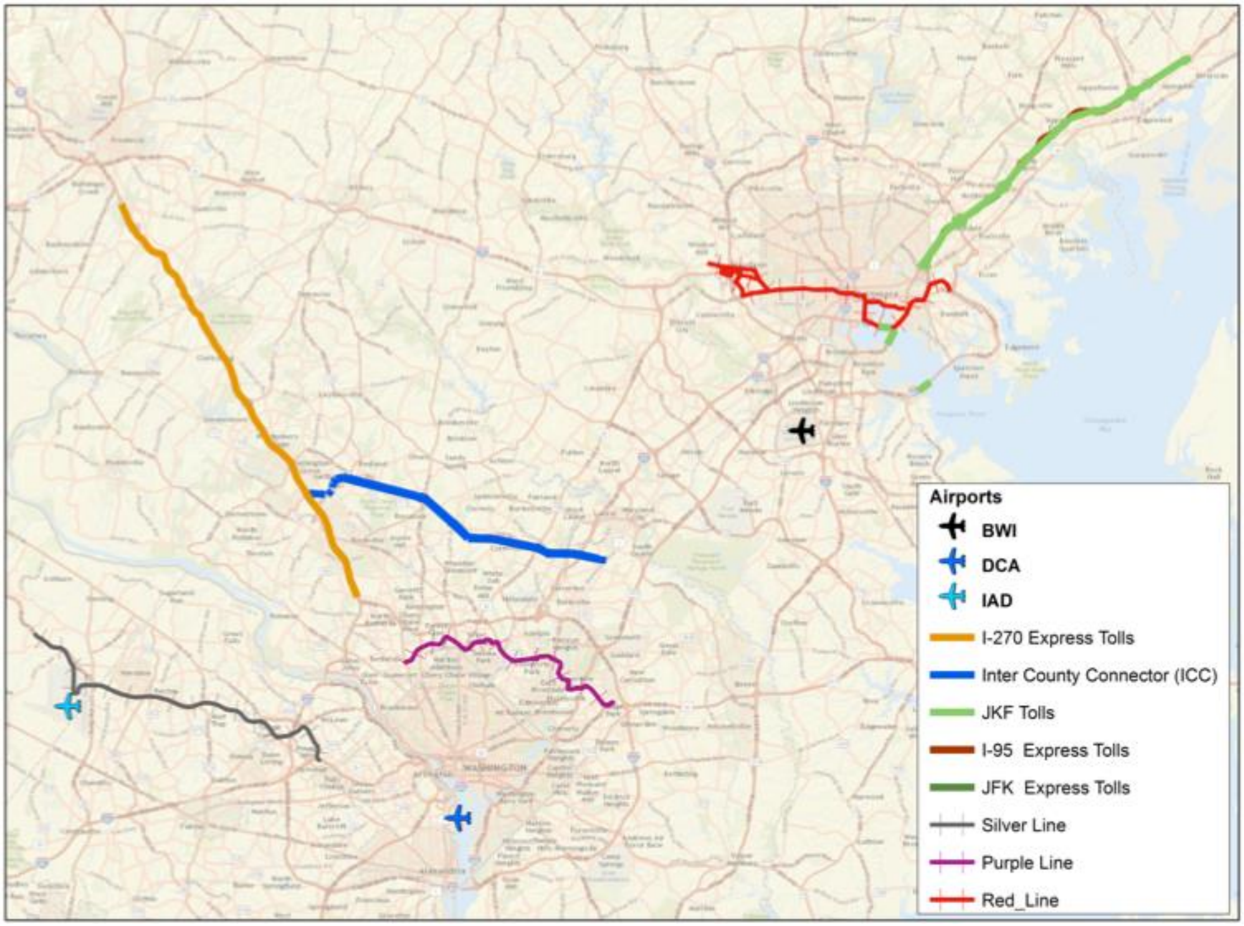

FIGURE 6 Location of current and planned highway and transit improvements