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FORECASTING FUTURE DEMAND IN TWO OF THE BUSIEST US AIRPORTS USING SIMPLIFIED MODELS

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ABSTRACT: - In airport planning process, there is always a crucial need for good and reliable air traffic demand estimate. It is equally important for airport authorities and airline carriers, for in the case of under estimated demand, there would be frequent congestions and delays. Conversely; overestimates would lead to unjustified expenditure which may lead to financial problems to all parties. The accurate and reliable models are not highly sophisticated *in nature*. In this paper, two econometric models were developed to forecast the passenger enplanements in two of the busiest airports in the United States of America. Many national and local socioeconomic variables were analyzed to come up with simple, yet accurate models. It was found that the total aggregate variables including per capita gross domestic production and population, have more influence on demand in the Hartsfield-Jackson Atlanta International Airport than the local variables, while the same factors, but in their regional scale, proofed to be more influencing in the case of John F Kennedy International Airport.
Keywords: Demand forecasting, econometric analysis, airport planning, regression, Simulation.

1. INTRODUCTION

Air travel demand forecasting plays a major role in airport planning, it usually represents the most challenging task for the aviation decision makers. It is a critical factor in any airport development process for if the forecasted demand was underestimated, the designed facilities would undergo some serious shortages in handling the projected demand what may lead to frequent congestions, delays and lack of capacity(1). If the demand was over estimated, then the designed facilities would provide greater capacity than needed and it would be empty for long times what may indicate unjustified expenses in construction, operation and maintenance.

The forecasting procedure is often facilitated by the utilization of regression or econometric models. The modeling process is conducted by relating several socioeconomic or transport system variables to demand for the aviation activity in question (2). This method has been extensively used in the last four decades for it provides more reliable predictive ability than the former time series extrapolation method which often considered as unable to identify the causes of market growth and to link the future growth with expected developments of causative factors (3). Another advantage of this method that it is relatively easy to conduct the forecasting when the projected explanatory variables are available. But if the independent variables are rather difficult to observe, the regression model would be less reliable regardless of how good the calibrated model fits the historical data (4). To this reason and some other weaknesses, some aviation agencies do not rely on this method entirely and use instead combination of several methods (5). The aim of this paper is to develop simple econometric models to forecast the passenger enplanements in two of the busiest airports in

the United States of America depending on national and regional sets of socioeconomic variables.

2. LITERATURE REVIEW

The aviation system in the United States of America is by far the most sophisticated and the largest in the world in terms of airport numbers, passenger movements and aircraft operations. This may provide the capability to predict the high level aggregate demand easily depending on general socioeconomic factors. The International Civil Aviation Organization (ICAO) uses very simple econometric models to predict global scheduled traffic with a very high coefficient of determination and fitness to the historic data, due to the extreme aggregation of the traffic [(6)]. Likewise; the forecasts adopted by the Federal Aviation Administration always deal with the high level aggregate activities at first then share analyses is utilized to distribute these activities among airports. At the same time; another technique is used in the Terminal Area Forecast (TAF) at large, medium, and small hubs which is based on a bottom-up approach. The domestic enplanements are forecast by generating origin and destination market demand forecasts. The origin-destination (O&D) passenger demand forecasts are based on regression analysis using fares, regional demographics, and regional economic factors as the independent variables [(7)].

Stephan Ellsworth[(8)] in his effort for estimating air passenger travel in the Atlantic region stated that the demand estimation for regional and local air services has been historically difficult. Models that predict demand for regional and local air service are limited because forecasting at this level is more complex. He selected two approaches; the first involved developing a model that estimates the total amount of passenger traffic generated from the population in the airport catchment area. While the second approach also investigates passenger trips originating from a catchment area. This technique was based on the distribution of these trips on links between airports using a link estimation model. It was also concluded that the process of relating demographic and supply variables to air passenger trips provided an insight into air travel demand and the factors that influence travel propensity.

A top-down methodology was adopted to forecast annual international flight operations at sixty-six U.S. airports, the methodology is applied in three steps [(9)]. In the first step, individual linear regression models are developed to forecast the total annual international passenger enplanements.

In the second step, the forecasted passenger enplanements are distributed among international airports in the U.S. using individual airport market share factors. In the third and final step, the international passenger enplanements at each airport are converted to flight operations required for transporting the passengers. World Region GDP is used as the main explanatory variable along with a dummy variable reflecting the impact of Sep. 11, 2001 terrorist attack on the future international passenger enplanements demand in the U.S. The airport market share analysis concludes that the airline business is a crucial factor to explain the changes associated with airport market share.

Another study focused on analyzing and forecasting international air travel market in Saudi Arabia using econometric models, in which an attempt is made to develop several models for the air travel demand with different combinations of explanatory variables[(3)]. The study concluded that; population size and total expenditure are the main determinants of international air travel in Saudi Arabia.

A micro economic model was developed to estimate the domestic passenger demand for Yazd Airport which is one of the most important tourism hubs in Iran [(10)]. Econometric and non-econometric approaches were consulted for forecasting the future traffic of airports. Baxter & Hawrey model, one of the Micro Econometrical models, has been used. In this model socio-economic variables are related to regional data of where the Airport located. Domestic passengers of Yazd airport has shown the most correlation with Yazd's population as a social variable and Gross National Product as Economic variable.

3. METHODOLOGY.

The econometric model in this paper is designed to estimate the dependent variable represented by the enplaned passengers by relating it to a selected set of social and economic factors which were chosen carefully before being subjected to regression analyses by which the model is created. The selection process was guided mainly by the judgment based of the huge literature and great number of high accuracy models developed previously by the federal aviation agencies or the academic effort in the same field.

In developing a model to forecast air travel demand it is very important to ensure statistical validity and to select the models with high estimating accuracy (14). In the case of the busy airports in the United States, which is handled in this paper, the attention was focused on the most influential socioeconomic factors on the propensity to fly to have them subjected to the statistical analyses to come up with the best set of explanatory variables that form the best fit simulation model with the highest predictive ability. The concentration on few influential explanatory variables may save a lot of time and effort that could be consumed if all the potential socioeconomic factors were to be examined.

3.1- Data Collection

In this study, the data collection process has been greatly facilitated by the availability of various American airport and aviation data, mostly furnished by the Federal Aviation Administration (FAA) web page as well as that of the United States Department of Transportation/ Bureau of Transportation Statistics. The available data covers more than a decade ago and gives reasonable forecasts for about 25 years ahead. The historical data is fairly detailed in terms of distributed activities among airports and their time dispersal along year, month or day. The most extensively used data was the Passenger Boarding and All-Cargo Data for the U.S. airports provided by the FAA on the website [(11)]. They are available in the form of Excel sheets, each one contains the information of two successive years. These sheets were collected and re tabulated to gather the data of the enplanements of the Hartsfield- Jackson Atlanta International Airport (ATL) and the John F. Kennedy International Airport (JFK) for the period from 2001 to 2013. Table 1 shows this data.

The population data is collected either for the airports regional areas or nationwide. This data is collected and tabulated by many agencies and published through their websites. One of the leading organizations in this field is the United States Census Bureau which provides regularly the historical annual estimates of the population for the United States in many forms that grant the capability to analyze any related variable in multiple aspects [(12)]. Population projection estimates are also provided by this bureau for four decades ahead.

The economic data in this research has been collected from the website of the United States Department of Commerce, Bureau of Economic Analysis which provides several categories of economic variables such as; national, international, regional and industry economics [(13)]. Within these categories, the personal income, personal consumption expenditures, gross domestic production (GDP) and the per capita gross domestic production. The GDP is the most influencing one of these variables on transportation and especially on air travel passengers demand. The analyses in this study subjected two economic variables; the first is the real per capita gross domestic production of the United States while the second is the metropolitan Per Capita Real GDP. Both are chained to the 2009 dollars value. Table 2 contains the population and the per capita real GDP of the United States of America and the airports metropolitan areas.

3.1. Data Analysis.

The chosen list of the explanatory variables included three variables scaled nationwide which are; the United States per capita GDP, personal income and population, in addition to two variables collected for each airports metropolitan represented by the metropolitan per capita GDP and population. A correlation matrix was produced for each airport to study the relationship between variables. This attempt may give an insight to those variables to be utilized in formulating the simulation model.

As for the Hartsfield-Jackson Atlanta International Airport (ATL) which is located in Atlanta city in the state of Georgia (GA), the regional or metropolitan variables are correspondent for the metropolitan statistical area that includes Atlanta, Sandy Springs and Roswell. The correlation matrix for all variables shows high correlation between the dependent variable, the airport passenger enplanements, and both US personal income and population as well as the metropolitan population, less correlation is noticed with the US GDP and even lesser with the metropolitan GDP. Since there is high correlation between many explanatory variables, it is necessary to exclude them and keep one at a time in trails. Table 3 shows this correlation matrix.

The same correlation matrix was produced for the John F Kennedy International Airport (JFK) in New York City the most populous city and the economic hub of the state of New York (NY) as shown in Table 4. The metropolitan statistical area includes New York, Newark and Jersey City. The correlation matrix reveals high correlation between the airport passenger enplanements and the metropolitan per capita GDP and the US personal income and per capita GDP, less correlation is observed with the population of the metropolitan and that of the United States.

4. ECONOMETRIC MODELS DEVELOPMENT

In order to develop an econometric model that is statistically valid, a simplified approach has been adopted in which the potential explanatory variables were subjected to regression analysis in a way that deals with any group of highly correlated variables by choosing one of them in any trial and excluding the others to avoid auto correlation. This procedure eliminated many unnecessary trials and produces small number of models that have high statistical validity.

It was found reasonable to transform all social and economic variables to the logarithmic form and apply the multiple linear regression on them then re transform them to the standard form in the model. The benefit of redefining parameters in this manner is that multicollinearity is reduced. The linear regression will produce a model in a multiplicative form which may satisfy the concept that many of the factors associated with passenger travel have a multiplicative rather than additive effect [(3)] (Ellsworth, 2000).

4.1. MODELS DERIVATION

In the case of Hartsfield-Jackson Atlanta International Airport (ATL), many trials were made to produce some five models with different variables, the best of which statistically is the one that incorporates the US per capita GDP and the US population. The statistics of the model are summarized in Table 5 and the standard form of the model is as in Eq. 1. A graphical representation to the actual and predicted passenger enplanements is shown in Fig. 1.

$$Atlanta\ P.Enplanements = 1.6 \times 10^{-8} \times US\ GDP^{0.79} \times US\ Pop^{1.38} \quad (1)$$

The second model was developed to estimate the enplanements in John F Kennedy International Airport (JFK). After several trials in the same procedure that was adopted in the first case, the selected model this time depended on the New York metropolitan per capita GDP and the same metropolitan population. Table 6 contains the statistics of the model which indicate the significance of the model and the powerful simulation to the actual demand behavior as shown in Fig. 2. The standard form of the model is in Eq. 2.

$$John\ F.Kennedy\ Enplanements = 3.33 \times 10^{-46} \times NY\ GDP^{3.27} \times NY\ Pop^{5.08} \quad (2)$$

4.2. MODEL STATISTICAL EVALUATION

The statistics for each variable in both models indicated significant relationship with the dependent variables. The adjusted coefficient of determination *"R^2"* is a measure of the adequacy of the regression equation. Its value in the first and the second models are 0.941 and 0.95 respectively, and this would imply a strong relationship between the explanatory and dependent variable.

The "*F*" statistic provides an alternative method of evaluating the goodness of fit or the significance of the overall regression model. The value of "*F*" is 97.8 and 115.6 for the first and second models respectively, as shown in Tables 5 and 6. This may suggest that there is always a notable significant relationship between the dependent variable represented by passenger enplanements in each airport and the explanatory variables.

The "*t"* statistic is used to test the nul1 hypothesis that the coefficient does not contribute information to the prediction of dependent variable. The *t*-test value in Tables 5, 6 which are fairly higher than the critical value what implies that each variable coefficient is statistically significantly different from zero, therefore, the null hypothesis can be rejected and the corresponding independent variable may remain in the model.

The Durbin-Watson "*d*" statistic which is used to detect autocorrelation, when it is closer to zero a positive autocorrelation is indicated and when it is closer to 4 a negative autocorrelation is detected, the evidence is in favor of no autocorrelation when "*d*" is closer to 2. The first model has a "*d*" statistic of 2.137 which indicates no autocorrelation at all, while the second one has a "*d*" statistic of 1.441 which refers to slight positive autocorrelation tendency.

4.3. DISCUSSION

The selected econometric models are rather simple yet very efficient in terms of fitness and predictability. The most significant explanatory variables to be utilized in the first model, the one that simulates the Atlanta Airport, were the nationwide per capita gross domestic production and the total United States population. These high level aggregate socioeconomic variables proved to have higher influence on regional propensity for flying than the Atlanta metropolitan scale similar variables. This effect may appear unusual at first, but in fact it is quite logical due to the fact that enplaning passengers are motivated by the socioeconomic factors affecting their destinations as well as their origin, and in this case they have higher influence. In the second models which deals with the John F. Kennedy Airport, the independent variables were the metropolitan per capita GDP and the metropolitan population. This may reflect the nature of the trip generation in this metropolitan affected by its own characteristics. In both models, as shown in their regression equations, the population value has more effect than that of the per capita gross domestic production either in the nationwide total figures or in the metropolitan ones.

The graphical representation of these models in Figs. 1 and 2 show very close graphs of the predicted to those of the actual enplanements. This may reveal the excellent fitness of the models. At the same time, in order to examine the predictive ability of the models, it was deemed reasonable to compare their future estimates with those published by the FAA terminal area forecasts for the years 2015 through 2018. Table 7 contains the FAA estimates and those of the developed models in addition to the variance between them. The small value of the variance implies the high predictive ability especially for the short term periods. The comparison showed tangible divergence between these forecasts in the long term. The models estimates are noticeably higher than those of the FAA for the long term forecasts. Accordingly; the models produced by this approach are considered suitable for short and medium range forecasts.

5. CONCLUSIONS

In this paper, two econometric models are developed to simulate and forecast the future passenger enplanements in Hartsfield-Jackson Atlanta International Airport and John F. Kennedy International Airport which are among the busiest airports in the United States of America. A simplified approach has been adopted in the attempt to analyze and forecast the passenger enplanements by establishing statistical relationships with the social and economic factors on the regional scale and national or the high level aggregate scale. These factors were carefully selected in order to save time and effort and to create a simplified yet efficient models. The nominated factors to be analyzed are; the U S personal income, U S per capita

gross domestic production, and the U S population, in addition to the per capita GDP and population of the metropolitan in which the airport is being analyzed.

In the first model, which deals with Atlanta International Airport, it was found that the per capita GDP and the population both in their national scale are the most determinant variables to estimate the passenger enplanements. This implies that these high aggregate socioeconomic factors affect the trip generation process in this airport rather than those factors of the same nature in its vicinity, i.e. the passengers are motivated by external factors more than regional ones. The second model that deals with John F. Kennedy international Airport. The regional socio economic factors proved to have more influence and the model was related to the per capita GDP and the population both for the metropolitan in which the airport is located. This may suggest that passengers of the airport are mainly motivated by local trip generating factors.

These two models are excellent in terms of goodness of fit measures. No multicollinearity or autocorrelation is detected in any model. The application of both models returned forecasts that very close to those estimated by the Federal Aviation Administration in the short term. The variance between them was no more than 2.54% and 3.25% for the first and the second model respectively.

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Table 1: Annual Passenger enplanements

Year	Airport Enplanements	
	H. J. Atlanta	John F. Kennedy
	ATL	JFK
2001	37,181,068	14,553,815
2002	37,720,556	14,552,411
2003	38,893,670	15,676,352
2004	41,123,857	18,586,863
2005	42,402,653	20,260,359
2006	41,352,038	21,071,501
2007	43,236,665	23,401,351
2008	43,761,280	23,620,948
2009	42,280,868	22,710,272
2010	43,130,585	22,934,047
2011	44,414,121	23,664,832
2012	45,798,928	24,520,981
2013	45,308,407	25,036,358

Table 2: Population and per capita GDP in USA and airports metropolitan areas

Year	United States		Airports Regional Metropolitan Areas			
			Atlanta-Sandy Springs-Roswell, GA		New York-Newark-Jersey City, NY	
	Population	Per capita GDP	GA Pop	GA per capita GDP	NY Pop	NY Per capita GDP
2001	285,112,030	48081	8,422,127	57832	19,076,610	61206
2002	287,888,021	48450	8,591,169	57236	19,132,542	61186
2003	290,447,644	49182	8,740,008	56961	19,207,652	61294
2004	293,191,511	50384	8,921,371	57161	19,258,479	63030
2005	295,895,897	51563	9,107,719	58278	19,262,545	65641
2006	298,754,819	52434	9,342,080	57635	19,281,988	67539
2007	301,621,157	52716	9,544,750	57372	19,297,729	68515
2008	304,374,846	51800	9,697,838	54884	19,467,789	67037
2009	307,006,550	49869	9,829,211	52065	19,541,453	66352
2010	309,347,057	50446	9,714,464	51830	19,400,867	67499
2011	311,721,632	50790	9,813,201	51785	19,521,745	67716
2012	314,112,078	51655	9,919,000	51755	19,607,140	68822
2013	316,497,531	52093	9,994,759	52178	19,695,680	69074

Table 3: Correlation matrix for all variables related to Hartsfield-Jackson Atlanta Airport

	US Personal income	USA GDP	USA Population	GA GDP	GA Population	Atlanta Enplanements
US Personal income	1					
USA GDP	0.701428	1				
USA Population	0.985833	0.616503	1			
GA GDP	-0.80211	-0.16432	-0.87312	1		
GA Population	0.973216	0.691438	0.975821	-0.80872	1	
Atlanta Enplanement	0.955349	0.789295	0.936694	-0.69092	0.939322	1

Table 4: Correlation matrix for all variables related to John F. Kennedy International Airport

	US Personal income	USA Population	USA GDP	NY GDP	NY Population	JFK Enplanements
US Personal income	1					
US GDP	0.701428	1				
USA Pop	0.985833	0.616503	1			
NY GDP	0.935734	0.859306	0.896906	1		
NY Pop	0.943804	0.541716	0.960248	0.801325	1	
JFK Enplanements	0.960982	0.803987	0.939882	0.97092	0.882594	1

Table 5: Statistics of the model of Hartsfield-Jackson Atlanta International Airport

Regression Statistics					
Multiple R	0.975391748				
R Square	0.951389062				
Adjusted R Square	0.941666874				
Standard Error	0.016008955				
Durbin-Watson	2.137				
Observations	13				
ANOVA					
	df	SS	MS	F	Significance F
Regression	2	0.050159	0.02508	97.85751	2.71438E-07
Residual	10	0.002563	0.000256		
Total	12	0.052722			
	Coefficients	Standard Error	t Stat	P-value	
Intercept	-17.94415282	2.635324	-6.80909	4.69E-05	
Lin US GDP	0.790535139	0.19973	3.95802	0.002695	
Lin US Pop	1.379508288	0.173521	7.95008	1.24E-05	

Table 6: Statistics of the model of John F. Kennedy International Airport

Regression Statistics					
Multiple R	0.981792				
R Square	0.963916				
Adjusted R Square	0.956699				
Standard Error	0.041205				
Durbin-Watson	1.441				
Observations	13				
ANOVA					
	df	SS	MS	F	Significance F
Regression	2	0.453541	0.226771	133.5664	6.12E-08
Residual	10	0.016978	0.001698		
Total	12	0.470519			
	Coefficients	Standard Error	t Stat	P-value	
Intercept	-104.714	30.47736	-3.43579	0.006376	
Lin NY GDP	3.275341	0.427695	7.658129	1.72E-05	
Lin NY Pop	5.078688	2.035156	2.495478	0.031691	

Table 7: Passenger enplanements forecasts comparison

Airport		Annual passenger enplanements (1000)		
		2016	2017	2018
ATL	FAA	47,874	48,883	50,785
	Model	48,005	48,747	49,495
	Variance	-0.27%	0.28%	2.54%
JFK	FAA	27,593	27,173	29,101
	Model	26,911	27,535	28,156
	Variance	2.47%	-1.33%	3.25%

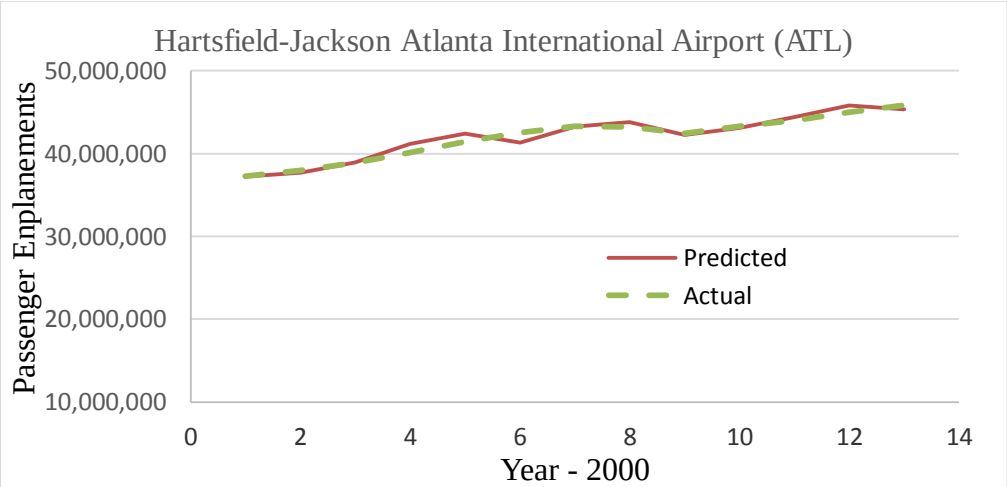

Fig. 1: The Actual and predicted passenger enplanements in ATL.

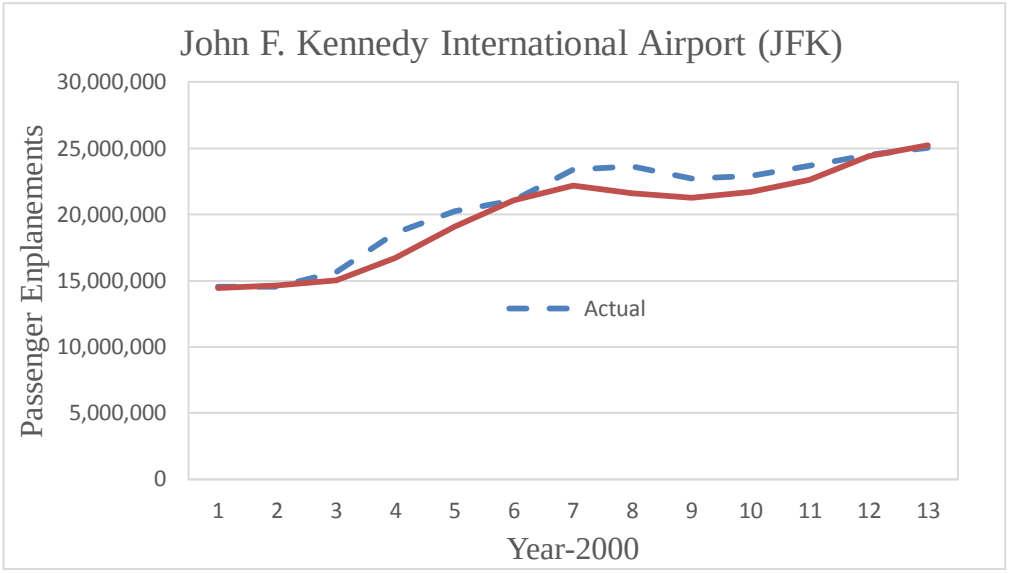

Fig. 2: The Actual and predicted passenger enplanements in JFK.

استقراء الطلب المستقبلي على مطارين مزدحمين في الولايات المتحدة الامريكية باستخدام موديلات مبسطة

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الخلاصة:

في عملية تخطيط المطارات هنالك دائما حاجة ملحة تفرض وجودها على سلطات الطيران المدني وادارات المطارات من جهة وعلى شركات الطيران من جهة اخرى وعلى حد سواء، حيث انه في حالة التخمين باقل من الطلب الحقيقي سيترتب على ذلك اختناقات متكررة وتاخير في النقل بصورة دائمة. وبالعكس ففي حالة التخمين المبالغ فيه فانه سيؤدي الى ايقاع مصاريف هائلة غير مبررة ستؤدي حتما الى مشاكل مالية كبيرة على كافة الاطراف المشتركة في نشاط النقل الجوي. ان موديلات الاستقراء الدقيقة والمعول عليها ليست معقدة بالضرورة. وفي هذا البحث تم انشاء موديلين استقرائيين باستخدام طريقة الانحدار الاحصائي لاستقراء الطلب المستقبلي على نقل المسافرين جوا في اثنين من اكثف المطارات انشغالا في الولايات المتحدة الامريكية، حيث تم تحليل عدد من العوامل الاجتماعية والاقتصادية للوصول الى الموديلين المبسطين والعاملين بكفاءة في عين الوقت. لقد ثبت بان العوامل الشمولية والماخوذة على المقاس الدولي بالنسبة للولايات المتحدة وهي اجمالي الدخل القومي مقيسا للفرد الواحد وعدد السكان الاجمالي هما العاملين المؤثرين على الطلب والنقل في مطار اطلنطا الدولي، في حين ان نفس العاملين المذكورين ولكن بمقياسهما المحلي وعلى نطاق المنطقة العمرانية لكل مطار فقد كانت هي العوامل المؤثرة على طلب النقل في مطار جون كندي في نيويورك.