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A Theoretical & Innovative Air-Transport Policy & Analysis Conducive to Economic Growth: Incorporating Flight Scheduling, and Delay Costs

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ABSTRACT

The focus of this study, while incorporating other related author's published works, is mainly on flight scheduling and various costs of delays. The intuitive concept of strong economic effects of aviation and air transport has been unexceptionally supported by the abundantly clear evidence. Hence, formulation of a dynamic and sustainable policy, based on massive evidence, is considered mandatory. Innovative policies would internalize major components of the existing positive externalities to enhance the success, efficiency, and viability of the industry, which would be conducive to economic development. Policy optimization in air transport industry could be a major ground for exploration of some innovative Integration of appropriate regulations and deregulations conducive to a tangible success in business and economic growth. This study applies an inductive method: Some already published evidence and empirically measured economic effects would lead to the formulation of an integrative economic policy framework that can be applied accordingly in the future for more empirical examinations and adoption.

INTRODUCTION

The economic impact of transportation, in general, and air transportation, in specific, has been clear and addressed appropriately at all times. Hence, the opportunity costs of any less than optimal and most efficient economic policy that would incorporate all the infrastructural growth potential into actual fruition would be too large. While in both of the following two tables, the economic contributions of civil aviation are demonstrated, in TABLE 2, billions of dollars of aviation-related manufacturing income are reported both for 2012.

TABLE 1: 2012 Economic Impact of Civil Aviation
(Percent of Top Ten States' GDP)

State	Contribution to GDP
Hawaii	17.9%
Nevada	12.1%
Arizona	7.9%
Alaska	7.5%
Florida	7.2%
Washington	6.7%
Colorado	6.2%
Georgia	5.7%
Utah	5.6%
California	4.7%

Source: U.S. Department of Transportation
Federal Aviation Administration, January 2015, p. 6
(Reorganized by the author)

TABLE 2: Total Economic Output (Manufacturing): Aircraft, Aircraft Engine, and Parts Manufacturing
Top Five States
(Top Five States, Billions of Dollars)

State	Manufacturing
California	34.9
Washington	25.4
Texas	16.3
Connecticut	13.4
Arizona	11.8

Source: U.S. Department of Transportation
Federal Aviation Administration, January 2015, p. 8
(Reorganized by the author)

It is also evident from TABLE 3 that in many other economic-benefit criteria, such as aviation's relative productivity, income, passengers carried, tourist travelers, etc., aviation and air transport industry have a significant and sustainable positive impact.

TABLE 3: Globalization & Aviation Benefits - 2014

Jobs Created	62.7 million
Relative Productivity: Aviation Jobs	3.8 times more productive than other jobs
Income	$2.7 trillion
If aviation were a country	21st biggest in GDP Size
Passengers Carried	3.3 billion (2014) 3.57 billion (2015)
Tourist Travelers	54% of all international tourists traveled by air
No of Commercial Airlines	1402
Commercial Aircraft in Service	26,065
Airports with Scheduled Commercial Flights	3,883
World-Wide Commercial Flights	32.8 million (2014) 34.8 million (2015)

Source: Aviation Benefits beyond Borders – Global Summary, ATAG, June 2016
(Reorganized & tabulated by the author)

The 20-year forecast of international air traffic growth seems to be promising, as is clear from TABLE 4.

TABLE 4: International Air Traffic Growth Forecast: 2014-2034

Africa	5.4%	APEC	3.9%
Asia-Pacific	5.1%	European Union	3.6%
Europe	3.6%	Small Island States	4.9%
Latin America & Caribbean	4.7%	Developing Countries	5.0%
Middle East	6.0%	OECD	3.5%
North America	2.7%	World	4.3%

Source: Aviation Benefits beyond Borders – Global Summary, ATAG, June 2016
(Reorganized & tabulated by the author)

RELATED RESEARCH BACKGROUND

The influence of transportation on different economies has never been ignored since ancient times. Civilization, as supported by socioeconomic, geopolitical and technological developments, has been leaning on transportation. As to air transport perspective, Button (2008) stresses appropriately:

> *From its earliest days, airlines were seen as having potential for providing high-speed mail services, and subsequently medium and long-term passenger transport. Technology now allows the carriage of much larger cargo pay-loads in a more reliable way. These strategic functions were used to pursue internal national policies of social, political, and economic integration within large countries such as Canada, the US, and Australia, but also took on international significance from the 1930s within the Imperial geopolitical systems centered mainly on the UK, France, Germany, and other European countries when technology allowed for intercontinental services to be developed. (p.7)*

Button (2008) has also highlighted the airlines' attempts in covering their costs through many ways, including subsidies, service bundling, and even vertical integration. He refers to some example of historical experiences such as American Airlines initiating the computer reservation systems (CRS). He also uses the experiences of strong business ties and cooperation between Boeing and Pan American on the one hand and those of Lockheed and TWA in building and using aircraft.

Hamzaee & Vasigh (2006) offered a theoretical framework, in which a mathematical model of airport-airlines cost-revenue sharing is recommended, which by itself would facilitate some internalization of external benefits in such a way that both independently operated entities would be incorporated into some sort of holding company.

Hamzaee & Vasigh (2001 and 2002) in their two other separate studies on enhancement of airport efficiency, applied benchmarking (2001) and total factor productivity model (2002), using many airports and airlines data at the time. Obviously airports' efficient operations would facilitate trade and the desired sustainable economic growth. In the following section, some theoretical model are formulated and offered through applying the existing knowledge on aviation strengths and challenges. A series of aviation (industrial) policy conducive to more investment and infrastructure effects on the economy would be the one of the most three significant pieces of the proposed models.

THE THREE PROPOSED THEORETICAL FRAMEWORKS AND METHODOLOGIES

1. A Proposed General Framework:

$$Y_t = f(X_{it}, Tr_{jt}, Tec_{ht}) \qquad (1)$$

Y_t = National output, real GDP in period t

X_{it} = Real spending on ith resource in period t, where i = 1, 2, …, n

Tr_{jt} = Real spending on jth transportation in period t, where j = 1, 2,…, m

Tec_{ht} = Real spending on hth type of technology in period t, where h = 1, 2, …, k

To stress the share of air transportation relative to all forms of transportation, let's adopt ATA_t defined in (2), as follows:

$$ATA_t = \frac{AAT_t}{\sum_{j=1}^{m} Tr_{jt}} \qquad (2)$$

ATA_t = All Air Transport in period t as a fraction of the entirety of all the transportations made in period t, all measured in real spending.
LL_t = The number of hours of labor lost due to the airline delays
∂ = The partial effect of LL_t on the aggregate production

Assuming an aggregate Cobb-Douglas production function, equation (1) can be restated as:

$$Y_t = \prod_{i=1}^{n} X_{it}^{\alpha_i} \prod_{h=1}^{k} Tec_{ht}^{\beta_h} ATA_t^{\delta} LL_t^{-\partial} \qquad (3)$$

where, for labor input, one may use one of the two alternatives:
(1) $X'_{jt} = X_{jt} - LL_t$
(2) or use X_{jt} = Number of hours of labor used in absence of any flight delays and then include LL_t in the production function, as seen above in Equation (3).

After transformation of the above nonlinear function into a log-linear for other researchers' possible application of regression analysis, the following is derived:

$$Y_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i Log X_{it} + \sum_{h=1}^{k} \beta_h Log Tec_{ht} + \delta Log\ ATA_t - \partial Log LL_t$$

So,

$$-\partial Log LL_t = Y_t - \alpha_0 - \sum_{i=1}^{n} \alpha_i Log X_{it} - \sum_{h=1}^{k} \beta_h Log Tec_{ht} - \delta Log\ ATA_t$$

$$ll_t = -\left[\frac{Y_t - \alpha_0 - \sum_{i=1}^{n} \alpha_i x_{it} - \sum_{h=1}^{k} \beta_h tec_{ht} - \delta ata_t}{\partial}\right] \qquad (4)$$

where,
$ll_t = \text{LogLL}_t$, $x_{it} = Log X_{it}$, $tec_{ht} = Log Tec_{ht}$, $ata_t = Log ATA_t$

One can estimate ll_t, and from there, LL_t can be calculated for the number of lost hours of labor due to flight delays. This would be one perspective to an estimate for economic cost of flight delays.

According to NEXTOR report (2010), the flight delays in 2007 costed US about $31.2 billion, which included a $4-billion loss of GDP. In addition to all costs addressed above and later in this paper, one may include delay costs (DC). While many have discussed the delay management by focusing on parameters such as time, distance, and resorting to increasing runways throughout, based on the delay cost defined by Duaa Serhan, Hanbong Lee, Sang Won Yoon. (2018), we may formulate the total delay cost to airlines to simply cover several types, including the following:

$$DC = TC + FC + MC + CC + ATT + LP + Q_{ll}(LL_t) \qquad (5)$$

$Q_{ll_{t+1}}(LL_t) =$ $AP_L.LL_t$ = Total rough estimate of loss of aggregate output in next leriod (t+1), attributable to LL_t

$AP_L = Average\ product\ of\ labor$

TC = Taxiing cost

FC = Fuel consumption

MC = Maintenance costs,

CC = Crew costs

ATT = Additional travel time

LP = Loss of passengers

LL_t = The number of hours of labor lost due to the airline delays

An Infrastructure-Investment Enhancement Policy for Air-transport Industry:
In order to enhance air-transport industry, some real incentives need to be built into the taxation formula. That approach would introduce an effective cost-benefit perspective into operational management in an attempt to optimize their services and activities. The author suggests the following investment model that should incorporate some policy-variables, including both punitive as well as persuasive measures.

$$\mathbf{ATK = a_0 - a_1\,TAR - a_2\,FL + a_3\,RORA - a_4\,RSK} \qquad (6)$$

ATK = Air-transport capital expenditures
TAR = Tax rates on air-transport revenues

TABLE 5: Cost of Air Transportation Delay in 2007

Line Item Cost Component	Category	$ Billions
Flight Delay Against Schedule	Airlines	4.6
Intrinsic Flight Delay due to Schedule Buffer	Airlines	3.7
Excess Travel Time due to Schedule Buffer	Passengers	6.0
Passenger Delay Against Schedule: Delayed Flights	Passengers	4.7
Passenger Delay Against Schedule: Canceled Flights	Passengers	3.2
Passenger Delay Against Schedule: Missed Connections	Passengers	1.5
Capacity-Induced Schedule Delay	Passengers	0.7
Voluntary Early-Departure-Time Adjustment	Passengers	0.6
Welfare loss due to switch from air to automobile	Shared	2.0
Externality cost from increased road traffic	Shared	0.2
Forgone GDP	Shared	4.0
Total U.S. Cost	**All**	**31.2**

Source: Airlines for America. (2010). Annual U.S. Impact of Flight Delays (NEXTOR Report), http://airlines.org/data/annual-u-s-impact-of-flight-delays-nextor-report/

FL = Fuel used for air-transport purposes
RORA = Rate of return on air-transport capital
RSK = Expected risk index on air-transport investment
a_i = all parameters for i = 0, 1, …., 4

The policy-focused tax rates on air-transport revenues are proposed to come into effect through the following formula:

$TAR = t_0 - t_1\, dEMA + t_2\, PDIS - t_3\, APLA - t_4\, FAAC$ (7)

dEMA = Percentage change in a contribution index of air-transport related infrastructural activities
PDIS = Passengers dissatisfaction index
APLA = Airport-airline joint capital expenditures (more theoretical analysis on this in subheading 3, as will follow)
FAAC = FAA- Security Compliance Index, which would be possible to dynamically evolve for more effective enhancement of environmental safety and overall security
t_i = all parameters, for i = 0, 1, ..., 4

$ATAR = (1-TAR).BTR$ (8)

Plugging (6) into (7), the following will be resulted:

$ATAR = (1- t_0 + t_1\, dEMA - t_2\, PDIS + t_3\, APLA + t_4\, FAAC).BTR$ (9)

Equation (9) can be summarized in a general functional form of:

$ATAR = f\,(t_0, dEMA, PDIS, APLA, FAAC, BTR)$ (10)

ATAR = Air-transport after-tax revenues
BTR= Before-tax revenues of air-transport enterprises

After tax earnings of air-transport enterprises would be influenced by the general tax rates, percentage change in corresponding employment, passengers' satisfaction, the extent of airport-airline joint capital expenditures, compliance with the FAA safety and environmental regulations, and their actual activities, as measured by their before-tax earnings.

A Theoretical Model of Airline-Airport Integration: Review of a Previous Work

Related to my proposed theoretical framework of subheading 1 and 2, as discussed above, the author is providing a thorough excerpt of what was previously published (Hamzaee and Vasigh, 2006), where an airline-airport integrated operation optimization model, in which all three stakeholders, the airlines, airports, and their customers (of both airside and landside services) are incorporated. What connects the other two segments of my model with this segment of our theoretical work is APLA = Airport-airline joint capital expenditures (as introduced in the last section).

Various solutions for group optimization are analyzed. Beginning with the two general groups of airside and landside outputs to be produced, there are n different resources to be used by both airlines and airports. Therefore, the n resource constraints are defined as:

$$\begin{aligned} a_{1AS} \bullet Q_1 + a_{1LS} \bullet Q_2 &\leq R_1 \\ a_{2AS} \bullet Q_1 + a_{2LS} \bullet Q_2 &\leq R_2 \\ \dots & \\ a_{nAS} \bullet Q_1 + a_{nLS} \bullet Q_2 &\leq R_n \end{aligned} \qquad (11)$$

where,

a_{iAS} = the amount of the ith resource necessary to produce one indexed unit of airside output (landing & departure), for i = 1,2,..., n

a_{iLS} = the amount of the ith resource necessary to produce one indexed unit of landside services to customers at the airport, for i = 1,2,..., n

Q_1 = the total indexed quantity of airside output (quantity of a composite output of landing/passengers + take off/passengers + miles/passengers, or alike)

Q_2 = the total indexed quantity of landside output

R_i = The total quantity of the ith utilized resource, for i = 1,2,..., n

In Figure 1, as an illustrating example, five of the aforementioned hypothetical resource constraints are graphed. Obviously, to arrive at a relevant production possibility frontier (the darker portions of the five constraints), all of the nth resource constraints listed above

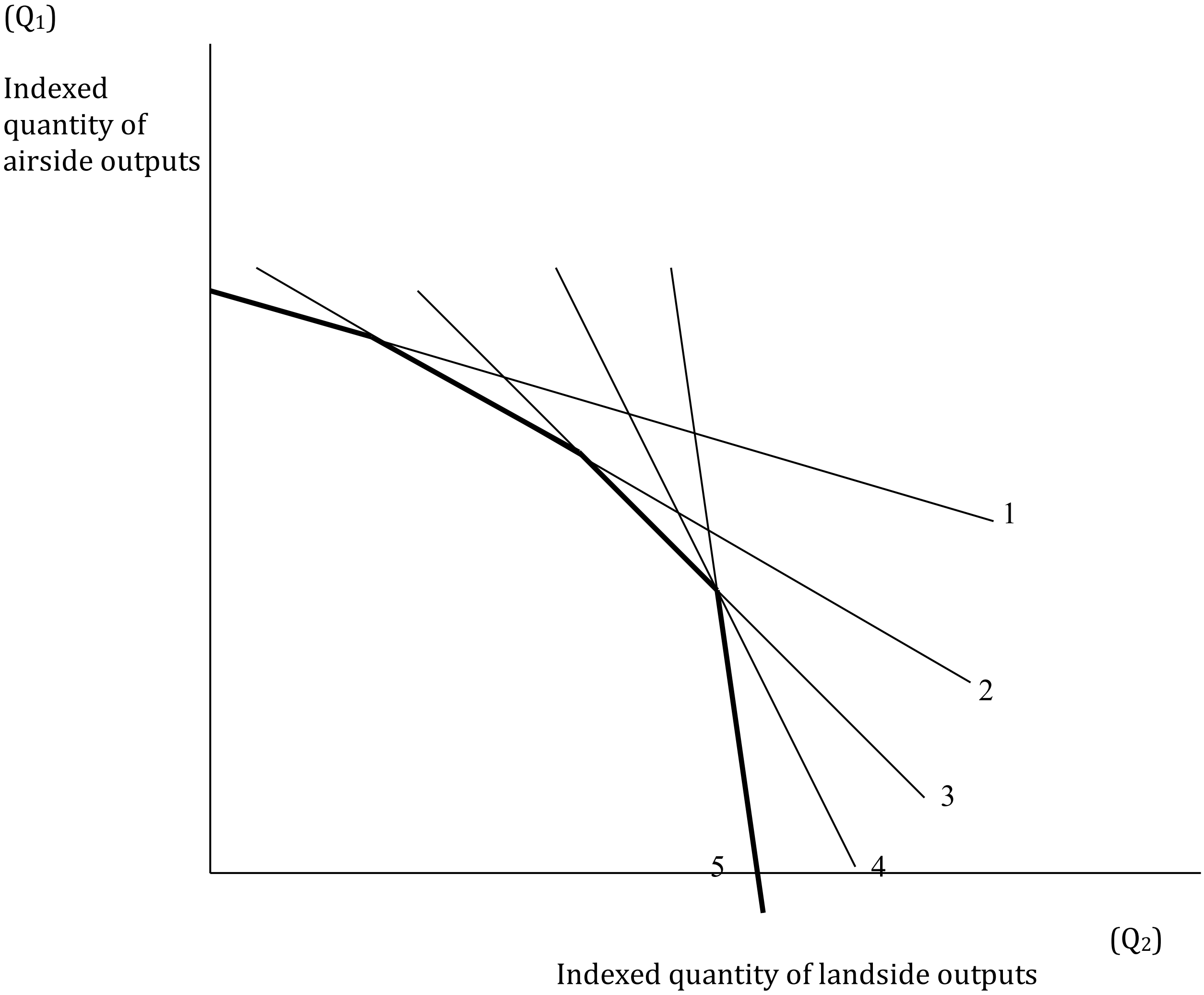

Figure 1
An Integrated Airline-Airport Production Possibility Frontier

in (11), must be simultaneously implemented. This model is proposed to include only one airport (at a time) as integrated with all the airlines chartered to have movement (traffic) through it. An integration of all the resource constraints for one airport and all the airlines using that airport would be summarized in constraint (12), as follows next.

$$\sum_{i=1}^{n} (a_{iFL} \bullet Q_1 + a_{iLS} \bullet Q_2) \leq \sum_{i=1}^{n} R_i \qquad (12)$$

Equation (12) shows an integrative resource constraint of one airport - only – along with those of all the airlines using it. Such resources, as an example, could include - but not limited to - the following list:
R_1= quantity of Gas
R_2= number of pilots
R_3= number of airside personnel

R_4= number of aircraft
R_5= number of runways
R_6= number of maintenance bases
R_7= number of maintenance technicians and engineers
R_8= number of tower controllers
R_9= amount of computer hardware and software to utilize
R_8=number of airlines' on-land employees excluding airside personnel, technicians and engineers
R_7= number of landside operational employees
R_{10}= number of security personnel
R_{11}= number of janitorial employees
R_{12}= number of value of security facilities
R_{13}= number of airport restaurants

The Airlines-Airport Budget Line

Then under competitive conditions, the following condition should hold:

$$P_1 = ATC_1 \qquad (13)$$

Also, by definition,

$$ATC_1 = \frac{\sum_{i=1}^{k} r_i R_i}{Q_1} \qquad (14)$$

which is the average resource cost, considering k different resources to be used for provision of airside output (Q_1).
P_1 = Indexed average price of a composite unit of output (landings/passengers, departures/passengers, plus miles/passengers of traveling)
Q_1 = Quantity of a composite output of landing/passengers (q_1) + takeoff/passengers (q_2) + Miles/passengers (q_3)
ATC_1 =average total cost of all resources needed for each composite unit of the airside output produced in a certain period of time
r_i = the rental price (cost) of the ith resource in production of airside output for i = 1,2, …, k
Comparing (3) and (4), the following definition, under competition, will result:

$$P_1 = \frac{\sum_{i=1}^{k} r_i R_i}{Q_1} \qquad (15)$$

Also, P_2, the price of an indexed quantity of landside output (Q_2), can be similarly defined as:

$$P_2 = ATC_2 = \frac{\sum_{j=1}^{m} r_j R_j}{Q_2} \qquad (16)$$

where:
ATC_2 = average total cost of all land-side output supplied in a certain period of time
r_j = the rental price (cost) of the jth resource in production of landside output for j = 1,2, …, m
n = k + m

Then the following relationship (17) will represent the budget constraint for the passengers and/or general customers, which would also represent the airlines-airport budget constraint, assuming that their incomes under competitive conditions would be the same as their total costs:

$$P_1Q_1 + P_2Q_2 \leq B$$
$$B = B_1 + B_2 \quad (17)$$

B_1 = Airlines total budget
B_2 = Airport's total budget
$B = B_1 + B_2$ = Airportlines' total budget

Now, plugging (15) and (16) in (17), the following budget constraint will be resulted:

$$\frac{\sum_{i=1}^{k} r_i R_i}{Q_1} \bullet Q_1 + \frac{\sum_{j=1}^{m} r_j R_j}{Q_2} \bullet Q_2 \leq B$$

$$Q_1 = \left[\frac{B}{\frac{\sum_{i=1}^{k} r_i R_i}{Q_1}} \right] - \left[\frac{\left(\sum_{j=1}^{m} r_j R_j \Big/ Q_2 \right)}{\frac{\sum r_i R_i}{Q_1}} \right] Q_2 \quad (18)$$

(Q1-Intercept) (Slope of the Budget Constraint)

$$Q_1 = \frac{\text{(Total airport-airlines integrated budget)}}{\text{(Airlines average cost of operation)}} - \frac{ATC_{Landside}}{ATC_{Airside}} Q_2 \quad (19)$$

Now all the three stakeholders are put together into interaction, and find various possible optimization solutions to the model. In Figure 2, the optimum solution for all three groups is the same, Q^*_1 and Q^*_2 should be produced and consumed.

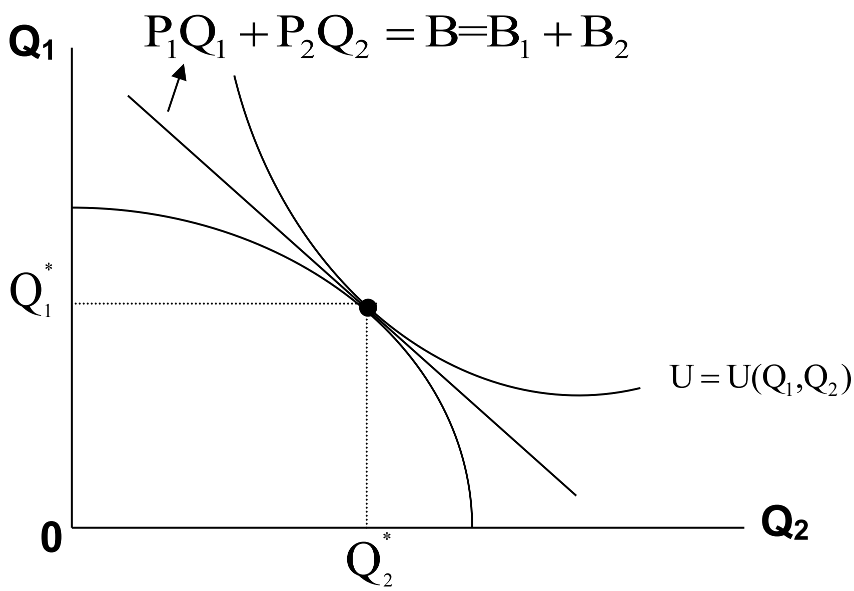

Figure 2
The Optimum Solution for All Three Groups Is the Same, Q^*_1 and Q^*_2 Should Be Produced and Consumed

In Figure 3, consumers of both services would have a different optimal solution than the "airportlines" would. The consumers' preferences are more heavily towards airside than landside services. However, for the "airportlines" more of the landside and less of the airside would be the best solution.

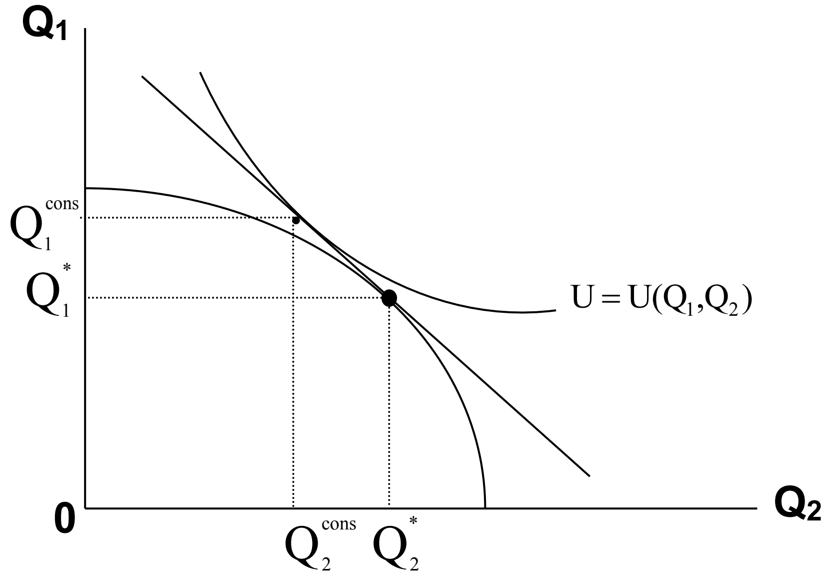

Figure 3
Consumers of Both Services Would Have a Different Optimal Solution Than Would the "airportlines"

In the following case (Figure 4), the providers (airports and airlines or just "airportlines") will have again a different optimal solution than the consumers would. Consumers are preferring more landside than airside services.

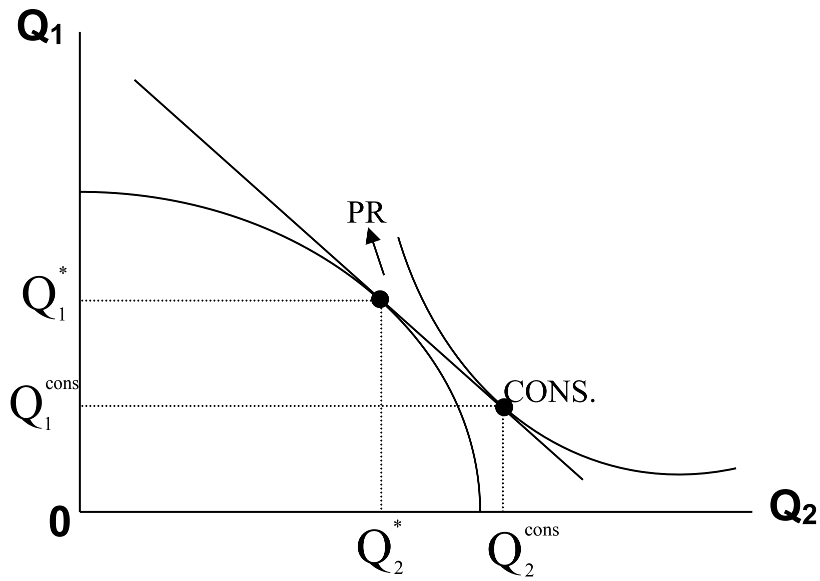

Figure 4
When Consumers' Biases Are Towards Landside Services

A TREND ANALYSIS OF SOME AVIATION DATA

Focusing on several frequently watched airlines performance indicators, the author has applied some trend analysis. The linear trend estimations (Figures 6 and 7) have been revealed as optimal, considering various minimum error criteria.

Before focusing on some relevant trend estimations, Figure 5 indicates the significance of domestic and international air cargo revenues in terms of both frequencies and levels.

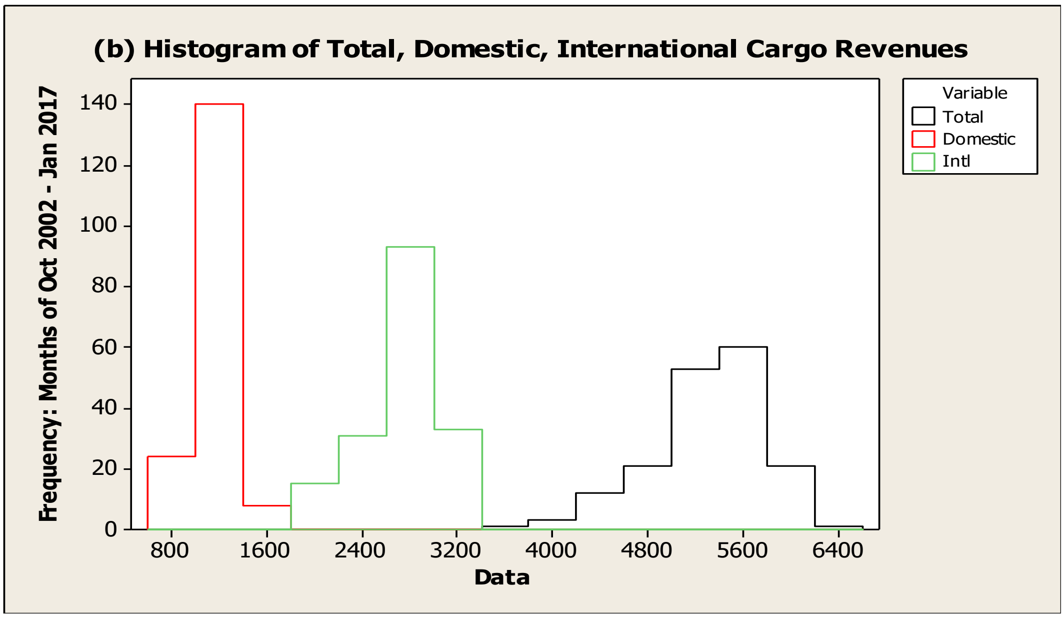

Figure 5
The Three Levels and Frequencies of Air Cargo Revenues

Load factor is a major profitability indicator in aviation. A high load factor is just about a high rate of passenger occupancy conducive to higher profit, given the high fixed costs of fuel, well-maintained aircraft, full flight crew and support staff. Load factor would reflect expected profit index and even a component of the expected risk factor for corresponding investors. As is clear in Figure 6, both trends of load factor and revenues are upward, despite shorter-term fluctuations.

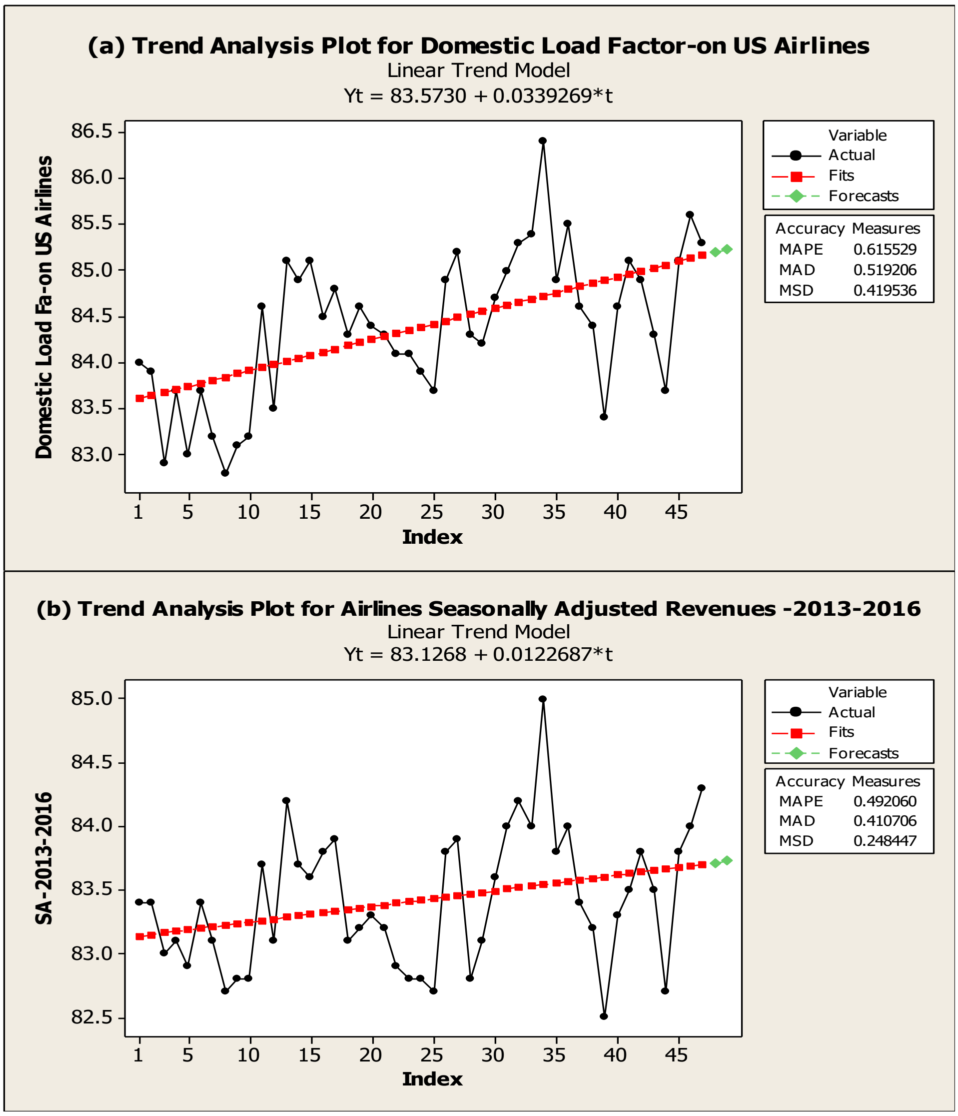

Figure 6
US Airlines' Upward Domestic Load Factor Trend (a) and Revenues Trend (b)

In Figure 7, however the trend behaviors for Air cargo revenues and international load factor are different than those depicted in Figure 6.

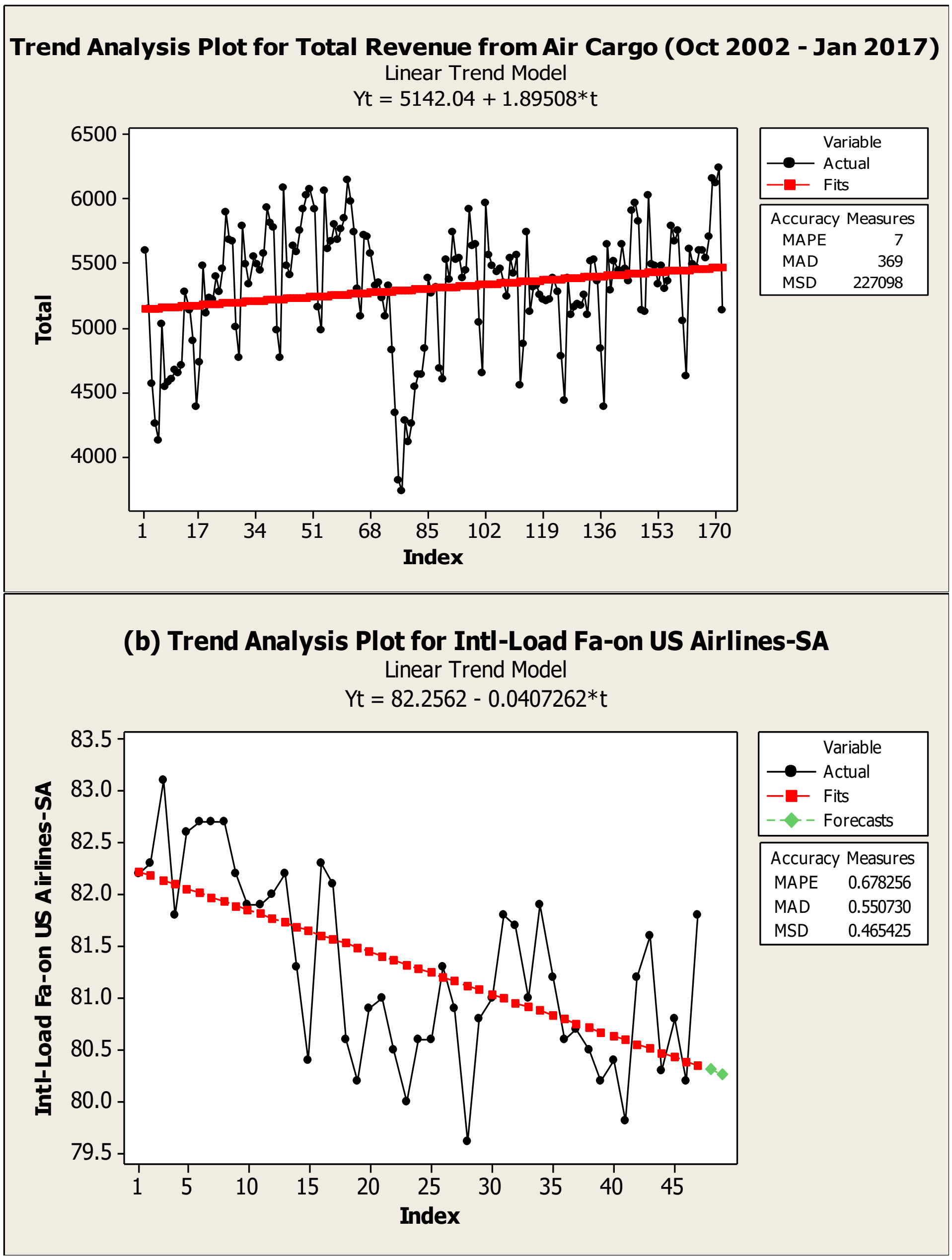

Figure 7
U.S. Cargo Airlines' Total Revenue Trend (a) and Downward International Load Factor Trend (b)

SUMMARY

The focus of this study, while incorporating other related author's published works, is mainly on flight scheduling and various costs of delays. This paper is composed of three major theoretical frameworks, in which innovative economic policy choices are proposed, a merger of airline & airports operations is proposed and finally in the first model, the roles and effects of scheduling and various costs of flight delays are injected. The intuitive concept of strong economic effects of aviation and air transport has been unexceptionally supported by the abundantly clear evidence. Hence, formulation of a dynamic and sustainable policy, based on massive evidence, is considered mandatory. Innovative policies would internalize major components of the existing positive externalities to enhance the success, efficiency, and viability of the industry, which would be conducive to economic development. Policy optimization in air transport industry could be a major ground for exploration of some innovative Integration of appropriate regulations and deregulations conducive to a tangible success in business and economic growth. This study applies an inductive method: Some already published evidence and empirically measured economic effects would lead to the formulation of an integrative economic policy framework that can be applied accordingly in the future for more empirical examinations and adoption.

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