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Effect of open skies in the Middle East region

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Abstract

This research aims to estimate potential inter-regional passenger flows for air transport in the Middle East under open skies polices, once deregulation agreements are reached between neighboring countries. To arrive at reasonable demand estimates, Western and Eastern European demand data was analyzed as a first step, since it is assumed that current Middle Eastern demand is distorted as a direct result of regional political instability. The major factors affecting demand, based on the European dataset, included population size, gross domestic product (GDP) per capita, absolute difference in GDP per capita between two countries, great circle distance and membership of the European Union and World Trade Organization. Subsequently, a 21 country database was estimated for passenger flow in the Middle East region on an average peak season day. The demand estimations became input for a hub location model (p-hub median formulation) in order to achieve the second major aim of this research, objective identification of potential regional gateways. The results proved robust to both single and multiple allocation model assumptions, with Cairo and Tehran consistently achieving hub status, along with Istanbul and Riyadh, as the number of potential hubs increased. Finally, this research shows that under conditions of peace, given existing socio-economic indicators, inter-regional passenger demand flow could increase by upwards of 51% and regulatory authorities ought to consider the necessary infrastructure and demand management policies to enable the conservative regional demand growth estimated.

Keywords: Air transport; Demand forecasting; Hub and spoke networks; Deregulation; Middle East

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1. Introduction

There is little doubt that the Middle East is one of the troubled regions in the world. Over the last century the Middle East has been a center for international disputes, national conflicts, religious hostility, ethnic tension and internal instabilities. Nevertheless, there is a small probability that the Middle East will change in the foreseeable future and peace may not be totally imaginary. If the Israeli-Palestinian peace process were to yield positive results, if the recent war in Iraq were to lead to the establishment of a stable regime and if other conflicts were at least partially resolved, we may well witness a quieter region. Based on this assumption, the current study evaluates the potential demand and network effects of deregulation in the air transport industry in the Middle East, which may help in enhancing regional economic stability.

A sharp reduction in the violence in the Middle East is likely to have a significant positive effect on the regional air-transport industry. Increase in international trade flows, in regional and international tourism and in incoming foreign direct investments are all expected to augment the number of passengers and flight frequencies and destinations in the Middle East. The expected regional growth in the air-transport industry to be analyzed in this research is naturally dependent on deregulation of the air transport industry within the Middle East region. Hence, another base assumption of this study is that the various governments in the region can reach a liberalization agreement similar to that of the European Union. Several countries within the region have already completed deregulation in domestic markets. Turkey and Morocco have gone through such a process, whilst Egypt has passed partial liberalization rules (Williams, 2002). The aims of such liberalization are to enable lower costs and stronger competition on the supply side and increased frequency and lower airfares on the demand side. This can be accomplished, for example, through the development of hub-and-spoke networks (see Adler and Berechman, 2001; Adler, 2001; Button, 2002).

The specific aim of this research is to evaluate the air transport needs of the Middle East region by identifying potential hub airports. To the best of the authors' knowledge, this is the first time such an analysis has been undertaken. It may aid relevant authorities to realize the potential benefits of increased demand through competition and encourage development of regional gateways at the most relevant airports in the area. Potentially important regional hubs have been identified based on objective models and current socio-economic data. However, due to data limitations, this research is based on country rather than city level aggregate data, hence considers only traffic between the countries included in the dataset. Domestic demand within countries has been ignored, but can only boost the demand flow presented in this analysis.

In Section 2 we present a demand model that will be used to estimate the potential market for air transport in the Middle East. This has been undertaken by identifying the factors that explain current passenger flows in Western and Eastern Europe and computing the relevant function and parameters. The final output of the forecasting model is estimated passenger demand between 21 major cities (each one representing a country) within the Middle East region. The demand matrix represents the estimated passenger flow between each pair of airports on an average day during the peak season. In Section 3 we discuss multi-hub and spoke (HS) networks that could be developed in the Middle East, drawing on the estimated demand matrix and utilizing the p-hub median formulation (O'Kelly, 1987). Finally, Section 4 discusses the specific findings with respect to the Middle East region and Section 5 presents general conclusions and avenues for future research.

2. Estimating air-travel demand

Our point of departure is the assumption that the current political situation in the Middle East has a strong negative impact on the regional air-transport industry. This may take various forms of which one is to hamper trade between neighbors. Israel, for instance, does not trade with most of the Arab countries, while the intra-Arab trade volume is very low compared to intra-regional trade in other areas of the world (Fischer, 1992; Halbach et al., 1995). Moreover, it is clear that regional and international tourism as well as incoming foreign direct investment (FDI) are discouraged by the current situation in the Middle East. However, if we are to learn from the experience of Western Europe after the end of World War II, it seems that once peace reigns, international trade, tourism and FDI are all expected to grow significantly. This expectation is supported by: (1) various estimations regarding a substantial growth in Israeli-Arab trade under conditions of peace in the region (Hashai, 2000, 2003, 2004; Hirsch and Hashai, 2000) and in the recent past (IATA International Traffic Statistics, 2005); (2) the growth that was experienced in international and regional tourism and in FDI during the first half of the 1990s when the Middle East peace euphoria was at its peak (Economist Intelligence Unit, 2000); and (3) infrastructure and industrial projects that may become viable once the area achieves calm (Ben Shahar et al., 1989; Government of Israel, 1997). Further assuming that peace may be a significant catalyst to growth in both leisure and business air-travel, permitting liberalization of the regional air-transport industry, we aim to investigate the patterns of passenger flow and their potential impact on specific airports in the region.

We have estimated the potential demand for inter-regional air travel in the Middle East using a regression model, which enables us to construct a passenger demand matrix between 21 major airports within the Middle East region. Since current air travel demand in the Middle East is assumed to be distorted due to unease in the region, we chose to analyze the existing demand in Western and Eastern Europe in order to identify the most relevant factors and parameter values explaining air traffic flow. Europe was deemed the most appropriate for this type of analysis since it contains countries that significantly differ in their per capita income levels and have undergone varying levels of liberalization, similar to that of the Middle East. The regression model contains various generative and impedance variables as discussed in the original gravity model literature (Doganis, 2002). Population sizes at both the origin and destination adjusted by the purchasing power and nature of economic activity of the population were considered important generative variables. Geographical distance was considered a major impediment to air traffic flow together with "commercial" and "economic" distance. For reasons of simplicity and data availability, we have chosen to focus on one major airport in each country that is assumed to absorb virtually all intra-regional air traffic demand. This was assumed in order to better accommodate our aim of predicating air traffic flows at the country level. It is noteworthy that, while several countries in Western Europe (e.g. the UK, France, Germany) have more than one major airport, many other countries, in particular in Eastern Europe and the Middle East rely solely on a single airport that generates most international air traffic movements.

Taking into account the various generative and impedance variables discussed, we contend that passenger flow between each pair of airports (countries) may be analyzed as shown in Eq. (1).

$$\mathrm{PF}_{ij}^{\frac{1}{4}} = k + (\mathrm{POP}_i * \mathrm{POP}_j) + (\mathrm{GDP}_i * \mathrm{GDP}_j) + \mathrm{EU} + \mathrm{WTO} + \Delta\mathrm{GDPC}_{ij} + \mathrm{GCD}_{ij} \qquad (1)$$

In Eq. (1), *i* and *j* denote a pair of countries. PF_{ij} denotes the passenger flow between the major airports of country *i* and country *j*; POP_i and POP_j denote the population size of the countries. The product of population size in *i* and *j* is expected to be a generative predictor of passenger flow between the countries. GDP_i, and GDP_j denote the Gross Domestic Product of both countries. The product of these variables is expected to be another generative predictor of passenger flows, this time taking into account the purchasing power of each country. Commercial distance presents an indication of the level of potential bilateral business transactions between two countries in order to capture business oriented air travel. We identified and collected information on two variables that will act as proxies measuring commercial distance; one was a dummy variable that indicates whether both countries are members of the European Union (EU) and the other was a dummy variable that indicates whether both countries are members of the World Trade Organization (WTO).

Finally, Eq. (1) contains two impedance variables.GCD_{ij} represents the great circle distance between the airports of the two countries and $\Delta GDPC_{ij}$ denotes economic distance represented by the absolute difference between the per-capita income of country *i* and country *j*. $\Delta GDPC_{ij}$ is expected to be negatively correlated to trade flows and consequently to business oriented air-traffic flows based on the Linder (1961) effect that predicts a larger volume of trade between countries with similar income levels.

It should be noted that while variables such as total air traffic at each of the airports/cities concerned and airfares are frequently chosen in aviation related traffic estimation models (Doganis, 2002), we have not included these variables.[1] Since we assume that current air traffic in the Middle East is distorted, we could not base our predictions on these variables. Based on similar logic, we could not use tourism data as a predictor of passenger flows in the Middle East. While tourism may increase significantly once peace reigns in the Middle East, current tourism data are naturally highly affected by the political situation thus cannot be used to estimate future passenger flows in the region. We therefore reverted to using population size, GDP, geographic distance and economic distance as our explanatory variables. Other variables, such as the airfare between two nodes, the competition at route level and total number of airlines serving the route, would likely help to explain passenger demand flows, however this data was not available or not relevant in the current climate.

Overall, while dynamically specified time series models have advantages over the static approach we have chosen, considering the nature of the data we at present possess (see Section 4) and the currently distorted Middle Eastern air traffic demand, we believe that our model is sufficient to provide a conservative estimate of future Middle Eastern air transport needs.

3. Identifying hub and spoke networks

One of the key strategies of airlines, in order to be profitable, is the choice of network. An 'open skies' deregulation agreement permits airlines to set prices and quantities freely. Under such

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[1] We did analyze passenger flow in Europe using the total traffic flow variable at the relevant airports in place of population size, but found little difference in the explanatory power of the model, as opposed to Doganis (2002).

market conditions, we assume that the airlines will have cabotage rights authorizing them to carry passengers from one country in the region to any other, hence permitting the airlines freedom to develop any network in the region based on purely economic grounds.

It has been shown in many research papers and in the real world that a hub and spoke (HS) network ensures not only profit maximization but entry deterrence too (Button, 2002). Bailey et al. (1985) argued that in a long-run equilibrium "*…a large portion of city-pair markets cannot support convenient nonstop service, [thus] hub-and-spoke operations should continue to be a major networking strategy of air carriers*". Bailey et al. also argued that load factors were likely to rise, restricted discount and leisure fares would vary with demand, specialist carriers would serve distinct types of passengers and that "*deregulation is leading to a substantially more efficient airline system*". Oum and Yu (1997) stated that the US aviation industry is among the most efficient in the world, partly due to the fact that the US was the first to deregulate its aviation industry. Morrison and Winston (1986, 1995) examine the effects of deregulation and competition on the US air transport market. The latter treatise argued that "*the vision of greater public welfare springing from minimal government intervention in the air transportation market has been supported by events and by what one can see of the future*". They pointed out that whilst there are fewer national competitors, the carriers compete more frequently at the route level. In addition, they reached the conclusion that deregulation led to 22% lower fares than would have been the case had regulation continued. Based on an analysis of the North Atlantic aviation market, Maillebiau and Hansen (1995) concluded that US market reform resulted in significant benefits to passengers in the form of substantial traffic growth and fare reduction. On the supply side, liberalization resulted in cost reductions too, though not all carriers fully realized concurrent higher profits. To conclude, there is an extensive economic literature that evaluates the cost, marketing and competitive advantages associated with the hubbing phenomenon (e.g. Caves et al., 1984; McShan and Windle, 1989; Brueckner and Spiller, 1994; Nero, 1999; Barla and Constantatos, 2000; Pels et al., 2000; Brueckner and Zhang, 2001; Adler, 2005).

Based on the demand matrix, calculated according to the variables described in Section 2, we will investigate multi-hub and spoke networks that could be developed in the Middle East. An example of a single-allocation HS network configuration is given in Fig. 1, in which nodes (airports) 4 and 5 represent hubs to which all other airports are connected.

In order to analyze potential HS networks, we utilize the standard p-hub median problem first formulated in O'Kelly (1987). The p-hub median problem determines the optimal location of hubs

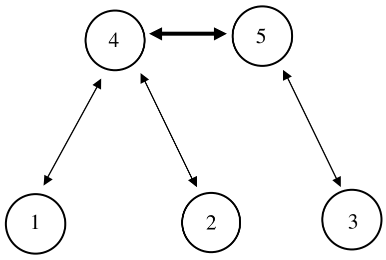

Fig. 1. Hub-and-spoke network configuration.

within a network and the allocation of demand nodes to hubs such that the demand weighted cost traveled in a network is minimized. It should be noted here that the p-hub median problem is quadratic in nature due to the multiplication of decision variables in the objective function. The formulation has proven exacting to solve (Campbell, 1994a; Bryan and O'Kelly, 1999). The most important breakthroughs so far appear to be Campbell (1994b, 1996), in which the problem was linearized and solved for up to approximately 40 nodes; the tabu search procedure described in Skorin-Kapov and Skorin-Kapov (1994); and more recently the adjusted mixed integer linear program in Ebery (2001). In summary, an exact solution can be found for around 40 nodes and a heuristic solution can be found for approximately 200 nodes, with a small number of hubs. Hence, optimal solutions to the Middle East region with 21 major airports can be found using a tightened form of Campbell's integer linearization (1994b, 1996).

Next, we present the data, decision variables and model for computing optimal hubs in a network.

Data:

N	set of all nodes in the network
H	set of all potential hub locations in the network, $H \subseteq N$
PF_{ij}	passenger flow from node $i \in N$ to node $j \in N$ (passengers per time period)
c_{ij}	cost per passenger to travel from node $i \in N$ to node $j \in N$
α	cost reduction factor on links between hubs
P	number of hubs to locate

Decision variables:

X_j	1 if hub is located at node $j \in N$;	0 otherwise
Y_{ih}	1 if node $i \in N$ is connected to hub $h \in H$;	0 otherwise

$$\mathrm{Min} \sum_{i \in N} \sum_{h \in H} c_{ih} Y_{ih} \left(\sum_{j \in N} \mathrm{PF}_{ij} \right) + \sum_{h \in H} \sum_{i \in N} c_{hi} Y_{hi} \left(\sum_{j \in N} \mathrm{PF}_{ji} \right) + \alpha \sum_{i \in N} \sum_{j \in N} \sum_{h \in H} \sum_{m \in H} \mathrm{PF}_{ij} c_{hm} Y_{ih} Y_{jm} \tag{2}$$

subject to

$$\sum_{h \in H} Y_{ih} = 1 \quad \forall i \in N \tag{3}$$

$$\sum_{h \in H} X_h = P \tag{4}$$

$$Y_{ih} - X_h \leqslant 0 \quad \forall i \in N, \ h \in H \tag{5}$$

$$X_h = \{0, 1\} \quad \forall h \in H \tag{6}$$

$$Y_{ih} = \{0, 1\} \quad \forall i \in N, \ h \in H \tag{7}$$

The objective function (2) minimizes the total, demand-weighted cost associated with P hub location decisions and the assignment of nodes to hubs. The first two terms in (2) compute the cost of flow between spokes and hubs and the last expression computes a discounted cost of hub-to-hub flows, based on the assumption that all hubs are completely connected. Constraint (3) specifies that all spokes must be connected to precisely one hub; constraint (4) states that there must be exactly P hubs; constraint (5) restricts the assignment problem to chosen hubs alone; the last two constraints (6) and (7) specify that both the location and allocation variables are binary. Hence, the costs of flying between nodes i and j are given by c_{ij}, with flights between two hubs being discounted by a parameter α, to account for economies of density between hubs. Eqs. (2)–(7) present a single allocation model in which each spoke is connected to precisely one hub. The multiple allocation model will also be solved, in which case Y_{ih} is a linear variable and spokes may be connected to any combination of the chosen hubs.

Little attention in the literature has focused on the value of the cost function, c_{ij}. Swan and Adler (2003) found that trip length and the number of seats on an aircraft, are the two main factors affecting aircraft trip costs. For purposes of computation in this research, parameters were computed for medium to short haul markets and separately for long haul markets, i.e. trips equal to or more than 5000 km. The costs include pilot and crew wages, fuel, capital, maintenance and station charges, on a cost-per-seat basis, irrespective of whether the seat is filled or not. The parameter computation is based on worldwide data and can be used with little adjustment in the analysis of the Middle East. The short haul and long haul equations are presented in Eqs. (8) and (9) respectively.

$$C = (\mathrm{GCD} + 722) * (S + 104) * \$\,0.0199 \tag{8}$$

$$C = (\mathrm{GCD} + 514) * (S + 143) * \$\,0.0255 \tag{9}$$

whereby C represents the aircraft trip cost, based on design seat count, S, and trip distance, GCD.

4. Data and findings

The required data, detailed in the previous sections, was primarily taken from a database that was constructed by the Boeing Corporation. The Boeing Corporation has kindly agreed to share this information with the authors of this study for academic purposes only. The database includes average daily demand in May, 2000 in terms of passengers traveling between every airport in Western and Eastern Europe. It also included most of the explanatory socio-economic variables required for both Western and Eastern Europe and the Middle East. More specifically the database contained data on: population size and Gross Domestic Product (GDP) per country in 1999, as well the as great circle distance between pairs of airports. In addition, we collected data on countries that were members of the EU and countries that were members of the WTO in 1999 (World Trade Organization, 2000).

When collecting data on passenger flow, it is necessary to consider airports between which there is currently no air travel, for purposes of forecasting accurately. Such data indicates potentially low demand between the pairs of airports concerned and is therefore necessary in order to capture the full effect of the socio-economic variables to be examined. Thus, we also included data indicating a null demand for all airports between which there was no recorded air travel. Since we decided to look only at inter-country demand, when analyzing Europe we considered only one major airport in each country, resulting in the computation of air traffic (in terms of passengers) between pairs of countries hence our calculations ignore intra-country passenger flows. Our rule of thumb was to choose the airport that had the highest air traffic volume per country in the year 2000.

Next, we present the results of the demand forecasting model described in Section 2. The parameters relate to 36 Western and Eastern Europe countries and contain 629 observations on daily, average, high season passenger flows between these countries. The parameters calculated for Europe were then used to compute potential demand between every two countries in the Middle East.

We employed an Ordinary Least Squares (OLS) regression in order to compute the coefficients of the explanatory variables of the model detailed in Eq. (1). The model is a linear-transformed regression model. Table 1 details the coefficients of the explanatory variables, the T-values and significance levels.

In order to ensure a normal distribution of the dependent variable in this model (hereinafter the transformed linear model), PF_{ij} was raised by a power of 0.25. The Kolmogorov–Smirnov test confirmed the normal distribution of the transformed variable. Table 1 indicates that in the transformed linear model all the explanatory variables are statistically significant ($p < 0.05$) and affect the dependent variable (passenger flow) in the expected direction,[2] with an adjusted R^2 of 0.625. The variables that contribute most to explaining transport flows (in terms of the standard coefficients) are: the difference in GDP per capita and the population size at both origin and destination.

Based on the coefficients detailed in Table 1 the passenger demand matrix for 21 Middle Eastern based countries was calculated. The countries included in the database, and the estimated passenger demand, are presented in Appendix A. Summation of the passenger flows reveals that the total average daily passenger flow between all 21 countries is expected to reach over 16,800 per day during the peak season. This is an increase of 51% compared to current passenger flows between these countries. On average, passenger flows between the 21 countries analyzed are expected to grow by 27.66 passengers per day. Hence, our results demonstrate the potentially positive impact of deregulating the air-traffic industry in the Middle East.

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[2] A comparison of our model to a gravity model that includes the same variables showed the transformed linear model to be superior to the gravity model in terms of forecasting. We re-computed the parameters of the models using 95% of the Western and Eastern Europe data (randomly selected) and these parameters were then used to predict the passenger flow in the remaining 5% of the observations. Using the goodness of fit test (χ^2), the null hypothesis that there is no difference between the estimated and observed data was rejected for the gravity model but accepted for the linear-transformed model.

Table 1
Regression results of a transformed linear model

Variable	Coefficient	Standardized coefficient	t-Value	Significance
Constant	1.4760		11.854	0.000
$\mathrm{POP}_i * \mathrm{POP}_j$	0.0013	0.413	16.153	0.000
$\mathrm{GDP}_i * \mathrm{GDP}_j$	0.0000	0.211	7.186	0.000
EU	1.6540	0.314	10.779	0.000
WTO	0.7980	0.194	6.962	0.000
GCD_{ij}	−0.0007	−0.183	−7.225	0.000
GDPC_{ij}	−0.0001	−0.500	−1.991	0.047
Adjusted R^2	0.6250			

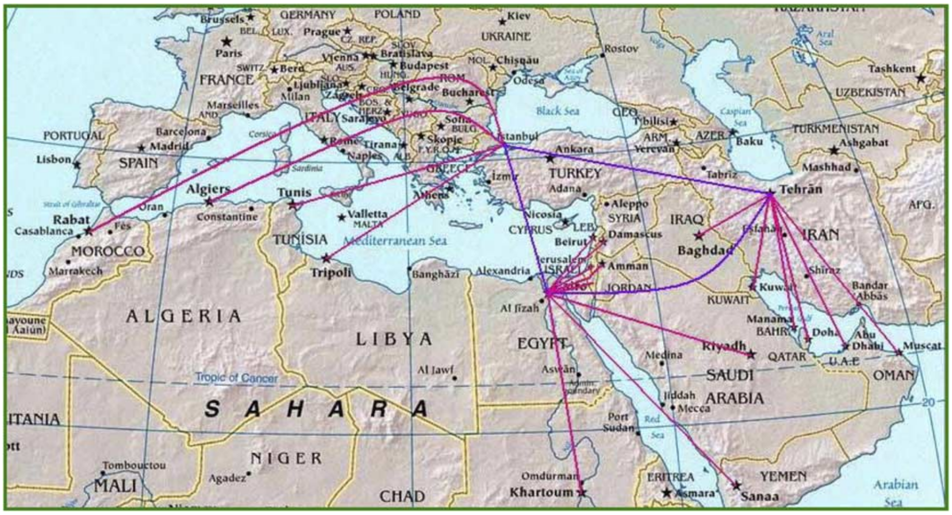

Fig. 2. Typical 21-node network solution for 3 hub, single allocation model.

A typical result of the model (2)–(7), showing both allocation and location decisions, is presented in Fig. 2. Some of the results of the p-hub median problem are presented in Table 2 for the multiple allocation model and in Table 3 for the single allocation model. The sum of costs and the hubs are identified for $p = 2$, 3 and 4 over a range of discount values, α. The results appear robust to changes in the parameter values, single and multiple allocation models and small changes in demand. The three most important hubs appear to be based in Cairo (Egypt), Istanbul (Turkey) and Tehran (Iran), with Riyadh (Saudi Arabia) and Algiers (Algeria) being included as the number of hubs rises. It should be noted that the multiple allocation results were consistently cheaper than the single allocation restricted model and that some results changed for α greater than 0.9, i.e. if there is no discount when flying between hubs, a slightly different combination may be preferable, although the choice was always from within the same subset.

Table 2
Hub location choice based on *p*-hub median multiple allocation model

Seats	Hubs	$\alpha = 0.5$	$\alpha = 0.8$	$\alpha = 1.0$
150	2	Tehran, Istanbul 2.187	Tehran, Istanbul 2.460	Cairo, Istanbul 2.609
	3	Cairo, Tehran, Istanbul 1.584	Cairo, Tehran, Istanbul 2.145	Cairo, Tehran, Istanbul 2.518
	4	Cairo, Tehran, Riyadh, Istanbul 1.452	Cairo, Tehran, Riyadh, Istanbul 2.088	Algiers, Cairo, Tehran, Istanbul 2.504
200	2	Tehran, Istanbul 1.963	Tehran, Istanbul 2.209	Cairo, Istanbul 2.342
	3	Cairo, Tehran, Istanbul 1.422	Cairo, Tehran, Istanbul 1.926	Cairo, Tehran, Istanbul 2.260
	4	Cairo, Tehran, Riyadh, Istanbul 1.304	Cairo, Tehran, Riyadh, Istanbul 1.874	Algiers, Cairo, Tehran, Istanbul 2.248
250	2	Tehran, Istanbul 1.829	Tehran, Istanbul 2.057	Cairo, Istanbul 2.182
	3	Cairo, Tehran, Istanbul 1.325	Cairo, Tehran, Istanbul 1.794	Cairo, Tehran, Istanbul 2.106
	4	Cairo, Tehran, Riyadh, Istanbul 1.214	Cairo, Tehran, Riyadh, Istanbul 1.746	Algiers, Cairo, Tehran, Istanbul 2.094

Each cell specifies the chosen hubs and the objective function costs in millions $US per day.

Table 3
Hub location choice based on *p*-hub median single allocation model

Seats	Hubs	$\alpha = 0.5$	$\alpha = 0.8$	$\alpha = 1.0$
150	2	Tehran, Istanbul 2.342	Tehran, Istanbul 2.772	Cairo, Istanbul 3.050
	3	Cairo, Tehran, Istanbul 1.635	Cairo, Tehran, Istanbul 2.289	Cairo, Tehran, Istanbul 2.723
	4	Cairo, Tehran, Riyadh, Istanbul 1.490	Cairo, Tehran, Riyadh, Istanbul 2.172	Cairo, Tehran, Riyadh, Istanbul 2.624
200	2	Tehran, Istanbul 2.102	Tehran, Istanbul 2.489	Cairo, Istanbul 2.738
	3	Cairo, Tehran, Istanbul 1.468	Cairo, Tehran, Istanbul 2.055	Cairo, Tehran, Istanbul 2.444
	4	Cairo, Tehran, Riyadh, Istanbul 1.337	Cairo, Tehran, Riyadh, Istanbul 1.950	Cairo, Tehran, Riyadh, Istanbul 2.356
250	2	Tehran, Istanbul 1.958	Tehran, Istanbul 2.318	Cairo, Istanbul 2.551
	3	Cairo, Tehran, Istanbul 1.367	Cairo, Tehran, Istanbul 1.914	Cairo, Tehran, Istanbul 2.277
	4	Cairo, Tehran, Riyadh, Istanbul 1.246	Cairo, Tehran, Riyadh, Istanbul 1.816	Cairo, Tehran, Riyadh, Istanbul 2.194

Each cell specifies the chosen hubs and the objective function costs in millions $US per day.

In order to further ascertain the consistency of the results, the North African countries (Algeria, Libya, Morocco and Tunisia) were removed from the dataset and the *p*-hub median formulations re-run. The results in terms of hubs chosen did not differ from those presented in Tables 2 and 3, except for the removal of Algiers from the dataset hence results. Finally, we replaced the demand data drawn from the transformed linear model to that of a gravity model. The gravity model's estimated coefficients and the demand matrix forecast are presented in Appendix B. The demand matrix forecast is substantially different from that presented in Appendix A, with no zero demand between countries (as compared to over 100 zero demand pairs in the case of the transformed linear model). Moreover, the predicted demand in the case of the gravity model is significantly higher, suggesting a potential demand of 19,300 passengers per day (an increase of 73% compared to current passenger flows). This augmented demand explains the increase in the objective function value in the case of the gravity model over that of the transformed linear model (as indicated in Table 4). Furthermore, it should be noted that the *p*-hub median formulation is purely cost-based and assumes that all passengers will be carried. The results presented in Table 4 show a marginal difference in hub choice with Israel entering the subset of potential hubs. The explanation for this change stems from the greater weight that the GDP variable receives and the lower weight the population variable receives in the gravity model as compared to the transformed linear one. This implies that Israel, which is relatively small in its population size but has a relatively

Table 4
Hub location based on *p*-hub median multiple allocation model using gravity model parameters

Seats	Hubs	$\alpha = 0.5$	$\alpha = 0.8$	$\alpha = 1.0$
150	2	Israel, Istanbul 3.424	Israel, Istanbul 3.469	Israel, Istanbul 3.500
	3	Cairo, Tehran, Istanbul 2.934	Cairo, Tehran, Istanbul 3.019	Cairo, Tehran, Istanbul 3.063
	4	Cairo, Tehran, Israel, Istanbul 2.558	Cairo, Tehran, Israel, Istanbul 2.759	Cairo, Tehran, Israel, Istanbul 2.877
200	2	Israel, Istanbul 3.073	Israel, Istanbul 3.114	Israel, Istanbul 3.141
	3	Cairo, Tehran, Istanbul 2.634	Cairo, Tehran, Istanbul 2.710	Cairo, Tehran, Istanbul 2.750
	4	Cairo, Tehran, Israel, Istanbul 2.296	Cairo, Tehran, Israel, Istanbul 2.477	Cairo, Tehran, Israel, Istanbul 2.582
250	2	Israel, Istanbul 2.863	Israel, Istanbul 2.901	Israel, Istanbul 2.926
	3	Cairo, Tehran, Istanbul 2.454	Cairo, Tehran, Istanbul 2.524	Cairo, Tehran, Istanbul 2.562
	4	Cairo, Tehran, Israel, Istanbul 2.139	Cairo, Tehran, Israel, Istanbul 2.307	Cairo, Tehran, Israel, Istanbul 2.405

Each cell specifies the chosen hubs and the objective function costs in millions $US per day.

large GDP compared to its neighbors, may become a viable hub under the gravity model prediction.

5. Conclusions

This research has provided two major contributions to the existing literature: (1) under the assumption of complete deregulation, the mapping and estimation of potential passenger traffic between 21 Middle Eastern airports, given current socio-economic data and (2) the identification of potential hub airports in the region, utilizing the *p*-hub median location formulation. Conclusions drawn from this investigation may enable both researchers and policy makers to develop a greater understanding of the social welfare impacts of deregulation in the regional air-transport industry and the economic benefits to individual air carriers, countries and passengers alike, once peace reigns in the region. Indeed, our analysis has led to the conclusion that the increase in both leisure and business air traffic due to the reduction in violence in the Middle East may lead to an increase of 51% in inter-country passenger flow under the assumption of deregulation of the regional air-transport industry. Taking into account the fact that our calculations are fairly conservative (as we ignore the expected increase in intra-country passenger flow and possible increase in various socio-economic indicators), this observation clearly indicates the economic potential that exists in the region.

It is clear from Appendix A, where we present the estimated passenger flow per day in peak season, that demand between most regional airports is likely to be insufficient to justify direct flights. Consequently, we expect airlines to aggregate demand through the use of hub-spoke networks in order to remain economically viable and not require substantial subsidization. One of the byproducts of choosing an optimal hub-spoke system for an airline is the impact this will have subsequently on the airports chosen as hubs. The liberalization policies that will affect airlines and encourage them to develop such networks in order to accommodate demand, will also lead to economic ties between the countries in the region. This, in turn, ought to help sustain peaceable connections within the region. Consequently, airports chosen as hub bases will need to either increase their size in order to accommodate the additional traffic or put in place demand management techniques of the sort discussed in Daniels (1995) and Adler and Berechman (2002). It should be noted that the impact of liberalization is not clear cut and there has been some discussion on this subject particularly in the European literature, see for example Williams (2002) and Helm and Holt (2003). In Williams it was argued that the volatility of the unconstrained airline sector has led to consistent over-supply and subsequently poor financial results. In Helm and Holt, it is argued that the correct pricing of airport slots, including noise, environmental externalities and peak pricing, may aid the air transport industry to accurately track demand. The output of our study should therefore serve policy makers in future plans for the development of the air-transport industry in the Middle East region.

The identification of Cairo, Teheran, Istanbul and Riyadh as the major potential hubs that could minimize the hub-spoke network costs in the region, is important for both airlines' future plans regarding their development in the Middle East and the relevant government agencies. On the other hand, one should consider the fact that while our findings may be the efficient outcome, they should be interpreted in the context of real life circumstances. For instance, Istanbul's airport is already a significant hub for air-traffic between Europe and the Middle East and between Europe and former USSR countries. Thus, the prediction that Istanbul may become a viable hub appears to have a reasonably strong chance of realization. However, Bahrain is currently trying to become a hub between Europe and Asia as well as a regional hub. Whilst Bahrain was not identified as a potential hub in this study, the fact that it is already making efforts in this direction while other cities are not, may lead to a situation where Bahrain becomes a hub at the expense of other cities (e.g. Teheran or Riyadh). Bahrain's initial advantage in achieving economies of agglomeration may lead to path dependent considerations that will facilitate its efforts in becoming a hub.

The identification of Cairo, Teheran and Istanbul as potential hubs in the region proved robust over several estimation and allocation models. This outcome is interesting in its geo-political implications as it may imply that the economies of Egypt, Iran and Turkey could increase substantially as a result of the end of the conflicts in the area and liberalization of the air-transport industry. While Egypt and Turkey already absorb most of the current air-traffic in the region, Iran is expected to benefit the most from the end of the Middle Eastern conflict. This finding is certainly intriguing bearing in mind the central role Iran is often believed to have in various Middle Eastern conflicts. The same argument may apply to Saudi-Arabia and Algiers that were identified as potential hubs under certain scenarios. Tel Aviv airport in Israel, on the other hand, was not identified as a potential hub based on the demand estimations of the transformed linear regression model (although Israel was identified as a potential hub when the p-hub median formulation was analyzed using the gravity model estimations). This may imply that Israel is not expected to gain much in terms of regional air-transport if and when peace arrives. Policy wise, Israeli authorities may prefer to become part of deregulated European air transport agreements rather than (or in addition to) joining Middle Eastern deregulation treaties.

Potential future directions for this research include analyzing worldwide data in order to assess the most important factors contributing to specific passenger flows. Accurate longitudinal data, as processed in the Unites States, would be extremely helpful. Furthermore, directional demand data (i.e. data on passenger flow from i to j and from j to i) could also yield more accurate passenger flow predictions. Such databases also ought to include ticket prices, number of competitors on a route and the existence of low-cost no-frill carriers. Given such data, it would then be possible to test whether revenue-based hub location and allocation decisions are the same or similar to the cost-based solutions presented in this research. It may also be helpful to widen the analysis in order to consider the competitive solution, i.e. the best response of airlines and airports to the decisions of their competitors (Adler, 2005). Finally, given the dynamic nature of air transport today, it may also be useful to consider the Middle East hub location issue with respect to a global alliance, i.e. both inter-continental as well as intra-continental flows.

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Appendix A: Potential passenger demand per day in peak season

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Algeria	1	120	58	1	0	0	4	0	2	29	2	5	2	1	0	8	309	9	0	0
2	Bahrain		1	0	0	0	0	4	0	0	0	1	10	3	0	0	0	1	3	0	0
3	Egypt			2392	109	40	9	0	5	2	121	0	0	246	92	52	28	4972	0	7	13
4	Iran				181	6	3	0	2	0	13	1	0	288	42	31	1	5608	1	1	10
5	Iraq					0	3	0	1	0	0	0	0	14	2	8	0	194	0	2	1
6	Israel						0	17	1	0	0	0	3	22	0	0	0	195	15	0	0
7	Jordan							0	1	0	0	0	0	0	0	5	0	4	0	4	0
8	Kuwait								0	1	1	0	11	1	0	0	0	2	15	0	0
9	Lebanon									0	0	0	0	4	0	2	0	10	0	1	0
10	Libya										0	0	1	0	0	0	2	8	3	0	0
11	Morocco											7	2	0	0	0	13	248	5	0	0
12	Oman												0	2	0	0	1	0	0	0	0
13	Qatar													1	0	0	0	0	10	0	0
14	Saudi Arabia														5	1	0	969	0	0	2
15	Sudan															1	0	52	1	0	6
16	Syria																0	52	0	4	0
17	Tunisia																	64	1	0	0
18	Turkey																		2	2	4
19	U-Arab Emirates																			0	0
20	Palestinian Authority																				0
21	Yemen																				

Appendix B: Results of a gravity model and potential passenger demand per day in peak season

Variable	Coefficient	Standardized coefficient	t-Value	Significance
Constant	−1.478		−6.079	0.000
$\mathrm{Ln}(\mathrm{POP}_i * \mathrm{POP}_j)$	0.281	0.131	3.125	0.002
$\mathrm{Ln}(\mathrm{GDP}_i * \mathrm{GDP}_j)$	0.641	0.441	9.098	0.000
EU	1.373	0.118	3.545	0.000
WTO	1.804	0.199	6.588	0.000
$\mathrm{Ln}(\mathrm{GCD}_{ij})$	−1.128	−0.171	−5.827	0.000
$\mathrm{Ln}(\mathrm{GDPC}_{ij})$	−0.274	−0.090	−3.060	0.002
Adjusted R^2	0.543			

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	Algeria	1	171	104	43	24	15	5	13	48	170	4	2	43	13	30	136	184	6	13	7
2	Bahrain		43	17	7	26	1	42	2	1	6	3	58	60	1	2	5	54	50	1	1
3	Egypt			401	243	2559	200	175	136	47	524	14	52	274	61	390	363	666	160	231	32
4	Iran				761	101	96	76	58	26	50	33	19	194	34	132	43	445	410	33	30
5	Iraq					79	52	46	47	13	22	11	8	118	18	104	24	253	24	22	14
6	Israel						171	258	236	15	84	7	45	125	14	220	82	1344	268	149	8
7	Jordan							4	41	4	6	2	1	31	5	113	6	73	3	59	3
8	Kuwait								9	3	20	5	59	122	4	10	17	210	177	2	4
9	Lebanon									9	7	6	2	93	6	241	7	139	7	21	4
10	Libya										18	2	1	29	5	14	46	99	3	2	3
11	Morocco											2	7	26	9	42	194	549	25	4	5
12	Oman												4	52	2	4	2	20	30	1	3
13	Qatar													50	1	3	6	64	124	1	2
14	Saudi Arabia														67	46	22	237	43	16	52
15	Sudan															13	6	42	5	3	23
16	Syria																12	188	8	48	8
17	Tunisia																	806	19	3	3
18	Turkey																		208	44	25
19	U-Arab Emirates																			2	6
20	Palestinian Authority																				2
21	Yemen																				

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