Airline-Airport Cooperation in Liberalized Network

Batari SARASWATI[1] and Shinya HANAOKA[2]

[1]Dept. of International Development Eng., Tokyo Institute of Technology
(2-12-1 O-okayama Meguro-ku, Tokyo 152-8550, Japan)
E-mail: batari@tp.ide.titech.ac.jp
[2]Associate Professor, Dept. of International Development Eng., Tokyo Institute of Technology
(2-12-1 O-okayama Meguro-ku, Tokyo 152-8550, Japan)
E-mail: hanaoke@ide.titech.ac.jp

This study analyses the characteristics of airline-airport cooperation, in term of revenue sharing, in hub-and-spoke network and fully-connected network. Liberalization gives opportunity for airlines to expand route, where an airline's decision to expand route will affect its competitors' decision. In this study, airlines' decision in route expansion is modeled as sequential game where airlines expand route if and only if there is profit to do so. We use non-cooperative game theory-network model to maximize airlines' profits where airfare and flight frequency are the variable decisions. Network and revenue sharing are defined exogenously and treated as scenarios.

Key Words : *route expansion, airline-airport revenue sharing, non-cooperative game theory*

1. INTRODUCTION

There are increasing trends of liberalization in airline industry in many parts of the world. Liberalization removes constraints on route entry and allows airlines to expand and optimize their network within and cross country. This pushes airline to compete more effectively and operate more efficiently, which in turn led to substantial economic and traffic growth (Oum et al., 2008).

New routes can strengthen airline's market power and entice customers away from competitors (Burghouwt and Veldhuis, 2006), however they are not costless. For example, airlines need to cover incremental operating costs of new routes, and incur costs in overcoming entry barriers built up by incumbents. Airlines do not necessarily serve all routes that they are allowed to enter after liberalization. An airline's decision in expanding route is highly affected by costs incurred and the revenue earned.

On the other hand, liberalization also creates opportunity for airline to cooperate with airport. Close cooperation brings mutual benefit, for example airlines obtain competitive advantage by securing key airport facilities, and airports receive financial support from airlines and secure business volumes. This is crucial issue for both airlines and airports under the pressure of liberalization and competition.

Cooperation between airlines and airport can take several forms (Fu et al., 2011), such as terminal leases, negotiated aeronautical charges, signatory airline status in airport, airline ownership in airport, and concession revenue sharing. This study focuses on cooperation in the form of concession revenue sharing. In this form of cooperation, the airport offers to share some part of its concession revenue for a fixed fee with one or more airlines. Concession revenue is generated by non-aeronautical activities, including shopping concessions, car parking and rental, and banking and catering. This type of cooperation assumes more importance nowadays with airports being increasingly recognized as full-fledged business enterprises.

This study attempts to analyse the characteristics of airline-airport cooperation, in term of revenue sharing, in hub-and-spoke network and fully-connected network. A fully-connected network is defined as an airline's network with direct route(s) expansion that invades competitor's market, e.g. connecting two hubs between second and third country as a result of liberalization. A term fully-connected network and liberalized network is used interchangebly in this study.

This study is motivated by the forthcoming open sky policy in Southeast Asia. Under the proposed policy, airlines in Southeast Asia are allowed to expand route serving points between second and third country with direct flight. This has been perceived as unattractive since airlines may be reluctant to steer traffic away from their hub (Forsyth et al., 2006).

We modeled airline as a profit maximizing firms.

Airline expand route if and only if it is profitable to do so. Airline's decision in expanding route is studied as sequential game. The game described here consists of set of airlines whose stategy sets include expand or not expand route(s). Then, according to the network expansion strategy, we utilize game theory-network model to optimize airlines' profits. Airlines are assumed to compete with flight frequency and airfare, while passengers minimize their own perceived travel disutility, i.e. generalized travel cost, given airlines' flight frequency and airfare. Revenue sharing with airport, as well as route expansion, will affect airline and airport profit function, and in turn affects airline's optimal frequency and airfare.

The main aim of this study is to examine how airline-airport revenue sharing outcomes, e.g. joint profit and social welfare, differ in hub-and-spoke and fully-connected network. The proportion of revenue shared (r_{in}) is treated as scenarios. The framework of this study is provided in Fig. 1.

The rest of the paper is organized as follows. Section 2 explains model development that includes glossary and model formulation for profit maximization and route expansion. Section 3 gives an application example and analysis of result. Section 4 concludes the study.

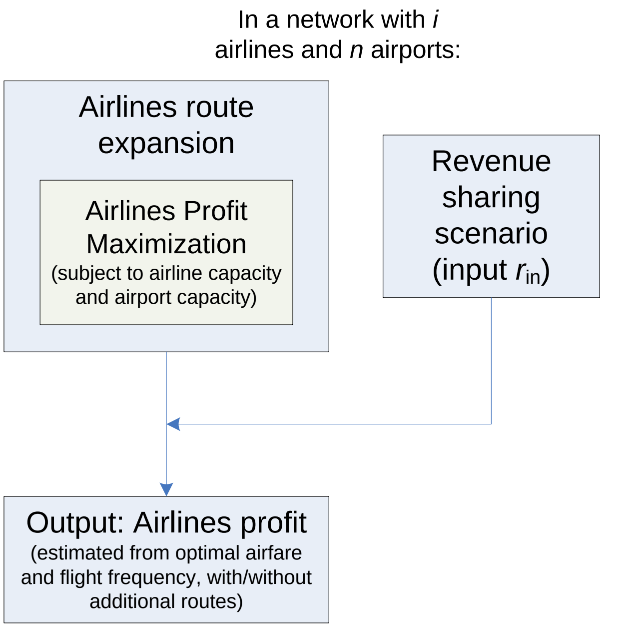


Fig. 1 Framework

2. MODEL DEVELOPMENT

(1) Glossary

I	Set of airlines in network
N	Set of airports
M	Set of origin-destination (OD) in network
K	Set of routes serving each OD
q^0_m	Potential passenger demand on OD *m*
q_m	Resultant passenger demand on OD *m*
φ_m	Expected disutily on OD *m*
q_{imk}	Passenger flow of airline *i* on OD *m* route *k*
u_{imk}	Passenger travel disutility of airline *i* on OD *m* route *k*
d_{imk}	Schedule delay of airline *i* on OD *m* route *k*
t_{imk}	Travel time of airline *i* on OD *m* route *k*
tr_{imk}	Transit time of airline *i* on OD *m* route *k*
p_{imk}	Airfare of airline *i* on OD *m* route *k*
f_{ia}	Flight frequency of airline *i* on arc *a*
s_{ia}	Aircraft size used by airline *i* to serve arc *a*
c_{ia}	Cost/available seat-km for airline *i* on arc *a*
q_{ia}	Passenger flow of airline *i* on arc *a*
d_{ia}	Schedule delay of airline *i* on arc *a*
t_{ia}	Travel time of airline *i* on arc *a*
α	Parameter to convert schedule delay to travel time
α_{vot}	Passenger's value of time
θ	Parameter represents variation in passenger perception of travel disutility
β	Demand sensitivity to travel disutility
T	Operating hours of airport
D_a	Flight distance of arc *a*
LC_{in}	Landing charge in airport *n* for airline *i*
PC_{in}	Passenger charge in airport *n* for airline *i*
PCt_{in}	Transit passenger charge in airport *n* for airline *i*
λ_{mka}	0-1 variable, equals 1 if arc *a* is on OD *m* route *k*
$\lambda_{mkn(o)}$	0-1 variable, equals 1 if airport *n* is origin airport on OD *m* route *k*
$\lambda_{mkn(t)}$	0-1 variable, equals 1 if airport *n* is transit airport on OD *m* route *k*
$\lambda_{an(o)}$	0-1 variable, equals 1 if airport *n* is origin airport on arc *a*
$\lambda_{an(d)}$	0-1 variable, equals 1 if airport *n* is destination airport on arc *a*
$y_{n(o)}$	Maximum number of departure flights in airport *n*
$y_{n(d)}$	Maximum number of landing flights in airport *n*
π_i	Profit of airline *i*
Π_n	Profit of airport *n*
r_{in}	Proportion of airport's *n* concession revenue being shared to airline *i*
h_{in}	Concession surplus per airline's *i* passenger in airport *n*
b_{in}	Payment to be made by airline *i* to airport *n* for the revenue share received

(2) Airline profit optimization

A network model allows us to assess several co-operation scenarios based on the firms involved. Revenue shares (r_{in}) are determined for every scenario, where $0 \le r_{in} \le 1, \forall i \in I$ (an airline can receive a maximum 100% revenue share from every airport) and $\sum_i r_{in} \le 1, \forall n \in N$ (a total revenue share in every airport is 100%).

Airline market share estimation and airline profit maximization in the downstream market are formulated as follows. In this model, airlines are assumed to offer similar services, and passengers make airline and route choice based on travel disutility of all routes.

a) Airlines market share

We estimate the airline market share with a multinomial logit model, following Takebayashi and Kanafani (2005) and Li et al (2010). It is estimated based on passenger perceptions over travel disutility of airlines routes. The components that define travel disutility (u_{imk}) are assumed as basic airfare before taxes and surcharges (p_{imk}), monetary units of travel time (t_{imk}), scheduled delay time (d_{imk}), and connection time (tr_{imk}). For a direct route, tr_{imk} = 0. Parameter θ represents the variation in passenger perceptions of travel disutility, α_{vot} the value of time, and α a parameter to convert passenger schedule delay time to equivalent travel time units.

The travel time for a route is the sum of travel times for all its arcs; λ_{mka} equals 1 if arc/flight leg a is on route k and OD m, and 0 otherwise. Passenger scheduled delay time is defined as the difference between the time at which a passenger desires to travel and the time at which he or she can actually travel because of the inflexibility of the airline's schedule. It can be approximated as a quarter of the average headway (Kanafani and Ghobrial, 1985); f_{ia} denotes the flight frequency of airline i in leg a.

Every airline serves certain ODs and routes based on its commercial rights governed by the ASA, so that in the equations below, $(m, k) \in (M, K)^i$ and $a \in A^i$ apply.

$$u_{imk} = \alpha_{vot}(t_{imk} + \alpha d_{imk} + tr_{imk}) + p_{imk} \quad (1)$$

$$d_{imk} = \sum_a d_{ia}\lambda_{mka} \quad (2)$$

$$t_{imk} = \sum_a t_{ia}\lambda_{mka} \quad (3)$$

$$d_{ia} = \frac{T}{4 f_{ia}} \quad (4)$$

$$q_m = q_m^0 \exp(-\beta\varphi_m) \quad (5)$$

$$\varphi_m = -\frac{1}{\theta}\left[\ln \sum_i \sum_k \exp(-\theta u_{imk})\right] \quad (6)$$

$$q_{imk} = q_m \frac{\exp(-\theta u_{imk})}{\sum_k \sum_i \exp(-\theta u_{imk})} , \quad (7)$$

$$q_{ia} = \sum_{(m,k)} q_{imk}\lambda_{mka} \quad (8)$$

The exponential demand function is used to capture passenger response to airfare and frequency levels. Variable q^0_m denotes the potential passenger demand for OD m. Parameter β denotes demand sensitivity to travel disutility by OD, and φ_m denotes the expected disutility on OD m. From Eq. (7) and (8), we can obtain passenger flow on every route (q_{imk}) and every leg (q_{ia}).

b) Airlines profit maximization

Airline profit is defined as the sum of profits from flight service and concession revenue sharing with the airport. Profit from flight service is based on revenues from passenger airfares and operating costs. Profit from concession revenue sharing is determined by r_{in}, the airport concession revenue share given to the airline.

For set (r_{in}, $\mathbf{r_{-in}}$), profit of airline i can be expressed as follows:

$$\begin{aligned}\pi_i(\mathbf{x_i}, \mathbf{x_{-i}}) = & \sum_{(m,k)} p_{imk}q_{imk} \\ & - \sum_{(m,k)} \sum_n (PC_{in}q_{imk}\lambda_{mk}^{n(o)} + PCt_{in}q_{imk}\lambda_{mk}^{n(t)}) \\ & - \sum_a \left[c_{ia} f_{ia} D_a s_{ia} + \sum_n LC_{in} f_{ia} \lambda_a^{n(d)} \right] \\ & + \sum_n \left[r_i^n h_i^n (\sum_i \sum_{(m,k)} q_{imk}\lambda_{mk}^n) - b_i^n(r_i^n, \mathbf{r_{-i}^n}) \right] \end{aligned} \quad (9)$$

where $\mathbf{x_i} = (\mathbf{p_i}, \mathbf{f_i})$ is a vector of airfare and frequency of airline i and $\mathbf{x_{-i}} = (\mathbf{p_{-i}}, \mathbf{f_{-i}})$is a vector of airfares and frequencies of other airlines, excluding i.

Operating costs are estimated based on airline cost per available seat-kilometer on every flight leg (c_{ia}), where D_{ia} and s_{ia} are flight distance and aircraft seat capacity, respectively, on leg a. This estimation is based on the generally linear relationship between airline operating costs and distance, as has been shown by Swan et al. (2006). Additional costs result from payments made by airlines in the form of airport landing and passenger charge. Landing charge (LC) paid to the arrival airport is based on maximum take-off weight, defined by airline type. Passenger charge (PC) is paid to the departure airport. Passenger transfer charge (PC_t) is paid at subsequent hubs when the passenger is carried on two or more legs. This pricing system, also followed in Adler (2001), is in line with most international airport rules. LC and PC can be modified to include other relevant charges, such as handling and noise charges. The binary variable $\lambda^{n(o)}_{mk}$ equals 1 if airport n is the origin airport in OD m route k, and 0 otherwise.

Profit from concession revenue sharing is estimated as concession shares (r_{in}) multiplied by concession surplus per passenger (h_{in}) and total number of passengers in the partner airport. Variable b_{in} represents the payment to be made by the airline to the airport for the revenue share received. The payment has to be less than the reservation price. The reservation price is the maximum payment that the airport can charge when the airline is indifferent between sharing revenue and not doing so, given all the other airlines' and airports' decisions remain unchanged (Fu and Zhang, 2010).

$$b_{in}(r_{in},\mathbf{r}_{-\mathbf{in}}) < \pi_i^{C}(r_{in},\mathbf{r}_{-\mathbf{in}}) - \pi_i^{0}(0,\mathbf{r}_{-\mathbf{in}}) \quad (10)$$

$$\pi_i^{C}(\mathbf{x_i},\mathbf{x_{-i}}) = \sum_{(m,k)} p_{imk}q_{imk} - \sum_{(m,k)}\sum_{n}(PC_{in}q_{imk}\lambda_{mk}^{n(o)} + PCt_{in}q_{imk}\lambda_{mk}^{n(t)}) - \sum_{a}\left[c_{ia}f_{ia}D_a s_{ia} + \sum_{n} LC_{in}f_{ia}\lambda_a^{n(d)}\right] \quad (11)$$

Airlines maximize their profit under the Cournot-Nash non-cooperative game assumption. The maximization problem is subject to several constraints. The first constraint ensures the passenger flow on every leg is less than total seat capacity offered. The second and third constraints ensure the total number of arrivals/departures must not exceed the available quota of the destination/origin airports.

$$\text{Max}\,\pi_i(\mathbf{x}_i,\mathbf{x_{-i}}),\ \forall i \quad (12)$$

subject to

$$q_{ia} \le s_{ia}f_{ia}, \quad \forall\ m,k,a,i \quad (13)$$

$$\sum_i\sum_a f_{ia}\lambda_a^{n(d)} \le y_{n(d)},\ \forall n \quad (14)$$

$$\sum_i\sum_a f_{ia}\lambda_a^{n(o)} \le y_{n(o)},\ \forall n \quad (15)$$

The Lagrangian relaxation approach and penalty function are utilized to solve the airline's profit maximization problem (see the appendix), where the constraints are integrated with the objective function. To find the equilibrium solutions for airfares and service frequencies, we use a heuristic solution algorithm utilizing the Hooke-Jeeves method, following Li et al. (2010). We solve the unconstrained augmented Lagrangian function separately and sequentially, using the Hooke-Jeeves method; auxiliary fare and frequency patterns are then generated. If all constraints are satisfied, we terminate the optimal solution; otherwise, we update the Lagrange multipliers and the penalty constant.

The airport profit function is estimated as the total income from aeronautical and concession activities (Eq. 16). It should be noted that we maximize the airline profit functions, with the airport profits being the by-product of the results.

$$\Pi_n = \sum_i\sum_{(m,k)}\sum_a LC_{in}f_{ia}\lambda_{mka}^{n(d)} + \sum_i\sum_{(m,k)} PC_{in}q_{imk}\lambda_{mk}^{n(o)} + PCt_{in}q_{imk}\lambda_{mk}^{n(t)} + (1-\sum_i r_{in})(\sum_i\sum_{(m,k)} q_{imk}\lambda_{mk}^{n}h_{in}) + \sum_i b_{in}(r_{in},\mathbf{r}_{-\mathbf{in}}) \quad (16)$$

(3) Route expansion

The route expansion is looked into as a means of expanding the existing networks and starting new routes. The algorithm to determine whether airline decision on route expansion is as follows. The basic idea is to check the feasible network allocation strategies for I airlines one at a time for each airline while holding the route allocation strategies for other airlines fixed. The step-by-step procedure is described as follows.

Step 1. Initialization ($t = 0$)
Define initial feasible solution for each of the airlines. Calculate airline profits in original network: π_i ($t = 0$)

Step 2. Airline loop ($t = t + 1$). Set airline counter to $i = 1$ (start from the first airline in the sequence).

Step 2.1. Network loop**.** For airline i check all additional arc sequentially, one arc at a time while holding the network of other airlines fixed. Set the arc counter $j = 1$

Step 2.2. Solve airline market share sub-model (use Eq. 1–15) to obtain optimal airfare: $\mathbf{p}^*_{(j)}$ and frequency pattern: $\mathbf{f}^*_{(j)}$ and the responding passenger flow: $\mathbf{q}_{(j)} = \{q_{imk\ (j)}\}$. Then calculate airlines' profit: $\boldsymbol{\pi}_\mathbf{i}$ ($t = 1$).

Step 2.3. Termination check for network loop. If $\pi_{i\,(t)} - \pi_{i\,(t-1)} > 0$, then put $\mathbf{p}^* = \mathbf{p}_{(j)}$ and $\mathbf{f}^* = \mathbf{f}_{(j)}$, $j = j + 1$ and go to Step 2.1. Otherwise, set $j = j + 1$ and go to Step 2.1. If $j > \overline{A}$, go to Step 3.

Step 3. Termination check for airline loop. If $i > \bar{I}$ then terminate the algorithm and output the optimal solution. Otherwise, set $i = i + 1$ and $t = t + 1$ and go to step 2.

Under this algorithm, airline's decision is checked sequentially. The first mover decides and the second firm will then decide based on first mover's decision. In this sense, each airline's decision is locally optimal and a global optimum solution is not guaranteed. Furthermore, different airline sequence may result in different solution, therefore we test all possible combination of airline sequences.

3. MODEL APPLICATION

(1) Example of Application

To illustrate the concepts presented in this paper, we present an example using a simplified network with three airlines and three airports in Southeast Asia (as shown in Fig. 2). In this case, GA's hub is CGK, MH's hub is KUL, and TG's hub is BKK.

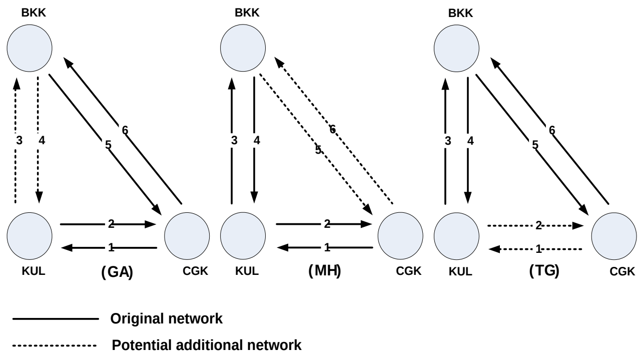


Fig. 2 Airline network

All our input parameters are based on real market data, where possible. Flight distance and duration are listed in Table 1. Cost per available seat-kilometer for all airlines is \$0.08. The actual cost per ASK of airlines GA, MH, and TG are \$7.61 cents (\$0.076), 0.248 ringgit (\$0.081), and 2.575 baht (\$0.084), respectively, as listed in the airlines' 2011 annual reports. Landing charges for international flights with narrow-body aircraft in CGK, KUL, and BKK are \$397.96, \$229.28, and \$412.64, respectively, while passenger charges for international flight are \$15, \$20, and \$22, respectively. Data of landing charges and passenger charges is obtained directly from each airport, either from airport's website or direct interview. We assume all airlines use narrow-body aircrafts with 170 passenger seats in the network. Flight distances between CGK–KUL, KUL–BKK, BKK–CGK are 1125, 1214, 2286 km, while the flight durations are 2, 2 and 3.43 hr, respectively.

We assume potential demand between airport pairs is 3000 passengers/day, one-way. Potential OD demands are different from one airport pair to another in reality. Potential demand of 3,000 passengers/day is a rough approximation from annual traffic data of KUL to CGK (2.944 million passengers in 2011) obtained from the CEIC database. Potential OD demand represents the number of people who wish to travel from the point of origin to destination, although they do not necessarily travel because of the disutility (time and monetary cost). Other input parameters are obtained from earlier studies: $\alpha_{vot} = 20.5$ \$/hour and $\alpha = 1.3$ (Hsu and Wen, 2003); $\theta = 0.02$ (Takebayashi and Kanafani, 2005); $\beta = 0.003$ (Li et al., 2007), and $T = 18$ hours.

(2) Result and Discussion

a) Route expansion

Different airline sequence may result in different solution, and we test all possible combination of sequences (see Table 1). Airlines are assumed to expand route if it is profitable to do so.

Table 1 Airlines' resultant profits (\$ 10^5)

	GA	MH	TG
$t = 0$	1.7518	2.4436	1.7266
GA-MH-TG	1.6986 (E)	1.4483 (NE)	1.6851 (E)
MH-GA-TG	1.6986 (E)	1.4483 (NE)	1.6851 (E)
MH-TG-GA	1.6074 (E)	1.414 (NE)	1.59 (E)
TG-GA-MH	1.6074 (E)	1.414 (NE)	1.59 (E)

Note: Resultant of GA-MH-TG sequence is similar with GA-TG-MH, while resultant of TG-GA-MH is similar with TG-MH-GA. (E) denotes "expand routes", while (NE) denotes "does not expand route".

Table 2 Profits in GA-MH-TG sequence (\$ 10^5)

	GA	MH	TG	Decision
$t = 0$	1.7518	2.4436	1.7266	-
$t = 1$	**2.1674**	1.9140	1.1444	GA expands
$t = 2$	1.7389	**1.9059**	0.9355	MH does not
$t = 3$	1.6986	1.4483	**1.6851**	TG expands

Assuming that GA incurs no cost in association with its entry in KUL-BKK in the first sequence, GA will earn positive profit from this entry. As GA serves direct flight between KUL-BKK, it gains more profit. Meanwhile, profits of MH and TG are reduced as there is a new competitor (i.e. GA) taking away passengers in their market (see Table 2). TG can recoup some lose profit by also expanding route, i.e. serving direct flight between KUL-CGK. This all in turn reduces all airlines' profit. In this situation, neither carrier actually ends up having incentives to add route connecting other airlines' hubs.

Network structure of airlines influences the result of route expansion. MH always chooses not to expand regardless of the sequences (see Table 1). This is due to the geographical location that makes it favorable for MH to offer indirect flight between BKK and CGK via its hub, KUL. Utilizing a fully connected network is less profitable for MH than utilizing hub-and-spoke network. MH's profit gets reduced the most as result of route expansion.

There has been other studies regarding hub-and-spoke network and market invasion. Zhang (1996) proved that in a market where economies of density is important, entry into a competitor's local markets will reduce the entry firm's profit in its own hub-and-spoke network. This is triggered by more aggressive behavior by the rival firm in the connecting market where two carriers engage in trans-hub competition. The entry firm's output in the trans-hub falls thus reduces the traffic thoroughout its own hub-and-spoke network. The traffic reduction may lower the profit the entry firm can derive from its own network, giving negative network effect of the local entry.

Table 3 Airport Profit, Consumer Surplus, and Social Welfare

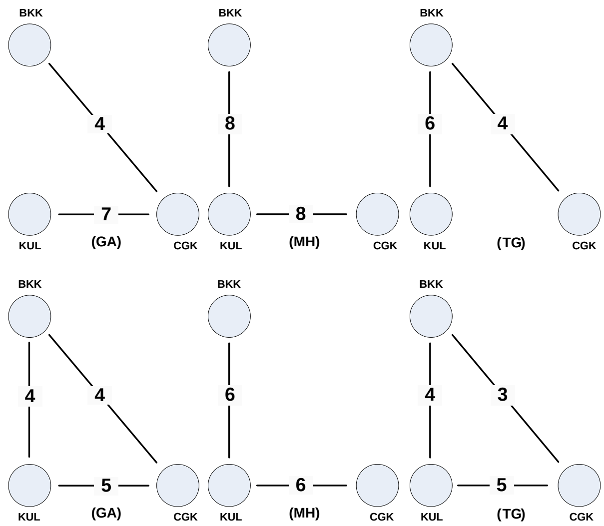
	AP ($ 10^5)	CS ($ 10^5)	SW ($ 10^5)
t = 0	13.5420	36.0280	55.492
GA-MH-TG	14.1975	37.7985	56.828
GA-TG-MH	14.1975	37.7985	56.828
MH-GA-TG	14.1975	37.7985	56.828
MH-TG-GA	14.2585	38.0051	56.875
TG-GA-MH	14.2585	38.0051	56.875

Social welfare increases with route expansion. Social welfare in this study is defined as sum of all airlines' profits, airports' profits, and consumer surplus. Social welfare increases as both airport profits and consumer surplus increase (see Table 3). This is triggered by lower airfare so that more travelers are attracted. Total number of passengers in original network is 11,462, and total number passengers after GA and TG expand routes is 12,034. GA and TG serve more passengers than before expansion, while MH serve less passengers.

Table 4 shows comparison of airfare in all ODs in the first sequence (GA and TG expand). Fare for indirect flight becomes more expensive as there are more convenient direct flights available. However, flight is less frequent in fully-connected network (after expansion) than in hub-and-spoke network. Resultant of flight frequency is provided in Fig. 3.

Table 4 Comparison of airfare ($) in GA-MH-TG

	Original		After GA and TG expand routes	
OD	Direct	Indirect	Direct	Indirect
CGK-KUL	116.21	230.28	113.16	372
KUL-BKK	124.34	202.37	115.28	273
BKK-CGK	177.68	181.19	109.49	178.89



Top: Original network, Bottom: After GA and TG add route (in GA-MH-TG sequence)
Fig. 3 Comparison of flight frequency

Furthermore, this study suggests higher social welfare after expansion. Zhang (1996) showed different result, that when economies of traffic density are important, market invasion can yield lower social welfare. Route entry benefits both the entry firm and passengers in the local markets where entry occurs, but it may harm the incumbent hub-and-spoke carrier and passengers in other markets so that the net change in social welfare is negative. In this study, economies of traffic density effect is not captured, so such difference is expected.

b) Revenue sharing in hub-and-spoke vs. in fully-connected network

Several studies have analysed the effects of airline-airport concession revenue sharing. Fu and Zhang (2010) study the effects of concession revenue sharing on social welfare and competition level. They discuss two cases: single airport served by (1) a single airline and (2) multiple airlines. In the first case, concession revenue sharing improves welfare as well as the joint profits of the airport and airline. In the second case, where only one of the airlines shares revenues, that airline's profits increase while the outsider's profits decrease. Zhang et al. (2010) extend the study on revenue sharing to multiple airlines and multiple airports. Airport competition results in a higher degree of revenue sharing than would be the case with single airports. Moreover, they analyze the relationship between the degrees of revenue sharing and how airlines' services are related to each other (complements, independent, or substitutes). When carriers provide strongly substitutable services to each other, revenue sharing improves profits but reduces social welfare.

Revenue sharing analyzed by network model also supports and adds into the earlier analytical studies:

(1) Concession revenue sharing essentially increases airline-airport profit. Concession sharing increases the airline's marginal revenue, and therefore encourages airlines to fly more passengers to/from the partner airport, which may in turn improve airline-airport joint profit.
(2) Concession revenue sharing favors exclusive cooperation between the hub airport and its dominant airline (e.g. it is more profitable for CGK to share revenue with GA solely than with any other airlines).
(3) Revenue sharing increases consumer surplus, but reduces profit of airlines that do not participate in the agreement.
(4) When airports share revenue with their dominant airlines simultaneously, all airlines become more competitive (by offering lower airfare and more frequent flights), such that their flight revenues decrease and airline profits are potentially lower relative to no cooperation.

In this study, we compare result of revenue sharing in liberalized network (fully-connected network) and in hub-and-spoke network.

Revenue sharing between GA and CGK results in higher joint profit when GA uses fully-connected network compared to when GA uses hub-and-spoke network (other airlines' network remain unchanged). When proportion of revenue shared is 50% (r_{11} = 0.5, other r_{in} = 0), GA-CGK raise additional daily joint profit of $2,930 in hub-and-spoke, while in fully-connected network they raise $18,100.

With revenue sharing, both GA and CGK are benefited by more passengers departing/landing in CGK, and as GA expand network to KUL-BKK (that is not directly connected with CGK), other airlines reduces fare (especially indirect fare) in other legs, i.e. KUL-CGK and CGK-BKK, thus contribute in increasing number of passengers in CGK, which in turn increases joint profit from revenue sharing between GA and CGK. Comparison of airfare after GA-CGK revenue sharing in hub-and-spoke vs. fully-connected network can be seen in Table 5.

Table 5 Comparison of airfare ($) after GA-CGK revenue sharing (r_{11} = 0.5)

OD	GA uses H-S network			GA uses F-C network		
	GA	MH	TG	GA	MH	TG
CGK-KUL	111.7	117.1	229.5 (ind)	115.9	122.89	185.1 (ind)
KUL-BKK	185.1	126.2	122.1	113.1	125.2	117.3
BKK-CGK	176.4	180.8 (ind)	177.4	166.5	165.8 (ind)	169.6

Revenue sharing of GA-CGK in fully-connected network gives higher consumer surplus than that of in hub-and-spoke network. Passengers obtain benefit both from additional direct flight serving KUL-BKK, and also from cheaper airfare triggered by revenue sharing. The similar pattern is also obtained when TG and BKK form a revenue sharing agreement, in addition to GA-CGK agreement. Revenue sharing in fully-connected network gives higher joint profit for both pairs than that of hub-and-spoke network.

However, this is not always the case. Revenue sharing between MH and KUL is more profitable in hub-and-spoke network. If route expansion is not beneficial for an airline, revenue sharing with its previous hub airport cannot help recouping the loss, and potentially reduce airline's profit even further (when the proportion of revenue share is high, e.g. r_{in} = 0.9).

Table 6 Revenue Sharing with Hub Airport (r_{in} = 0.5) and Route Expansion as Airlines' Strategy: Outcomes

Airline Profit ($$10^5$)				
	Do nothing	Revenue sharing (RS)	Expand route (E)	RS & E
GA	1.752	1.766	2.167	**2.044**
MH	2.443	**2.491**	2.353	2.172
Consumer Surplus ($$10^5$)				
	Do nothing	Revenue Sharing (RS)	Expand route (E)	RS & E
GA	36.028	36.117	**36.823**	36.799
MH	36.028	36.243	36.305	**36.523**

Note: GA receives 50% share of revenue from CGK, MH receives 50% share of revenue from KUL. GA expands route to KUL-BKK, MH expands route to CGK-BKK.

As shown in Table 6, when its competitors' strategies remain unchanged (no revenue sharing and no route expansion), GA is better-off when it expands route and at the same time forms revenue sharing with its hub. Meanwhile, MH is better-off when it forms revenue sharing without expanding route.

Furthermore, in this simplified network, as GA expands its route serving KUL-BKK, CGK is no longer the center of all GA's flights. GA spread its services more equally to all three airports in the network. Therefore, revenue sharing with CGK is no longer gives highest profit compared to revenue sharing with other airports. In fully-connected network, for GA to obtain highest joint profit is to cooperate with KUL (see Table 7). As we also have shown before, revenue sharing between GA-CGK gives higher joint profit in fully-connected network than in previous hub-and-spoke network.

In the case of MH, revenue sharing with BKK raises more profit than with KUL in fully-connected network, and it is actually higher than profit obtained in hub-and-spoke network with KUL.

Table 7 Δ Joint profit (\$$10^5$) of airline-airport as a result of revenue sharing (r_{in} = 0.5)

r_{1n} = 0.5 ∀ n	GA uses F-C network	GA uses H-S network
GA-CGK	0.181	**0.023**
GA-KUL	**0.212**	0.017
GA-BKK	0.152	0.019
r_{2n} = 0.5 ∀ n	MH uses F-C network	MH uses H-S network
MH-CGK	0.093	-0.009
MH-KUL	0.049	**0.094**
MH-BKK	**0.112**	0.005

Table 8 Δ Joint profit (\$$10^5$) of airline-airport ($r_{in}$ = 0.5), all airlines uses fully-connected network

r_{in} = 0.5, other r_{in} = 0	Δ Joint profit
GA-CGK	0.0012
GA-KUL	**0.0214**
GA-BKK	0.0145
MH-CGK	-0.0077
MH-KUL	**0.0034**
MH-BKK	0.0026
TG-CGK	0.0118
TG-KUL	**0.02**
TG-BKK	0.003

When all airlines expand route and thus have fully-connected liberalized network, joint profit resulted from revenue sharing is as shown in Table 8. All airlines obtain lower profits and joint profits compared to hub-and-spoke network, while consumer surplus is higher (passengers are benefited from direct flights). This shows that cooperation in terms of revenue sharing in fully-connected liberalized network has smaller effect on airline-airport profits than that of hub-and-spoke network. However, consumer surplus (as a result of cooperation) is higher in fully-connected network.

It is important to note that results previously shown in Table 5, 6, 7, and 8 are the results when other airlines (competitors) 'do nothing', meaning that competitors neither expand route nor form revenue sharing agreement with airport. The result will differ when the competitors decide to take the same strategy, all airlines' profits will potentially be lower.

Decision to expand route and/or to form revenue sharing with airport can be seen as airline's strategy in game-theory scheme. Each airline's payoff will be affected by strategy taken by its rivals. Both revenue sharing and route expansion are profitable if the competitors do nothing (not cooperating and not expanding). But 'do nothing' strategy is not a Nash equilibrium strategy for competitors, although it is a Pareto efficient strategy.

4. CONCLUSIONS

In relation with proposed ASEAN Open Sky policy, opportunity to serve direct flight between second and third country for any Southeast Asia airlines is generally unattractive (see Table 2) unless the competitor (that is the incumbent airlines) do nothing. However, 'do nothing' strategy is not a rational strategy. For example, if Garuda Indonesia decides to serve Changi Airport and No Bai Airport directly, it first will gain profit. However, Singapore Airlines can also enter Garuda's market, such as Jakarta-Kuala Lumpur. This in turn will decrease both airlines' profits, all else being equal.

When airlines actually utilize fully-connected network, airlines may explore opportunity to form revenue sharing agreement with airports other than its hub as it is potentially more profitable.

Cooperation in terms of revenue sharing in fully-connected liberalized network has smaller effect on airline-airport profits than that of hub-and-spoke network. However, consumer surplus (as a result of cooperation) is higher in fully-connected network. From consumer perspective, airline's decision to form revenue sharing with airport and/or to expand route is beneficial. Passengers are benefited from lower airfare and/or more frequent daily flight.

This study also assumes airlines as the only decision makers in revenue sharing cooperation. In future work, we focus on developing revenue sharing allocation model as endogenous formation of the airline-airport combination mechanism, where airports are also considered as decision makers.

REFERENCES

1) Adler, N. : Competition in a deregulated air transportation market, *European J. of Operational Research*, Vol 129, pt. 2, pp. 337–345, 2001.
2) Burghouwt, G. and Veldhuis, J. : The competitive position of hub airports in the transatlantic market. *J. of Air Transportation*, Vol 11, pt 1, pp. 106-130, 2006.
3) Forsyth, P., King, J. and Rodolfo, C.L. : Open skies in ASEAN, *J. of Air Transport Management*, Vol 12, pp. 143-152, 2006.
4) Fu, X., Homsombat, W. and Oum, T.H. : Airpot-airline vertical relationships, their effects and regulatory policy implications, *J. of Air Transport Management*, Vol. 17, pp. 347-353, 2011.
5) Fu, X. and Zhang, A. : Effects of airport concession revenue sharing on airline competition and social welfare, *J. of Transport Economics and Policy*, Vol 44, pt. 2, pp. 119-138, 2010.
6) Hsu, C. I. and Wen, Y. H. : Determining flight frequencies on an airline network. *Transportation Research Part E*, Vol 39, pp. 417-441, 2003.
7) Kanafani, A. and Ghobrial, A.A. : Airline hubbing: some implications for airport economics. *Transportation Research Part A*, Vol 19, pt. 1, pp 15–27, 1985.
8) Li, Z-C., Huang, H. J., Lam, W. H. K, and Wong, S. C. : A model for evaluation of transport policies in multimodal networks with road and parking capacity, *J. of Mathematical Modelling and Algorithms*, Vol 6, pt. 2, pp 239-257, 2007.
9) Li, Z-C., Lam, W. H. K, Wong, S.C. and Fu, X. : Optimal route allocation in a liberalizing airline market, *Transportation Research Part B*, Vol 44, pp. 886-902, 2010.
10) Oum, T.H., Fu, X. and Zhang, A. : Air transport liberalization and its impact on airline competition and air passenger traffic, *International Transport Forum OECD Report*, 2009.
11) Swan, W.M. and Adler, N. : Aircraft trip cost parameters: a function of stage length and seat capacity, *Transportation Research Part E*, Vol 42, pt. 2, pp. 105–115, 2006.
12) Takebayashi, M. and Kanafani, A. : Network competition in air transportation markets: bi-level approach, *Research in Transportation Economics*, Vol 13, pt. 1, pp. 101–119, 2005.
13) Zhang, A. : An analysis of fortress hubs in airline networks. *J. of Transport Economics and Policy*,Vol 30, pt 3, pp. 293-307, 1996.
14) Zhang, A., Fu, X. and Yang, H. : Revenue sharing with multiple airlines and airports, *Transportation Research Part B*, Vol 44, pp. 944-959, 2010.