ANALYSIS OF DOMESTIC AIR TRANSPORTATION NETWORK IN INDONESIA

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INTRODUCTION

The domestic air transportation network is as important for the economic and industrial development in the Republic of Indonesia same as the international air transport network. Since the country is composed of 13,677 islands, it is quite impossible to connect or link the major islands with tunnels or bridges. The air transportation network is also necessary for the security and political process.

Therefore, this research focused on (1) analysis of the current situation in usage of air transportation and (2) development of a model for use in proposing alternative plans to improve the domestic air transportation network in Indonesia.

1. CURRENT SITUATION OF DOMESTIC AIR TRANSPORT

1.1. Historical view

Indonesia government has concentrated to make Garuda Indonesia Airways (GIA) grow up as the national flag carrier of Indonesia in terms of protectionist measures.

Since GIA was set up by Indonesia government in 1949, GIA has mainly operated international air flights. On the other hand, Merpati Nusantara Airlines (MNA) was also established in 1962 by the government and has started the operation of domestic air flights by succeeding them from the national air force. During the 1980's, GIA had operated the air flights in main domestic air routes which connected between more than 30 major cities and MNA had operated in local lines, by absorbing MNA into GIA as a subsidiary company in 1978. Most of the domestic flights have been, however, transferred from GIA to MNA since 1989 according to the fifth Five-year development plan so as to improve the competitiveness of GIA in the international air flight market and at present, GIA operates domestic air flights in only air routes which connected between 14 cities.

In addition to GIA and MNA, three companies during the 1960's and two charter companies during the 1970's have been established, therefore seven airline operators have air flights in the domestic air network now, where GIA and MNA occupy more than 70 % of a total air flights. Operators and the number of their main fleets are shown in Table 1.

During a decade from 1976, total passengers and also cargos have increased until two times of them. However, these amounts are one-ten of Japan. Trend of total passengers and cargos are depicted in Fig.1.

Table 1 Main Airline Operators and their fleets in Indonesia

Operator	Main fleets
Airfast Indonesia	B737X2, BAe748X2
Bouraq Indonesia Airlines	V800X4, BAe748X15
Garuda Indonesia	B747X6, DC10X7, A300X18 DC9X19, B737X8, F28X34, F27X6
Merpati Nusantara Airlines	F28X12, F27X7, L100X2, V800X2
Mandala Airlines	V800X3, L188X6
Pelita Air Service	F28X6, DHC7X5, L100X4
Sempati Air Transport	F100X4, F27X6

Source : The World Airline & Airliner Directory '92-'93, IKAROS
Note : V; Viscount(BAe)

1.2. Current situation

1.2.1. Airports

In Indonesia, two principle international airports (Soekarno-Hatta and Denpasar), one sub-international airport (Medan) and one hundred forty three domestic airports are located through the whole nation. These airports are under the supervision of the Directorate General of Air Communications.

However, most of them have never had well equipped facilities to provide services for existing air transport with economical reasons.

1.2.2. Modal share of air transportation

The modal share of air transportation used for passengers trips in 1989 was 5%, where that of cars was over 80 %. However, among Southeast Asian countries, a dependance on air flights in Indonesia is not small (US; 12.9% in 1980, Japan; 3.7% in 1988, Thailand; negligible, Philippines; 5% in 1985).

On the other hand, the modal share of air transport on cargo movement was very small and 27% of cargo was transported by bouts, because of geographical characteristics of Indonesia like as an archipelago. These modal shares are shown in Fig. 2.

1.2.3. Passenger and cargo movements

About 90 % of the domestic air traffic is handled at 27 domestic airports (out of 53 major domestic airports in the country) by seven airlines providing scheduled services supplemented by charter and air-taxi companies.

Movements of the air transport were concentrated on the air route which was terminated in Soekarno-Hatta and Halim-Perdana airports, Jakarta. Especially, by a year, around three hundred thousand passengers on one way used the main routes such as Jakarta-Denpasar, Jakarta-Surabaya, etc. It is shown in Fig. 3.

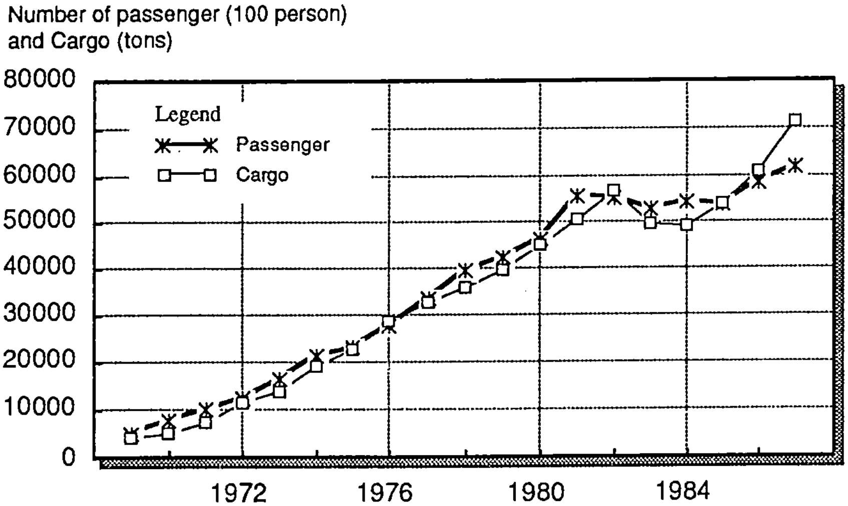

Fig. 1 Trend of passenger and cargo movement (1969 - 1987)

Source : The Outlook in 1989/90 - 1993/94 and Prospect in 2000, 1989

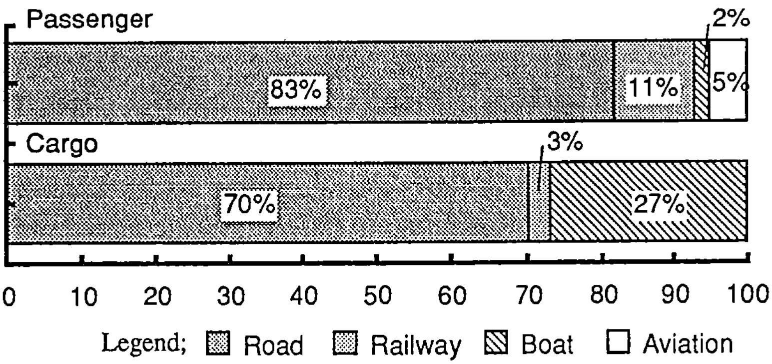

Fig. 2 Modal share of domestic transport in Indonesia

Source : Development and Management Profile of Transport Infrastructure in Asia and the Pacific, JICA, 1989

2. ANALYSIS OF THE PROBLEM ON THE AIR TRANSPORTATION

In the United State, after the Airline Deregulation Act of 1978, there was rather an abrupt change in air network structure from the point-to-point route network to the hub and spoke network. Presently, there are around 180 airline operators catering in the US, having a vast land area, and with the threat of competition, the establishment of airline territories became a necessity to them. The US air network can then be thought of as composed of several territories, and with the popularity of the hub and spoke network still on the rise, airline operators are then employing the hub and spoke network system to these territories.

In comparison, on most of countries in the South-East Asian (SEA) region, demand for air transportation services currently just start to increase. And there is no competition and the government protects operators. Therefore, it is not necessary to employ the hub and spoke air network. However, as a result of investment of an air network by adding a route one by one depend on demand, several airports have spontaneously had the function as the hub airport. And it is seemed that their location are depend on the geographical and economical reasons.

2.1. Geographical characteristics of Indonesia

To understand the problem on the air network development affected by the geographical characteristics of Indonesia, the continental United States was superimposed into the SEA region in Fig. 4.

In comparison with the US, Indonesia which consists of five main islands has almost same width, but it is very narrow. It is found that the countries in SEA not only Indonesia but also the Philippines, et al. is almost similar with one or several territories that made up the region in the US. Furthermore, the major airline operator of a country in SEA dominates the domestic air transportation business. With these, it is then similar to analyze an air network of a country in SEA and a US airline territory.

For this reason, the choice of a hub in SEA may be limited to only a few locations. Unlike in the US where most airports of region have high passenger demand, the choice of a hub location is also a lot. Furthermore, for a typical airline operator in the US, its territory is usually composed of airports sparsely scattered on its territory, not unlike in a country of SEA, such as Indonesia where the airports are more consolidated in its territory.

However, we can identify some hub airports in Indonesia, such as Ujung-pandang which already has the function as the hub airport spontaneously. It is seemed that theseairports play a role of a gateway for the east part of Indonesia and this is occurred by the geographical reason such as the east part is far from Jakarta to provide a direct flight.

2.2. Regional differential on economic development

On the other hand, the economical reason exist for the network development. Generally, most of population concentrate in few urban areas and the regional differential on economic development exists in SEA countries. In Indonesia, around 60 % of population and 54 % of gross regional domestic product (GRDP) are in Jawa Island in which Jakarta is located, where Jawa Island has only 7% in the area. The regional distribution of population and GRDP are depicted in Table 2.

This differential reflected in passengers and cargo movements by air transportation. Around 40% of passengers were originated or terminated in Jakarta and this situation spontaneously make Indonesia to have the hub and spoke air network.

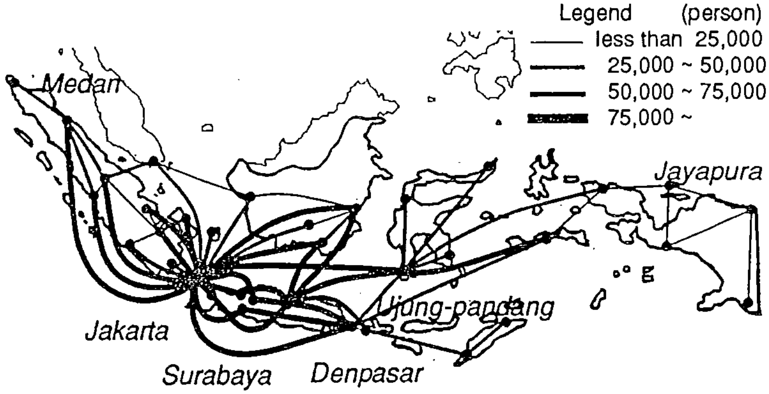

Fig. 3 Passenger movement between major airports (1989)

Source : Air Transport Statistics, 1989

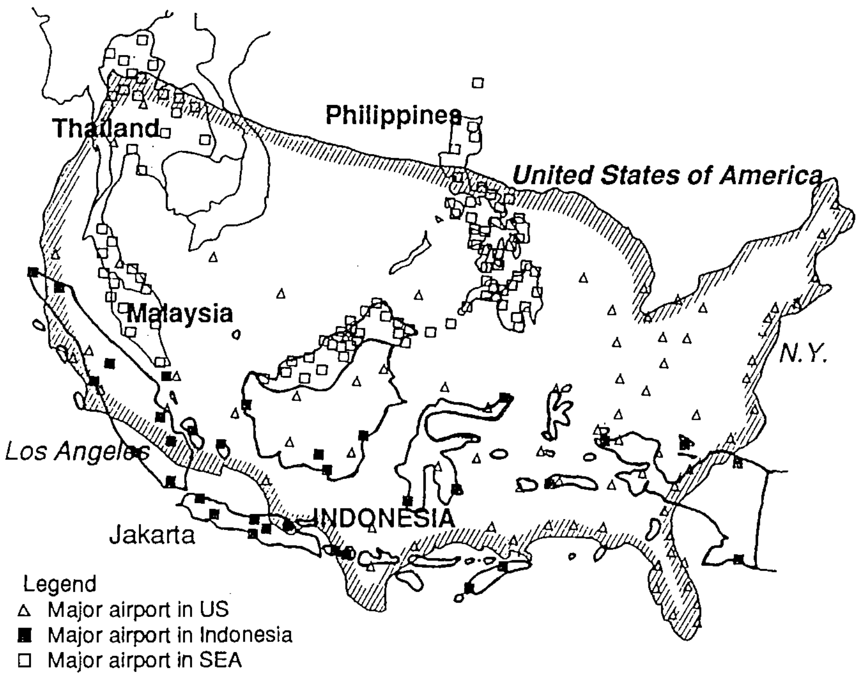

Fig. 4 A comparison of the geographical area of US and SEA

Table 2 Regional population and gross regional domestic product

Island	Population[1)] thousand	(%)	Population[2)] Density person / km^2	Gross Regional[1)] Domestic Product billion Rp.	(%)
Sumatera	34,786	(20.22)	69	33,482	(28.06)
Jawa	103,985	(60.45)	755	64,259	(53.85)
Nusa Tenggara	9,788	(5.69)	106	4,537	(3.80)
Kalimantan	8,206	(4.77)	14	10,776	(9.03)
Sulawesi	12,065	(7.01)	61	4,974	(4.17)
Maluku& Irian Jaya	3,180	(1.85)	6	1,310	(1.10)
Total	172,010	(100.00)	85	119,339	(100.00)

Source : Statistical Year Book of Indonesia 1989 *Note : 1) 1987, 2) 1985*

3. APPLYING THE HUB AND SPOKE SYSTEM IN INDONESIA

3.1 Configuration of air flight network

On this research, by consideration of undevelopment of airport facilities and the number of available fleets, the hub and spoke system is applied in Indonesia.

Two typical configuration of an air flight network have been discussed as an effective network in terms of economy, one is the *Robin and Around* system and the other one is the *Hub and Spoke* system. The robin and around is name for the network which is composed by air routes which connect each airport by the direct flight, where the hub and spoke is mainly developed by air routes (spoke) which connects local airports and main (hub) airports which were invested strategically.

Therefore, In the case of the hub and spoke network, there are the advantage that airline company can improve the efficiency of operation and users can travel to any place equally and fairly, because it is possible to connect whole airports by few number of air routes. However, there is one serious fault that sometime, users have to travel roundabout routes. On the other hand, the robin and around network requires increment on the fleets and the staffs, if it is possible, there are no fault for users and the company.

3.2 Formulation of network model

The problem to construct the efficient the hub and spoke network is similar with finding the optimum location of the hub airport that would be formulated as the problem that chose the optimal airport as the hub airport out of whole airports. Simple models for this problem were developed by O'kelly (1986).

Application was done as follows;

1) A hub and spoke network model was constructed and simulated the case of single hub airport would be located.

2) Adding a hub airport one by one to the case of single hub airport and connecting each hub airport by direct flights, the multi-hub network was tested.
3) Evaluate the efficiency of networks from the viewpoint of operator by comparing the results of simulations.

3.2.1 Single-hub air network

Assuming that every flights must be through the hub airport, the optimization could be formulated as the airport which can be minimized the total trip-distance as follows;

$$\underset{(H)}{Min} \sum_{i} \sum_{j} W_{ij} \{d(p_i, H) + (H, p_j)\} \tag{1}$$

where,
w_{ij}; the amount of trips which are originated in an airport i and terminated in an airport j,
H; the serial number of an airport which is chosen as the hub airport,
p_i; the serial number of an airport i,
$d(x, y)$; the distance between the airport x and the airport y.

Here, total trip-distance which is originated in an airport i; O_i and total trip-distance which is terminated in an airport j; D_j are shown as follows;

$$O_i = \sum_{j} W_{ij}, \quad D_j = \sum_{i} W_{ij} \tag{2}$$

Therefore the equation (1) can be rewrite as follows;

$$\underset{(H)}{Min} \left\{ \sum_{i} O_i \, d(p_i, H) + \sum_{j} D_j \, d(H, p_j) \right\} \tag{3}$$

The hub airport can be found as the airport which can minimize equation (3).

3.2.2. Multi-hub air network

In the case of the multi-hub network, assuming that each local airport must be served air flights by only one hub airport which is most close to them, it is apposed that two pattern of flights exist, one is flights which path only one hub airport, which can be formulated same as the model of the single-hub airport system, and the other one is flights which path two hub airports. Hence, the case of the two-hub airports system can be formulated as follows; where,

$$\underset{(H1,H2)}{Min} \sum_{i} \sum_{j} W_{ij} \{ d(p_i, H_1) + d(H_1, H_2) + d(H_2, p_j)\} \tag{4}$$

H_k; the serial number of the kth hub airport.

Also, the air networks with more than three hub airports can be formulated.

3.3. Application in Indonesia

The proposed model was applied for the 32 airports in which GIA was terminated by using data of total passenger trips between airports in 1984. The case of the one-hub and the five-hub air network systems are depicted in Fig. 6 and 7 as the example of results. The

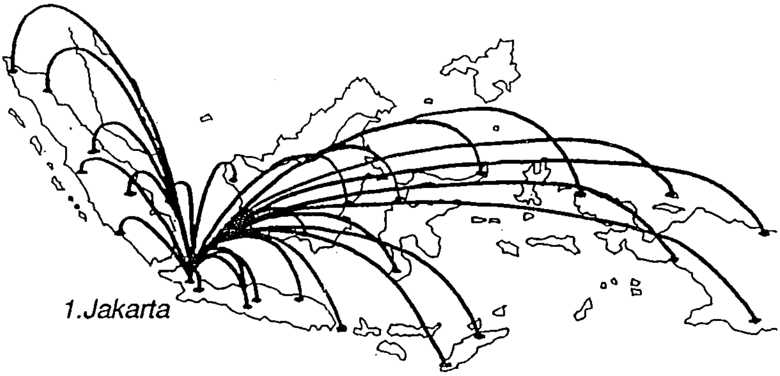

Fig. 5 Obtained air network with 1 hub airport

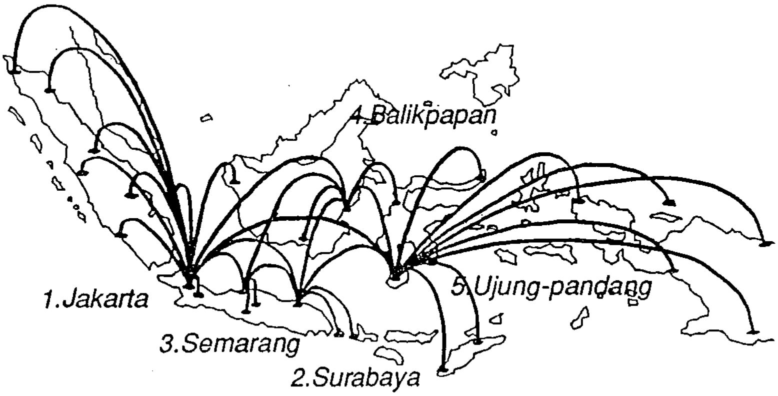

Fig. 6 Obtained air network with 5 hub airports

Soekarno-Hatta airport in Jakarta was chosen as the first hub airport, in which most of trips were terminated. Surabaya, Semarang, Balikpapan and Ujung-pandang were chosen as the 2nd to 5th hub airports by the number. These results show that an airport which has demand would be chosen as the hub airport and according to the increment of the number of hub airports, optimum solution (total trip-distance) was decreased.

3.4. Evaluating efficiency of air networks

Airline's operating costs, which consist of a direct and an indirect operating cost could be one of sound indicates to evaluate efficiency of an air network. A direct operating cost, which is made up a line-haul cost, a maintenance cost, a depreciation cost and a service cost, would be obtained by fleet size and sector distance. Also an indirect cost, which is a terminal cost, a sales cost and an administration cost, could be calculated from a total departed and arrived passengers at airports.

However, it is quite difficult to account these costs in details. Thus, it is necessary to set up several assumptions for the calculation of the airline's operating cost as follows; 1) Every routes on the air network must be assigned at least one flight a day because of an accomplishment of the network. For this calculation, three types of fleets, with difference on the number of seats (100, 200 and 400 seats) are available.

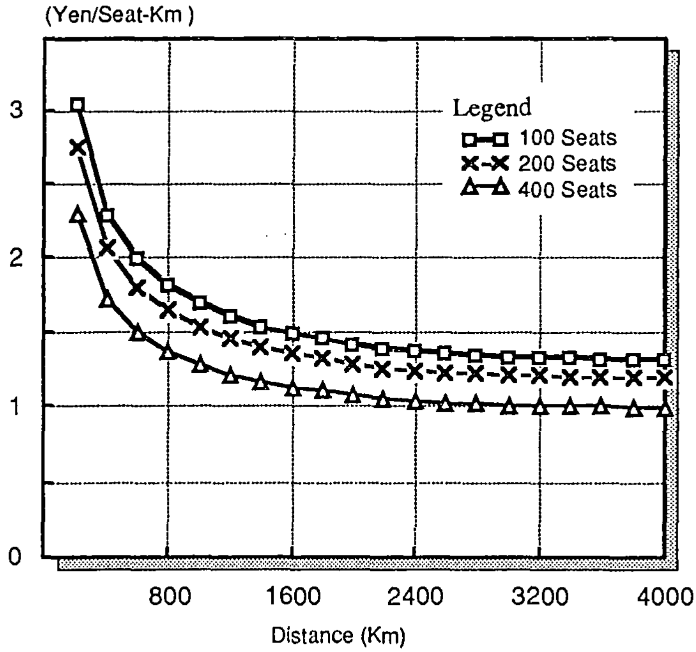

Fig. 7 Assumed capital direct operating cost

2) The capital direct operating cost can be formulated as the functions depicted in Fig.7.
3) The cost of services for a passenger on the ground can be estimated 700 yen.

The number and functions which were assumed on 2) and 3) were estimated by depending on the structure of airlines' cost (cf. ICAO, CAB, et al.) and adapting the revenue and expenditure reported by Japanese airlines.

With these assumptions, the airline's operating cost was calculated for several cases, by which there were difference on the number of given hub airports. The results of this calculation are shown in Table 3 and Fig. 8. It can be clear that setting up the hub airport until five, the direct operating cost could be decreased according to reduction of total direct air flight distance. Over the five hubs, this cost increased gradually in the cause of assigning direct flights to the route which connects each hub airport, but not has so many passengers. On the other hand, the indirect operating cost rises and falls, but this cost would decrease by adding to direct flights until connecting all airports.

As the result of this simulation, to set up the five hub airports is optimal solution for an airline under the assumptions, because the airline's operating cost became minimum in constructed air networks.

4. CONCLUSION AND DISCUSSION

The result of the analysis of the existing situation shows that air transportation usage is quite different than in developed countries such as the US, Japan, et al. It was clear that a demand for domestic air transportation is still low and the level of facilities, e.g. airports, are poor. Especially, it is noticeable that the imbalances of demand for domestic air transportation among regions occur because of the imbalances in economic development of the regions.

In the second part of this research, the model to obtain the total passenger movements was developed, tested and applied to the hub and spoke system for this study area, which is an effective network system to improve the efficiency of an air transportation network that has been extensively applied in the US. The hub and spoke system was applied following the procedures below; 1) locating of main hub airports as a locational problem, 2) calculating total passenger movements using the proposed model, and 3) evaluating the efficiency of formulated air networks in terms of airline's profitability which is obtained from operating cost consisting of a line-haul cost and a terminal cost. Also the optimal number of hub airports was obtained. As the results, it was concluded that we can measure the efficiency of improving the existing air transportation network by applying the hub and spoke system to Indonesia.

Finally, it must be mentioned that this analysis would provide useful information for the operation of fleets and development of the air network to the airline operators and nations not only in Indonesia but also in other developing countries, even though this research could discuss only few problems out of the many. This time, in our research, future demand of air transportation was not forecasted because of insufficient on the data (indeed, this is also one of important issue for the research in the developing countries) which is required to appraise the impacts of it's development on the regional economy. Thus, we know that it must be done and also the procedure to develop air networks must be sought because these are objectives of our ongoing research.

Table 3 Results of simulation

Number of hub airport		1	2	3	4	5	6	7
Number of fleet	100 seats	27	27	27	29	33	42	52
	200 seats	13	13	14	14	14	13	12
	400 seats	42	46	34	30	42	42	46
Flight distance by type of fleet	100 seats	49,571	38,743	38,605	34,274	66,313	54,398	74,413
	200 seats	16,334	13,461	13,505	11,994	10,763	7,710	4,962
	400 seats	36,479	27,094	28,708	30,150	29,137	29,137	28,292
Number of flights by distance (Km)	~ 400	4	8	10	13	15	16	19
	400 ~ 800	8	10	10	10	11	14	15
	800 ~1200	6	5	5	6	7	7	6
	1200 ~1600	4	3	3	4	4	3	4
	1600 ~2000	3	3	3	1	3	0	2
	2000 ~	1	4	4	4	2	0	7
Total Passenger 1)		6,112	6,813	6,598	6,756	6,209	6,198	6,810
Total trip-distance 2)		2,744	2,265	2,153	2,014	1,998	1,912	1,861

Note : 1) 1000 person, 2) 1000 Km

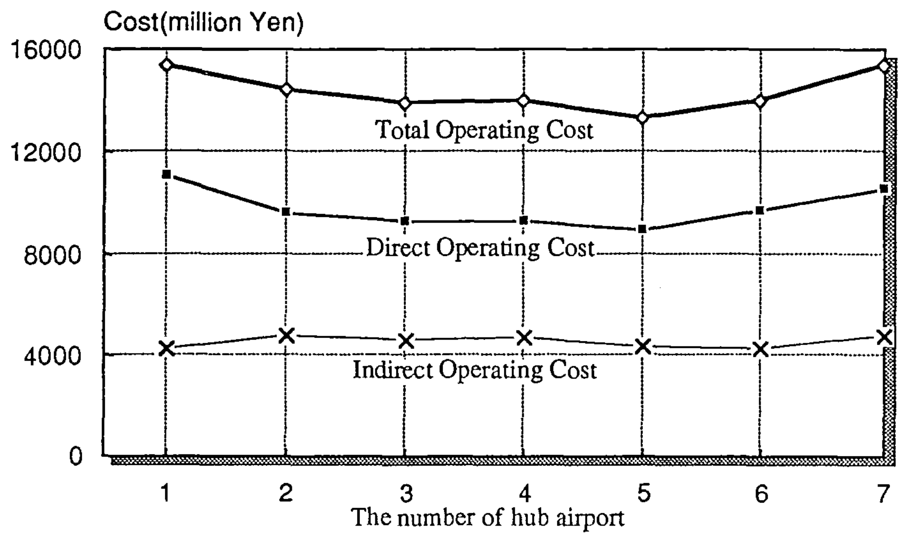

Fig. 8 Estimated cost by the number of hub airports

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