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AIRLINE DISTRESS PREDICTION
USING NON-FINANCIAL INDICATORS

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ABSTRACT

When comparing the performance of airlines across countries, substantial differences are encountered in the financial environment that can be difficult to reconcile in the construction of a multi-country failure or distress prediction model. By using non-financial operating data and proxy variables for governmental influence and quality of economic environment, some of these problems are circumvented. Thus, in this study, a logistic regression model of airline distress prediction is constructed using three years of worldwide airline data [1996-1998]. The findings demonstrated a fairly good model, having 90.3 percent overall prediction accuracy. These findings in conjunction with other research in this field, support that models based on non-financial variables show good prediction traits comparable to financial based models, yet providing more explanatory power.

INTRODUCTION

Failure prediction models have been used extensively by the financial community for company evaluations and as early warnings systems of potential business failure (Theodossiou, 1991). Such models have been used by commercial banks and creditors to assess the creditworthiness of commercial users, by investors to measure a firm's risk of insolvency, and by business managers to assess and manage the financial turnaround of distressed companies.

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Four main approaches have been used in the development of prediction models: Univariate, Discriminant (multivariate), Conditional Probability and Neural Networks.[1] Let us cover each of these approaches briefly.

Beaver (1966) applied an univariate analysis (UVA) approach in which the predictive ability of the ratios was analyzed on a one-by-one basis. Beaver used seventy-nine industrial firms in his sample over a five year period. Each non-failed firm was matched with a failed firm by industry and asset size. The data analysis proceeded in three steps: a comparison of means, a dichotomous classification test, and an analysis of likelihood ratios. The comparison of means showed that the means of each ratio were significantly different for the failed and the non-failed firms. With the dichotomous classification, Beaver arrayed each ratio to a cut-off point. The best performing ratio was the ratio of *cash flow to total debt*, in that it showed the minimum percentage error in predicting the two groups in the sample studied.

Although Beaver's predictors perform fairly well, the main difficulty with his approach is that the classification can take place for only one ratio at a time. The potential exists for finding conflicting classification of any given firm according to various ratios. Altman (1968) argued that the financial status of a firm is actually multidimensional, and no single ratio is able to capture those dimensions; thus, a multivariate approach would be necessary to capture the dimensions. Consequently, the largest body of the academic failure prediction literature is applying discriminant analysis (DMA). DMA works in the way that a linear discriminant function is used to distinguish between distressed and non-distressed firms. The discriminant function transforms the values of the individual variables of the firm into a single discriminant score (z score), which is then used arbitrarily to classify the firms into the failed or non failed group (Frederikslust, 1978).

Altman used, in his pioneering DMA work, a sample of thirty-three manufacturers that filed for bankruptcy under Chapter X of the National Bankruptcy Act during the period 1946-1965. The accuracy of his model in the prediction of bankruptcy was 95 percent in the first year prior to bankruptcy and 72 percent in the second year prior to bankruptcy. In the third year prior to bankruptcy, the accuracy fell rapidly to 48 percent (see Table 10), or no better than a flip of a coin.

Most studies that followed attempted to improve the Beaver and Altman models in one way or another. Edmister (1972), for example, recognized that when many closely correlated variables are included, the resulting function is likely to be biased towards the sample from which it was developed. Thus, he eliminated highly correlated variables from the model. He also included in the study only those ratios that were found to be

significant predictors of bankruptcy in previous empirical studies. The seven-variable discriminant function was accurate at an overall error rate of 7 percent in the first year prior.

At least two DMA studies have been applied to airline distress in the eighties (Altman and Gritta, 1984; Gritta, 1982): one specified a model, while the other applied the Altman Zeta model to the airline industry.

Other researchers have attempted to use different prediction techniques such as neural networks[2] and probability models. The conceptual basis of Neural Network (NN) models is rooted in attempts to simulate the neural construction of the human brain. One of the first applications of NN to failure prediction was by Tam and Kiang (1992), who specified models for bank failure. The models performed well one year and two years prior, but unlike most other prediction studies, no model testing was done on data three years or more prior to failure.

For predicting airline distress there have been two NN models, known to the author, one for major U.S. airlines (Davalos, Gritta, & Chow, 1999) and another for smaller carriers (Gritta, Wang, Davalos & Chow, 2000). Both of these models showed good prediction performance for the sample airlines one year prior to bankruptcy. The second model was not tested on two-year-prior or three-year-prior data for the same sample or a hold-out sample and cannot be fully compared with prediction models using other methodologies.

Although some methodological issues[3] are addressed with NN these models do not, so far, provide any break-through in prediction capability over MDA or Logistic Regression (LRA) approaches. For ease of comparability and interpetability, we selected the LRA methodology over NN for this study, which is a conditional probability approach.

Conditional probability models (Probit, Logit and LRA) are used to estimate the probability of occurrence of a choice or outcome. These models use the coefficients of the independent variables to predict the probability of occurrence of a dichotomous dependent variable. A cumulative probability distribution is needed in order to constrain the predicted values to comply with the limiting values (0, 1) of probability distributions. Some of the early applications of probabilistic methods in financial distress prediction are those of Ohlson (1980), Santomero and Vinso (1977) and Martin (1977).

Probability models are advantageous over discriminant models in that significant coefficients can be interpreted in terms of the relationship with the dependent variable and they are what is called distribution free methods, a considerable advantage over DMA. Ohlson (1980) argues, nevertheless, that certain discipline in data collection has to be adhered to. For example, the data has to be available prior to failure so that the model

can be evaluated realistically. At least one study (Gudmundsson, 1999) has applied the LRA approach to airline distress, using a sample of new-entrant airlines in the U.S.A.

Performance Measurement of International Airlines

The airline industry, like many other industries, is increasingly exposed to competition. Increased competition has two effects on firms: it creates downward pressures on output prices, and it creates incentives for improving productivity and efficiency. Many airlines have been forced to undertake major restructuring in order to meet these challenges. Oum and Yu (1998) used a model to decompose changes in airline profitability into two components: productivity and price recovery ability. The study concluded that increased competition in international air transport markets has put pressures on carriers' ability to raise prices. However input prices, like labor, fuel, materials, flight equipment, ground property and equipment have been increasing. They also demonstrated that airlines have made tremendous effort to improve efficiency to counteract such trends, yet large fluctuations in profitability are still an ongoing reality.

Due to these fluctuations in airline fortunes, early warning systems of imminent distress are of benefit to management and airline stakeholders such as creditors and investors. No prediction model standardised on international airlines exists as far as the author is aware. One plausible reason is a problem in predicting distress of airline companies world-wide due to differences in economic and political systems. For example, in many countries there may be only one airline or few airlines making an industry-specific model for one country impossible to achieve. Thus, the main question in this research was if it would be possible to construct a prediction model that could be applied world-wide, taking into account differences in the political and economic environment of airlines.

Thus, given what we have covered so far, we construct a distress prediction model for international airlines based on non-financial data and pre-selection of input parameters. In the following section we will explain the conceptual framework (see Figure 1) that guided the selection of variables. Then the methodology is explained, followed by a report on the research findings.

CONCEPTUAL BACKGROUND

The conceptual framework used in this research to guide the selection of variables assumes that airline performance is a function of input resources and political and economic influences. Figure 1 shows the hypothesized relationship.
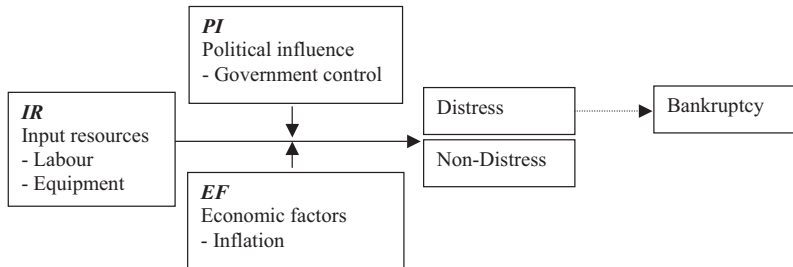
Figure 1. Relationship of factors used to predict airline distress

Input resources (IR) in airlines cluster around two main elements, namely labour and aircraft equipment, constituting the major part of the input costs in airlines. Poor management of equipment (fleet acquisition, composition and utilisation) and low labour productivity is assumed to be related to poor airline performance.

In general, newer aircraft are more efficient to run than older aircraft. Older planes have higher maintenance costs and fuel consumption. Thus, average fleet age should be a characteristic of poorer performing airlines. There can be two different reasons for this. First, the financial situation of the airline does not allow the acquisition or leasing of new equipment. Second, fleet acquisition and planning is poorly conducted due to inexperience or political influence. The last factor can play a role when political processes supersede airline operating interests in a market of substantial government influence (government airline or monopolistic market).

Since aircraft purchases take time (often two or three years), airlines should do some economic forecasting before going ahead with new aircraft orders to manage introduction in harmony with industry cycles. Poor fleet planning and aircraft acquisition policy can revert airlines to costly short-term solutions that fit poorly with the existing fleet composition. For example, by adding new poorly compatible brands[4] to the fleet raises costs due to increased crew costs and maintenance burden. Thus, it is assumed that airlines operating excessive number of aircraft brands will be poor performers.

The utilisation of aircraft, given the large associated cost and capital outlay, is of an outmost importance in airline management. Non-distressed carriers are expected to have higher number of departures per aircraft as a consequence of better overall management (schedules, distribution and

marketing). An expected intervening factor is *average stage length*, that is a good performing carrier operating mostly long-distance routes should have *fewer departures per aircraft*. However, there was weak correlation between these two variables so regardless of long stage lengths non-distressed carriers may still achieve higher fleet utilisation measured as departures per aircraft than a comparable distressed carrier.

Size economies exist in the airline industry in terms of aircraft size. Meaning that the larger the aircraft the lower the operating cost per seat. Thus, the greater the average number of passengers carried per departure, a function of aircraft size and passenger load, the better the airline operating performance. This indicator was not significantly correlated with load-factor and thus a separate measurement in our conceptual model.

Another important input resource is people. Pilots are usually the most expensive labour resource. Hence, it is assumed that higher number of flight hours per pilot is related to better performing carriers.

Airlines are labour intensive and the *number of employees per aircraft* measures labour productivity, that is the fewer the employees per aircraft the higher the assumed labour productivity. Aircraft size could be an intervening factor, meaning that the larger the average fleet size the larger the number of employees per aircraft. To pre-test this hypotheses we correlated *average number of passengers per departure* with *employees per aircraft* and found non significant ($r = 0.16$) relationship. Thus, we conclude that *number of employees per aircraft* is a satisfactory general productivity measurement for our sample of international airlines.

Political influence (PI) is a factor in international air transport. Thus, impacting the management quality of airlines. In a bankruptcy prediction model we would expect proportionally high government ownership to work as a deterrent to bankruptcy that is to be linked to non-failure.[5] However, in a distress prediction model the assumption made was that the higher the proportional government ownership the less incentive there would be for an airline to pursue competitive cost structures and other efficiency measures. Thus, high proportional government ownership is linked with poorer performance and higher likelihood of distress status.

Economic factors (EF) were expected to play a role in the operating results of airlines. Inflation was selected as a proxy for quality of the domestic economic environment in which the airline operates. It is assumed that high inflation rates indicate poor unstable economic management having negative impact on airlines' operating results.

Following what has been covered so far it was expected that variables pertaining to these three areas of airline management (IR, PI, EF) should be good predictors of airline distress and non-distress status. The next part of the conceptual model deals with the dichtomous performance state of

distress versus non-distress. Various definitions exist so we will discuss these in the context of our research.

One can argue that as long as a company is not dissolved or liquidated it must be seen as distressed, because a turnaround is still possible. According to Asquith (1991) financial distress can be associated with three main reason: an industry down turn, high interest expense, or poor firm operating performance relative to its industry. When is a firm financially distressed? *The Webster Dictionary* gives a general definition of distress as an acute financial hardship or being in great difficulty.

Altman (1993) distinguishes between technical insolvency and insolvency in a bankruptcy sense.[6] Technical insolvency is equal to the definition of financial distress. Altman defines the insolvency in a bankruptcy sense as a situation in which a firm's total liabilities exceed a fair valuation of its total assets. The two insolvency definitions do not lead to the same conclusion in all situations. A firm may have a negative economic net worth, but generate enough cash flow to escape bankruptcy (insolvent in a bankruptcy sense, but not technically). Or the other way around; cash flow is insufficient, but economic net worth is still positive (technically insolvent, but not in a bankruptcy sense).

Most prediction studies have relied on business closure, or sale, to trigger the classification of the business as either failed or non-failed. However, many businesses may continue operating even though they would be classified as having failed. In our research we assumed that bankruptcy is the total closure and liquidation of the firm following a period of distress. Thus, the focus is on predicting distress preceding bankruptcy rather than bankruptcy per se.

METHODOLOGY

In constructing a prediction model for the international airline industry we apply a non-financial approach to circumvent the problem of different accounting standards around the world. The airline industry is in many respects appropriate for non-financial approaches because of relatively homogenous sources of non-financial data available world wide through several statistical national and international programs: International Civil Aviation Organisation (ICAO), Association of European Airlines (AEA), and International Air Transport Association (IATA). Gudmundsson (1999) performed a comparison of various models constructed on data derived from a qualitative survey among airline managers and a quantitative data source containing traffic and financial data of new-entrant airlines. His main finding was that non-financial models performed better two and three years prior to distress than financial models, while the latter performed

better one year prior. Based on the good performance of these prior models, we constructed a non-financial dataset for the international airline industry and applied the LRA approach to develop the prediction model.

The LRA Approach

Collins and Green (1982) find the LRA approach to have much more theoretical appeal to bankruptcy prediction, than Multiple Discriminant Analysis (MDA). One of the reasons, according to them, is that the logistic cumulative distribution function (Figure 2) is a sigmoid curve (*S*-curve) that has the threshold trait that the bankruptcy forecasting problem logically needs.
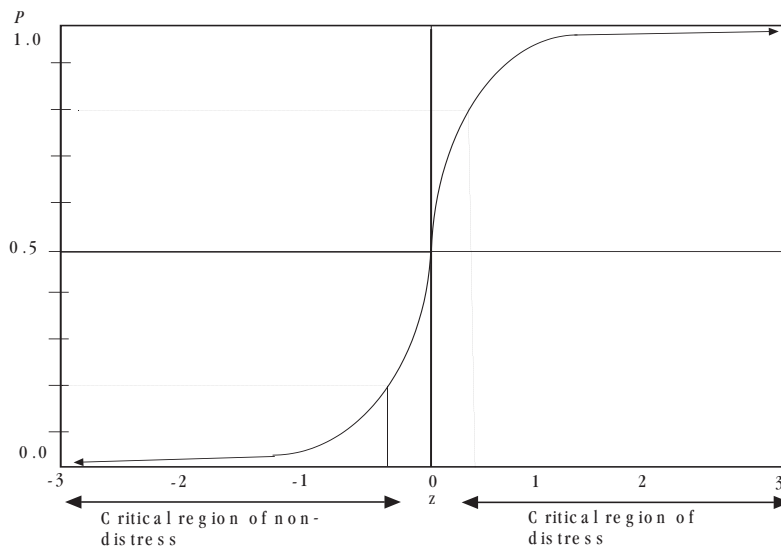
Figure 2. Sigmoid Probability Curve

We can see from Figure 2 that when the probability score falls along the lower bend of the curve ($p = 0$ to $p = .2$), the probability of failure is practically zero; however, if the score passes the bend and falls along the growth section of the curve ($p = 0.2$ to $p = 0.5$) the probability of failure increases dramatically. There is, however, little increase in the probability of failure as the change in the ratio falls along the upper bend of the curve ($p = 0.8$ to $p = 1$). Thus, the breaking point falls somewhere in the middle of the growth section of the curve (p 0.5) for example.

The logistic regression function produces a Z value that is transformed by the probability function into a probability. The *Z* is the linear

combination of the resulting model. The function takes the form,

$$p(\text{failure}) = \frac{1}{1+e^{-z}}$$

where,

$$Z = B_0 + B_1 X_1 + B_2 X_2 + \ldots\ldots\ldots + B_p X_p$$

and

$$e = 2.718 \text{ (the base of the natural logarithms).}$$

Data Description

The dataset used consists of ratios, as well as continuous and nominal variables collected over a period of three years (1996-1998) for 41 commercial airlines worldwide, covering economic, fleet, traffic and government equity in airlines.

The data was gathered from several sources. The primary sources were the *Air Transport World's* World Airline Report (1997, 1998, 1999) (government equity and fleet brands), *IATA World Airline Traffic Statistics* (1997, 1998, 1999) and *ICAO Annual Digest of Statistics: Series T and F* (1997, 1998, 1999).

Table 1 shows how the sample is spread geographically. Most airlines in the study are from Europe (39.0%), but fewest from Africa (4.9%) and Middle East (4.9%). Most distressed airlines come out of Europe (33.0%), as well as non-distressed airlines (43.0%).[7]

Table 1. Distressed and non-distressed airlines in sample by geographic location

Region	Distressed	Non-distressed	Total
Africa	2	0	2
Asia & Pacific	4	7	11
Europe	6	10	16
Latin America	4	2	6
Middle East	0	2	2
North America	2	2	4
	18	23	41

Table 2 shows the fleet size of the distressed (DA) and non-distressed (NDA) airlines. One can see that in the sample the non-distressed airlines have a larger fleet size than the distressed airlines in the categories 26-50 (NDA 33% vs. DA 20%) and 101-250 aircraft (NDA, 29% vs. DA, 10%), the distressed airlines have more frequency in the categories of less than 25 (NDA, 14.3% vs. DA, 20%) and 51-100 aircraft (NDA, 29% vs. DA, 40%).

Table 2. Fleet size of distressed and non-distressed airlines in sample

Fleet Size	Non-distressed	Distressed	Total
25 or less	3	4	7
26-50	7	4	11
51-100	6	8	14
101-250	6	2	8
More than 250	1	0	1
	23	18	41

The criteria applied to classify the airlines as either distressed (18 carriers) or non-distressed (23 carriers), was to look at the operating profit over a period. The operating profit and loss numbers were derived from the Airline Business (1997,1998,1999) and the *Air Transport World* (1997,1998,1999). An airline was classified as distressed, when it showed operating losses in the years 1997 and 1998, or when it had operating losses

Table 3. Airlines in sample, categorized as distressed and non-distressed

Distressed airlines (DA)	Passengers	GEQ	Non-distressed airlines (NDA)	Passengers	GEQ
Aerolineas Argentina	4,024,590	0	Aer Lingus	5,506,058	1
Air Afrique	995,620	1	Aeromexico	7,815,602	1
Air India	3,010,753	1	Air Canada	16,203,199	0
Canadian Airlines	8,168,862	0	Air China	6,453,623	1
Garuda Indonesia	6,623,472	1	Air Europe	2,564,591	0
Iberia	2,2259,083	1	Air France	33,497,633	1
Malaysian Airlines	13,654,438	0	Air Malta	1,159,398	1
Malev	1,749,232	0	Air New Zealand	6,426,013	0
Olympic Airways	6,403,393	1	Alaska Airlines	13,028,998	0
Philippine Airlines	7,405,147	0	All Nippon Airways	41,471,160	0
Sabena	8,748,544	0	Ansett Australia	11,970,225	0
South African Airw.	5,117,284	1	Austrian Airlines	3,234,190	1
Tarom	907,608	1	British Airways	36,592,684	0
Transbrasil	2,895,116	0	British Midland Airw	5,974,636	0
Turkish Airlines	9,949,301	1	China Southern Airli	14,455,242	1
TWA	23,909,333	0	El Al	2729022	0
Varig	11,214,963	0	Emirates	4,056,800	1
VASP	5,387,272	0	Finnair	6,771,138	1
			Japan Air System	19,518,067	0
			Korean Airlines	19,605,225	0
			Lan Chile	2,998,455	0
			SAS	21,506,858	1
			TAP Air Portugal	4,680,916	1
n = 18			*n* = 23		

GEQ = 1, government equity (equal to or greater than 25%); 0, no government equity. N = 41.

in three (or more) out of five years in the period 1994 until 1998. Since the purpose of the study is to segregate between the two performance states, this approach is more useful in identifying bona fide difference in the predictor variables.[8]

The Choice of Variables

In the research framework we used a number of ratios as well as other variables, continuous and nominal (Table 4). The reason for using ratios in a prediction model is to control for the effect of size on a dependent variable.

Table 4. Variables used in the model to predict airline distress

Variable	*Description*	*Type*
LF	load factor	Ratio
AVG.PASS	number of passengers carried per departure	Ratio
HRS.PILO	number of hours flown per pilot	Ratio
DEP.FLTS	number of departures per aircraft	Ratio
PLT.FLTS	number of pilots per aircraft	Ratio
EMP.FLTS	number of employees per aircraft	Ratio
AVG.AGE	average age of the aircraft fleet	Continuous
INFLATIO	annual inflation in the economy	Continuous
AC_BRANDS	number of different brands of aircraft operated	Continuous
GOVERM	political influence 1= yes, 0 = no.	Nominal

There is no generally accepted theoretical base on picking or selecting variables for prediction models, so an exploratory stance has usually been taken. In this study, however, a framework model guided the selection of variables.

As discussed earlier a study by Oum and Yu (1997) guided the selection of variables pertaining to input, while other variables were selected to fit into the prior conceptual model. At the beginning several ratios and variables were included for each of the categories as seen in Figure 1, but correlation analysis was used to eliminate highly correlated variables within each category. A condition of at least one variable in each category was set a priori.[9] We will now cover each of the variables in the model.

Variable Descriptions

Tables 5 and 6 give a detailed statistical description of each of the variables. Table 5 shows the means analysis and table 6 the correlations. The first variable is the *load factor* (LF), which is the degree of occupancy of an aircraft. It is calculated, as the number of seats sold divided by the number of seats available or more specifically revenue passenger kilometers divided by available seat kilometers. *Number of passenger*

carried per departure (AVG.PASS), indicates average equipment size as well as load efficiency. The next variable (HRS.PILO) depicts the *number of hours flown per pilot*. The following variable (DEP.FLTS) measures the *number of departures per aircraft*. This ratio measures both route structure characteristics (short-haul, long-haul) and effective utilization of aircraft. The next ratio measures the *number of employees per aircraft* (EMPL.FLTS). The ratio is also a labor efficiency ratio and measures the number of employees in all employment categories per aircraft. The following variable is continuous and measures the *average age of the aircraft fleet* (AVG.AGE) employed. *Annual inflation* (INLATIO) is a continuous variable for each airline's national inflation level. The next variable is an indicator variable that depicts domestic *political influence* (GOVERM) on the airline through controlling stake (25% or more) or full ownership of the respective government. The final variable (is continuous and depicts the *number of different brands of aircraft operated* (AC_BRANDS) by each airline.

A t-test (Table 5) revealed three variables (LF, AVG.AGE, INFLATIO) having statistically significant difference between distressed and non-distressed airlines. This finding however does not necessarily mean that these ratios are significant predictor coefficients alone in a prediction model—as pointed out by Altman (1968).

Table 5. Significant differences between distressed and non-distressed airlines in sample

NDA = 23, *DA = 18*	*STATUS*	*Mean*	*S.D.*	*S.E. Mean*	*t-test*	*sig.of diff.*
LF	Non-distressed	67	4.80	1.00	2.01	0.045
	Distresseded	64	4.57	1.08		
AVG.PASS	Non-distressed	93.72	34.08	7.11	1.46	0.152
	Distressed	80.18	22.02	5.19		
HRS.PILO	Non-distressed	257.83	43.25	9.02	-0.86	0.394
	Distressed	27512	83.08	19.59		
DEP.FLTS	Non-distressed	1657.50	702.77	146.54	0.89	0.381
	Distressed	1484.26	496.65	117.06		
EMP.FLTS	Non-distressed	161.63	57.53	11.99	-1.63	0.111
	Distressed	211.93	133.02	31.35		
AVG.AGE	Non-distressed	9.40	2.75	0.57	-3.66	0.001
	Distressed	13.29	4.03	0.95		
INFLATIO	Non-distressed	3.02	3.84	0.80	-2.31	0.025
	Distressed	14.57	23.45	5.53		
AC_BRANDS	Non-distressed	3.17	1.80	0.38	-0.99	0.922
	Distressed	3.22	1.17	0.27		
GOVERM	Non-distressed	0.48	0.51	0.11	0.21	0.835
	Distressed	044	0.51	0.13		

Correlations

Table 6 shows the correlations of 8 of 10 variables included in the model. To test for collinearity both the TOLERANCE and the Variance Inflation Factor (VIF) was calculated. Variables under consideration were eliminated from the dataset if they posed a problem according to these tests. The TOLERANCE ranged from 0.79 to 0.89 and the VIF from 1.13 to 1.30. Thus, it was safely concluded that collinearity did not pose a problem in the eventual variable set.

FINDINGS

Table 7 shows the resulting model. As the model was constructed on pre-determined framework that guided variable selection, all variables entered the model without any forward or backward elimination allowed.[10] Four variables had negative signs: load factor (LF), government equity (GOV_EQ), average number of passengers per departure (AVG.PASS) and departures per aircraft (DEP.FLTS). Negative sign indicates that the average mean is higher for the NDA carriers. However, only two coefficients were significant in the model so the relationships are only indicative for other variables. Although, insignificant, one would expect that high load factor, controlling government stake, more departures per aircraft and high average number of passengers carried per departure are positively related with non-distress.

The variables that appear associated with distress are also in accordance with expected direction of the relationship with the exception of flight hours per pilot. Airlines operating many brand types of aircraft, older fleets and in an unstable economy (high inflation) can be expected to be more prone to be distressed. However, flight hours per pilot was expected to be lower for distressed carriers. Means analysis, however, revealed non-significant difference between the two groups (NDA = 257.83 hours vs. DA 275.12 hours; $p = 0.394$). Yet this variable in combination with other variables was an effective predictor of the dichotomous dependent variable. This ratio had a weak negative correlation with average number of passengers per departure ($r = 0.174$). This could indicate that distressed carriers have on the average fewer departures per aircraft but more flight hours per pilot. Which could indicate higher average stage lengths, although our data did not reveal a significant difference in stage length between the two groups (NDA = 1357 vs. DA = 1401; $p = 0.80$). The same applied to average passenger haul (average km each passenger was carried). Although, this distance was higher on the average for distressed carriers the difference was non significant for the two groups (NDA = 1885 vs. DA = 2200; $p = 0.24$).

Table 6. Correlations between variables used to predict airline distress

	INFLATIO	AC_BRANDS		AVG.PASS	EMP.FLTS	AVG.AGE	HRS.PILO	GOVERM
LF	-.313*							
AVG.PASS	.007	-.069						
HRS.PILO	-.156	.032	.174					
DEP.FLTS	-.066	-.068	.149	-.174				
EMP.FLTS	.230	-.258	-.035	-.398**	-.071			
AVG.AGE	-.014	-.065	-.007	.162	.017	.203		
AC_BRANDS	.027	-.168	-.121	-.310*	.036	-.057	.220	
GOVERM	.320*	.171	-.008	.020	.299	-.048	-.147	-.188

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Two coefficients were significant in the model: average age of fleet (AVG.AGE) ($p < 0.043$) and number of employees per aircraft (EMP.FLTS) ($p < 0.068$). As to the accuracy of the prediction model, non-significant coefficients do not pose a problem. However, lack of significance does limit interpretability of a coefficient in a LRA model. For prediction models, it is well established, that variables poor in distinguishing between distressed and non-distressed firms alone can in combination with other variables be effective in doing so (Zavgren, 1983).

Table 7. Airline distress prediction model

	B	*S.E.*	*Wald*	*Sign.*
LF	-.329	.217	2.297	.130
AVG.PASS	-.052	.047	1.248	.264
HRS.PILO	.016	.016	1.049	.306
DEP.FLTS	-.002	.002	1.787	.181
EMP.FLTS	.047?	.026	3.324	.068*
AVG.AGE	.685	.338	4.110	.043*
INFLATIO	.157	.113	1.922	.166
AC_BRANDS	.651	.538	1.464	.226
GOV_ERM	-1.518	1.201	1.597	.206
Constant	6.757	8.807	.589	.443

*statistically significant

The model summary statistics in Table 8 allow us to reject the null hypotheses that the independent variables are not related to the dependent variable. Furthermore, the level of association of the COX & SNELL R Square (0.559) and NAGELKERKE R Square (0.749) demonstrate good association between the independent variables and the dependent variable.

Table 8. Summary of airline distress prediction model

-2 Log likelihood	*Cox & Snell R Square*	*Nagelkerke R Square*
22.663	0.559	0.749

Table 9 shows the predictive power of the model. In each category there were two misclassified cases leading to 91.3 percent accuracy for the NDA group and 88.9 percent for the DA group. Overall accuracy of the model was 90.2 percent, which must be considered a good result compared to

traditional benchmark models and airline industry specific prediction models (Table 10).

Table 9. Predictive power of airline distress prediction model

		Predicted STATUS		*Percentage Correct*
		Non-distressed	Distressed	
Observed STATUS	Non-distressed	21	2	91.3
	Distressed	2	16	88.9
				Overall 90.2

The cut value is 0.50.

Figure 3 shows the observed and predicted probabilities of each of the cases. Substantial number of the case probabilities fall into the extreme left ($p = 0.0$ to $p = 0.1$) and right ($p = 0.9$ to $p = 1.0$), which is a good trait of the model. A number of misclassified cases are near to the cut-off value ($p = 0.5$) showing borderline traits such as low profits but characteristic of a distressed carrier or vice versa.

LIMITATIONS

Perfect prediction capability of a model is unattainable for the reason of borderline cases, that is carriers shifting from a non-distress state to a distress state and vice versa, showing the characteristics of one over the other in the short- to medium-term. There are also other biasing factors such as creative adjustment of the numbers making the sample data non-reflective of the actual state of some firms. Given adequate sample size this problem is kept to a minimum, but can never be totally eliminated. Thus, some misclassification should always be expected.

There are some practical problems associated with prediction models. The most important problem is in the strict industry requirement, which is embodied in the methodology. Using such a model across a wide range of industries can be compared with the traditional custom of using the same benchmark for a current ratios across a wide range of industries: common but not a good practice. Our study meets this requirement by focusing on the airline industry.

Furthermore, usually the ratios contained in a model are determined at the time the model is developed. Thus, changing the specification of a ratio requires a complete re-evaluation of the model, as none of the ratios can be considered in isolation from the others. Any change to a single ratio has repercussions on the whole model. Yet, in our study we specified a

Table 10. Comparison of misclassification rates of several bankruptcy prediction studies

Method	*Beaver (1966)* *Univariate*			*Altman (1968)* *MDA*			*Gritta, et al. (2000)* *NN* *(U.S. small airlines)*			*Gudmundsson (1998)* *LRA* *(U.S. N.E. airlines)*			*Gudmundsson* *LRA* *(Int. airlines)*		
Years prior to failure	Overall %	Type I %	II	Overall %	Type I %	II	Overall %	Type I %	II	Overall %	Type I %	II	Overall %	Type I %	II
1	13	17	4	5 (27)	2 (1)	1 (14)	12	3	1	17	3	3	9.8	2	2
2	21	26	6	18	9	2				25	5	4	12	3	2
3	23	28	6	52						28	5	5	26	7	4
4	24	29	2	71											
5	22	23	3	64											

1. Figures in parentheses test against holdout sample. Figures not in parentheses are tested against same sample from which dichotomous classification test was estimated.

2. Type I error is misclassifying a failed firm. Type II error is misclassifying a non-failed firm.

3. Type I and II errors were only presented for the first two years.

```
   16  +                                                                    +
        |                                                                    |
   F    |                                                                    |
   R  12|                                                                    +
   E    |                                                                    |
   Q    |                                                                    |
   U    |                        N                                    D      |
   E   8|                        N                                    D      |
   N    |                        N                                    D      |
   C    |                        N                                    D      |
   Y    |                        N                                    D      |
      4 +                        N                                    D      |
        |                        N                                    D      |
        |        N   N           N                                    D      |
        |      N N   NN   NN     N                     DD D  DD D D  D DND    |
Predicted|    N N N  NN   NN    N NND    D  N D  D N D DD D  DD  D    D DND    |
Probability=0 |----------------------------------------------------------------|
Group = > |-----------N-----------------|-------------------D------------|
              .1   .2  .3  .4  .5  .6  .7  .8  .9   1
```

Predicted Probability is of Membership for Distress. The Cut Value is 0.50. Each Symbol Represents 1 Case.
Symbols: N - Non-distress
          D - Distress
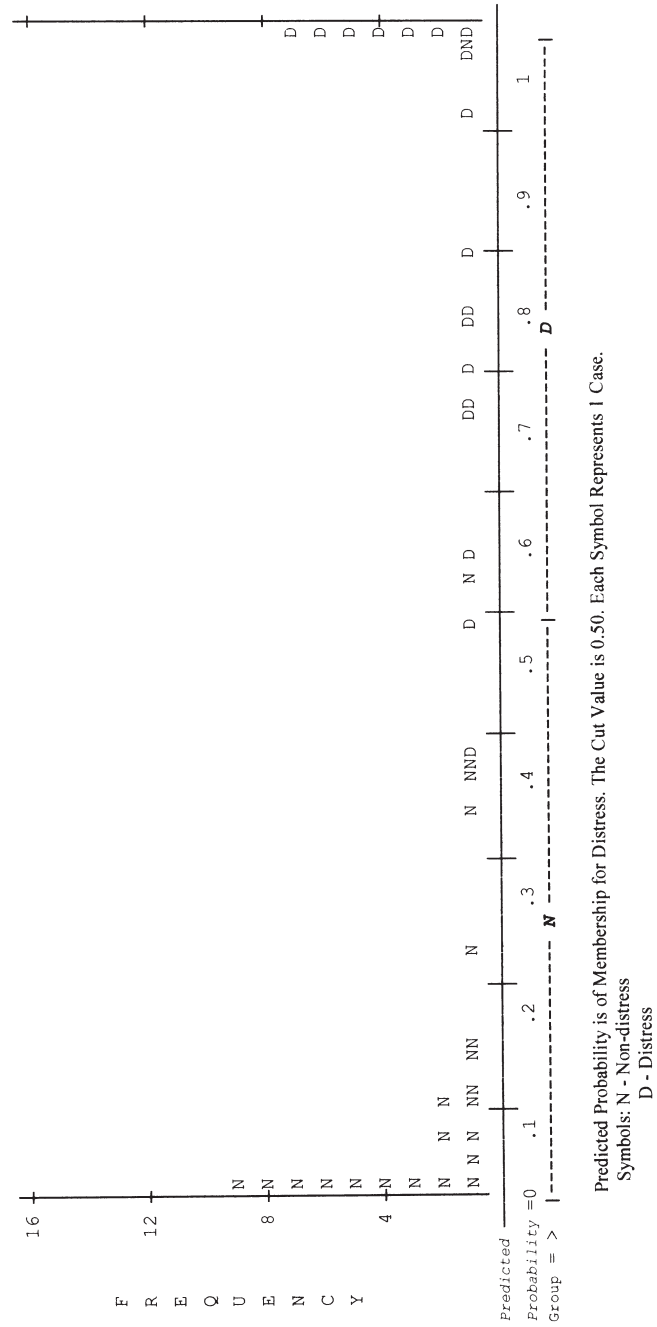
Figure 3. Observed groups and predicted probabilities of distress

conceptual relationship a priori and eliminated unnecessary variables based on correlation analysis. Thus, we believe that our model is conceptually more robust than if a traditional approach was used, that is selecting variables based on prediction ability alone.

The main limitation of this study is that we were unable to test the results on a hold-out sample. However, based on Edmister (1972), we have a reason to believe that our approach of eliminating variables from the initial set based on correlation analysis will reduce the sample specificity of the model.

CONCLUSION

The model demonstrated a fairly high prediction capability of 90.2 percent overall. Compared to other usual benchmark models (see Table 10) such as the Beaver (1966) and Altman (1968) models the performance of the model was superior in first and second years prior and almost matching Beaver's results in the third year prior. For airline models the model had superior performance to Gritta et. al. (2000) Neural Network model in the first year prior. The same applied to the non-financial LRA model specified by Gudmundsson (1998) for U.S. new-entrant airlines, which was outperformed in first and second years prior.

This research has demonstrated that an international distress prediction model seems to be feasible given that political and economic environment variables can be specified and included to capture the impact of important differences between operating environments of international airlines.

Another important new feature of our approach is the inclusion of effective prediction variables pertaining to productivity of the fleet and employees. Previous research, especially Oum and Yu (1998) demonstrated the importance of these measures to distinguish between profitability of the world airlines. But most importantly, this research used a conceptual framework to guide variable selection a priori. This is unusual in failure prediction studies, as most studies allow the selection of variables according to prediction capability only,[11] rather than using a conceptual foundation. Past research on failure prediction models has not improved the understanding of failure processes much, but rather improved the statistical methodology in segregating the two states in the dichotomous variable. It is hoped that this research has demonstrated that conceptual underpinning of a model can lead to as good of results from as those traditional non-conceptual models.

Although this study had a conceptual foundation and good prediction results, only two of the prediction coefficients were significant. This poses problem in interpreting the relationships between variables and distress and

non-distress. Yet we can state with confidence that each variable in combination with other variables is effective in distinguishing between distressed and non-distressed airlines. Yet, the two significant variables in the model allow us to state that airlines with relatively high average age of the aircraft fleet and more employees per aircraft are more likely to be in a distressed state. Thus, it is a worthwhile research project to examine the relationship of these two factors on airline performance in detail.

All in all, prediction results for our international prediction model are promising and do lend some confidence to the viability of a multi-country model. It is, however, essential that differences in economic and political environments are captured in such a model as was accomplished in the research presented here.

ENDNOTES

1. The resulting models can be based on financial ratios, non-financial ratios or a mixture of both.

2. The Neural Network approach is the most recent development in this stream of research.

3. See a good discussion on these issues in Tam and Kiang (1992).

4. Most common aircraft brands are Boeing, Airbus, MDC, etc.

5. This assumption is based on the historic fact that governmentally owned airlines are usually bailed out in times of financial crises.

6. The technical insolvency also goes by the name of insolvency on a (cash) flow basis and the insolvency in a bankruptcy sense as an insolvency on a stock basis.

7. These proportions in each group are not representative for the airline industry at large.

8. The approach may have positive impact on the 2 or 3 years prior to testing of the model for the distressed group.

9. No category was, however, empty as a result of the correlation test.

10. Forward or backward elimination is the usual approach in constructing prediction models. However, the approach leads to a model with no conceptual foundation at all.

11. Some studies select ratios according to popularity in other studies, which does not provide any better conceptual foundation for variable selection.

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The IMPACT OF MARKET LIBERALIZATION ON THE FORMATION OF AIRLINE ALLIANCES

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ABSTRACT

There has been concern raised about how airlines in the Asia Pacific (AP) region are slow in response to the liberalization of world airlines, compared with North America (NA) and the European Union (EU). There is little rigorous analysis that has examined the impact of market liberalization on formation of airline alliances. This research explores how strategic alliance activities are evolving and the critical factors that impact on the formation and development of airline alliances. Findings show the initiation of regional and more liberalized bilateral, or open skies, agreements have removed some of the impediments to structural changes in international aviation. Airlines in more liberal markets enter into greater numbers and more integrative forms of alliances. Also, the general examination of airline performance within the liberalisation process shows there is a significant difference in airline performance between the markets, and that airlines, on average, achieve better results of operation if the market is more liberal. Since currently access to new markets is still restricted, strategic alliances continue to be an important tool for airlines as they seek to expand their own networks to provide new service in a market. This suggests that regulatory coordination (or strategic airline alliances) and liberalization of international aviation reinforce each other and should therefore be pursued simultaneously.

RESEARCH ISSUES

In the last decade, it is not just the number of alliances that has increased; there are also various features of the alliances that have emerged (Wang & Evans, 2001). The term airline alliance has been used to describe an accord, partnership, cooperative agreement, joint operation, marketing alliance or code sharing agreement (IC, 1997). The strategic alliances forged in air transport markets also include intercontinental alliances (Oum & Taylor, 1995). Intercontinental alliances are the largest and fastest growing type of international alliance. Across-border alliance crosses

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geographical areas like AP, Europe and NA continents through activities like code sharing. Their aim is to expand operations abroad.

A joint venture is another type of airline alliance. This has been used to jointly develop, market, and improve airline performance through collaboration between international airlines, and to pool resources and benefit from economic scale and link (Dussauge & Garrette, 1995). Further, some airline alliances have the form of cross border equity deals (Rimmer, 1997). Equity deals refer to the agreements made under the bilateral system of air services and involve coordinating, such as routing decisions, joint fares, and sharing in cargo reservation and databases. From 1993, both joint activities and marketing alliances have progressed. Some carriers initially created frequent flyer programs (FFP) and joined together to handle ground service through joint services and marketing, sharing capacity and joint operation of the FFPs.

In 1994, the form of airline alliances moved towards a range of multilateral air transport agreements, such as single-skies agreements, air transport liberalization (open skies agreements), multilateral aviation rights, and cooperative agreements. From 1995, airline alliances have moved further towards the development of regional aviation blocs, blocking space agreements, and open skies agreements. Further, five major global groupings emerged in the airline industry in 1996, after a spate of alliance-building activities that started in 1994. The Star Alliance was formally established in 1997, followed by oneworld in 1998. In the meantime, more airlines entered these two global alliances or other global groupings (Oum, Park & Zhang, 2000). While more dynamic airline alliances have emerged, there are also some memorandums of understanding signed between countries, which enable operating the Fifth and Seventh Freedom Rights of Air, with some even including agreements of domestic flights (cabotage).

Since the 1944 Chicago Convention, all commercial aspects of international air transport have been governed by bilateral air service agreements (ASAs). Each international airline faces a complex web of bilateral ASAs signed by its home state (Oum & Yu, 1997). Air service rights are a product of a complex global network of bilateral ASAs that guarantee scheduled and non-scheduled (charter) airlines certain traffic freedoms (PC, 1998). The existence of the bilateral agreements has greatly constrained the freedom of individual scheduled airlines, and has limited competition in the international air transport industry (Oum & Yu). These constraints restrict which airlines may offer international services from their airports and to and from what points abroad airlines may offer international services. International air transport is both location-constrained and nationality-constrained (Staniland, 1997).

Facing these constraints, entering into strategic airline alliances is the major means for international carriers to obtain access to new markets, and to provide new services (Oum, Park & Zhang, 2000). With the development of strategic airline alliances, some liberal forms of formation have emerged in the aviation markets. As indicated by Rimmer (1997), there is a growing pressure to replace the bilateral system by a liberal multilateral system based on deregulation and the United States' open skies agreements. As the current regulatory system, including bilateral ASAs impediments, the initiation of regional and more liberalised bilateral, or open skies, agreements has removed some of the impediments to structural changes in international aviation (Oum et al., 2000).

With the US currently pursuing open skies agreements in world aviation markets, the Australian Industry Commission questioned that the US had not signaled its intention to hold open skies agreement discussion with Australia (PC, 1998). In fact only a few Asian Pacific (AP) region airlines have been invited to enter open skies (Eleck, Findlay, Hooper, and Warren, 1999). As the US bilateral open skies agreements provide its carriers more access to the global market, countries that do not enter into such agreements with US risk a loss of traffic (Eleck et al., 1999; Hooper & Findlay, 1998; PC, 1998). For example, the recent agreements negotiated between the US and Japan, and the US and Singapore enable US airlines to pick up traffic in a signatory country and carry them to other destinations (PC, 1998). On the other hand, although the airlines of the two Association of Southeast Asian Nations (ASEAN) economies have alliance agreements with the US, the agreements only offer the ASEAN carriers access on their direct routes to the US, but not necessarily between themselves (Eleck et al., 1999).

At present, it is generally seen that Asian airlines have been slow and entered few alliances with each other or other airlines (Hooper, 1997). In most Asian countries, governments still maintain restrictions in free trading policy (Hooper, 1997; IC, 1997; Oum, 1998; PC, 1998). There has been concern raised about how airlines in the AP region are slow in response to the liberalization of world airline markets, compared with NA and the EU. The question follows as to what are the critical factors involving the formation of alliances. Answering this question is pivotal for the studies of the development of strategic airline alliances. However, there is little rigorous analysis that has examined the question.

Previous research takes a general perspective of the objectives for forming alliances, and hence regards motivations, antecedent and environmental concerns as important factors influencing the propensity of a company to enter an alliance (Glaister, 1996; Varadarajan & Cunningham, 1995; Vyas, Shelburn & Rogers, 1995). This research

considers more specific factors and attempts to provide a detailed examination on the impact of liberalization on the development of strategic alliances, particularly the dynamic features of alliances. In pursuing liberalization, it has been argued that liberalization of the bilateral service trade hinges not on the process of trading itself, but rather on the conditions under which providers of services are permitted to establish an actual direct or indirect presence in a specific national market (Staniland, 1997).

The above discussion shows the central research problem: *What are the critical factors that impact on the formation and development of airline alliances?*

In tackling this research problem, several research issues have been identified:

1. *What is the liberalization process in NA, the EU and the AP region?*

2. *How are the major carriers in the three aviation markets involved in strategic airline alliances?*

3. *What are the critical factors involved in formation and development of strategic airline alliances?*

4. *Is there a significant difference between airline performance of the airlines in the three aviation markets, and, if so, does the difference result from the market liberalization process?*

Undertaking these research issues, a theoretical study is conducted, followed by an empirical investigation of the hypotheses.

LIBERALIZATION PROCESS AND DEVELOPMENT OF ALLIANCES

This section attempts to address the research issues through a theoretical examination of the liberalization process of NA and EU, and the aviation market situation in the AP region. It aims at developing theoretical models and hypotheses for an empirical investigation of the research issues.

The US Deregulation

After 1978, the US domestic air transport markets were deregulated, following the Airline Deregulation Act of 1978 and the International Air Transport Competition Act of 1979 (IATCA, 1979). The deregulation of US domestic air transport markets demonstrated the advantage of a competitive airline system. The deregulation enabled launching other policies to maximize consumer benefits through preservation and extension of competition between airlines in a fair market place (IATCA). Following the domestic market deregulation, a series of crucial bilateral negotiations

were conducted over the period 1977-1982. Also, some bilateral agreements were signed between the United States and 23 other countries (Oum, 1998). The effects of the liberal bilateral agreements were a dramatic expansion in the number of airlines operating, the total scheduled capacity offered in those markets, and the number of US gateway points with direct services to European or Asian destinations (DOT, 1998; PC, 1998).

In March 1992, the US offered to negotiate trans-border open skies agreements with all European countries. The open skies regime enables US carriers to pursue more liberal forms of alliances in the world air transport markets. The first US open skies deal was signed in September 1992 between the US and the Netherlands. In fact, the KLM Royal Dutch Airlines and Northwest Airlines (KLM/NW) alliance started in 1989 (Airline Alliance Survey, 1999; 2000). KLM and NW, as alliance partners, have long-haul code sharing and comprehensive marketing agreements, in the North Atlantic, in the US, Europe, Africa and the Middle East (GAO, 1995). They also have a joint FFP. They cooperate on ground handling, sales, catering, information technology, cargo and maintenance, and joint purchasing (Alliance Survey, 1999).

In 1993, the US Department of Transportation (DOT) granted anti-trust immunity to the alliance between NW and KLM, which allows the airlines from both countries unrestricted entry and capacity rights between and beyond both countries (PC, 1998). This permitted the airlines to conduct extensive code sharing and to jointly market capacity and determine fares without fear of legal challenge from the competing airlines (IC, 1997).

US aviation policy (see Table 1) appears to have recognized the importance of having unrestricted market access (PC, 1998). Under the open skies regime, the US extended invitations to enter into open aviation agreements to a number of countries that it believed shared its vision of liberalization, offering important traffic flow potential for its carriers (PC, 1999). The US had signed a total of 28 agreements by January 1998 with a range of countries in Europe, Central America and South America. Following the successes in Europe, the US started to shift the focus of its international aviation policy to Asia.

While US airlines were moving fast toward air transport market globalisation, the European market also made steady progress from a very fragmented market to a single market. This process is discussed below.

The EU Single Market

Before we start to examine the process of EU developing a single market, it is necessarily to review the EU itself. The EU consists of fifteen member states: Austria, Belgium, Denmark, Finland, France, Germany,

Table 1. US open skies policy

Item number	ITEMS
1	Open entry on all routes between the bilateral partners;
2	Unrestricted rights for partner airlines to operate between any international gateways in the US and participating countries, including to intermediate and beyond points;
3	Unrestricted capacity, frequency and aircraft on all routes;
4	Flexibility for airlines in setting fares within certain guidelines;
5	Liberal charter and cargo arrangements;
6	The ability of carriers to convert earnings into hard currency and return those earnings to their homelands without restriction;
7	Open code-sharing opportunities;
8	Rights for carriers to perform their own ground handling in the partner country;
9	The ability of carriers to enter freely into commercial transactions related to their flight operations; and
10	A commitment for non-discriminatory operation of, and access to, computer reservation systems.

Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom (UK). Before the mid-1980s, bilateral agreements had governed international aviation policies within the EU. Most member states of the EU had their own national carrier, which is generally considered to be a matter of national importance. The existence of bilateral treaties caused the market to be tightly regulated, behind high entry barriers, and hence the European airline industry was very fragmented before liberalization. Consequently, European air traffic was not very efficient. Costs, and therefore prices, were high.

To improve the efficiency of the airline industry, deregulation was introduced through three phases, termed as three policy packages. The first package became applicable beginning January 1, 1988. The second package was approved in June 1990, and the third package was approved in June 1991, but went into effect on January 1, 1993 (Graham, 1997b; PC, 1998). The implementation of the three packages was completely finished in 1997 (Graham, 1997). The first package allowed the airlines to increase their capacity shares on the routes between countries, allowed access to the markets and set the airfares. The second package removed airport deregulation in the position of the fourth freedom services and loosened capacity sharing contracts (see Table 2). It provided protection against discrimination of the airlines by their nationality in the cases of getting licenses in different member states.

In the phase of implementation of the third package, the EU airlines were allowed to freely set airfares (but has been limited by safeguards against predatory pricing) since 1993. From April 1997, the airlines have been allowed to fill a maximum of 50% of seats in a stopover in another

member state. The seventh freedom has also been permitted (see Table 2). Further, cabotage right, that is, operating domestic services, was also permitted. The third package, therefore, has removed most of the remaining regulatory constraints on intra-EU air transport. The only exceptions are some Public Service Obligation (PSO) routes, which remain protected from competition (Graham, 1997).

Table 2. The Seven Freedom Rights of Air

Item number	ITEMS
1	The right to fly over another country without landing.
2	The right to make a landing for technical reasons (eg. refuelling) in another country without disembarking or picking up revenue traffic.
3	The right to carry revenue traffic from your own country to another country with which you have an air services agreement.
4	The right to carry revenue back to your own country from a country with which you have an air services agreement.
5	The right of an airline from country A to carry revenue between country B and other countries, C. D. etc.
6	The right of country to exercise two sets of third and fourth freedom rights (A-B and A-C) but use its base at A as a transit point.
7	The right of an airline formation country to carry revenue traffic between two points with another country.

After the EU aviation market was liberalized in April 1997, EU carriers were allowed to enter into alliances unless they resulted in a virtual monopoly (McNeil, 1993). Pricing, market entry requirements and capacity were also determined by the airlines instead of respective governments or other bodies. By liberalizing the bilateral agreements among the members, EU carriers are able to fly between member states without restriction (Park, 1997; Button, 1997). Similar to the US domestic market, any EU registered carrier has the right to run domestic services within any of the EU's 15 member countries, as well as in Norway and Iceland. National ownership rules have been replaced by EU owner criteria. Airlines have been given freedom to set fares, with safeguards against predatory pricing through competition rules. The single European aviation market thus became the world's largest single aviation market with more than 370 million potential passengers in 1997.

Asian Pacific Cooperation

The AP region includes Japan, Taiwan, Korea, the People's Republic of China and other small nations, and includes Australia and New Zealand. A tourist boom and traffic growth in this region has led to Australia and New Zealand becoming major destinations (Wang, Pensde & Prosser, 1998), and hence alliances set up by Australia with other countries are significant.

Qantas ranks among the twelve largest international airlines in the AP region, with the others being China Airlines, Cathay Pacific, Garuda Indonesia, Japan Airlines, Korean Air, Malaysia Airlines, All Nippon Airways, Air New Zealand, Philippine Airways, and Thai Airways International. The International Air Transport Association (IATA) forecasts that air passenger traffic will grow from 13.2 million in 1995 to 40.3 million in 2010 with an annual growth rate of about 7.7% (IATA, 1997). Traffic between ASEAN to other regions is also predicted to grow at a rate between 7.4% and 8.9% with the busiest routes being between ASEAN and Northeast Asia.

Whilst the US and the EU markets have progressed with the expansion of air route networks, the airlines in the Asian Pacific region are also developing cooperative strategies. The privatization of Qantas and Australian started in 1991. In September 1992, Qantas acquired Australian Airlines saying that it planned to create a seamless domestic and international airline service and by October 1993, Australian was no longer being promoted as a separate entity. British Airways was permitted to purchase 25% of Qantas in March 1993 and by November 1995 the privatization process was completed. In 1993, Australia witnessed a very large increase in domestic passengers numbers following deregulation of international flights (Healey, 1994).

In November 1996, the Australian and New Zealand governments signed an agreement allowing designated carriers to fly within and between the two countries provided they are at least 50% owned and controlled by nations of either country.

Except for a few regional blocs for example, between Singapore and Brunei, there has been no other breakthrough among the ASEAN members (Airline Alliance Survey, 1999). The US and Singapore's establishment of an open skies agreement with the Philippines showed no progress, due to Philippines Airlines' poor financial performance in recent years, which would undermine its competitive position under an open skies environment (Airline Alliance Survey, 1999). Thus it is still too early to say what steps and measures are required that will make ASEAN a truly multilateral open skies region. It has been argued that this may be because the region is more diverse than Europe or NA, and that the airline industry in the AP region is in a relatively early state of its development and experiencing very high levels of growth (CAPA, 1996). With opportunity for profitable individual expansion, the region's airlines may have been less forthcoming in forming alliances (CAPA).

It has been recognized that while the economic crises in Asia have placed the carriers based in the region under financial stress, the process of globalization of the airline industry has taken a major step forward, for

instance, the Star Alliance, oneworld, and some alliances in South East Asia (Hooper & Findlay, 1998; Oum, 1998). It is argued that some of these alliances will help the Asian carriers in the short-term, in some cases, with injections of capital, through sharing the use of resources, by consolidating traffic and improving utilization of aircraft and by strengthening market positions (Hooper & Findlay, 1998; Oum, 1998). The decision by the government of Thailand to privatize Thai Airways attracted major world airlines as potential bidders. The current wave of alliance formation in Asia will help the region's airlines rationalize services, consolidate traffic and improve their finances, but it also will play a role in deciding the competitive strength of the major global alliances at key Asian hubs (Hooper & Findlay, 1998; Oum, 1998).

RESEARCH MODELS AND HYPOTHESES

The above discussion shows that liberalization processes differ strongly between regions. From 1988 to 1993, EU countries were in the process of deregulation while the first and second packages were in effect. The US was deregulated after 1979. Since 1995, NA and the EU had been in the process of liberalization. The US domestic market was fully liberalized from April 1997 followed by the EU market. From 1997, the EU market has also implemented full cabotage.

Based on the above examination, this research identifies five categories of market conditions representing each liberalization process of the three markets (see Figure 1).

Figure 1 Specification of maket conditions (NA, EU, AP)

1=Regulated markets (most airlines of the Asia Pacific region)
2=Incompletely deregulated (eg. airlines of the EU countries
   whilst the first two packages were on effects untill 1993)
3=Deregualated markets (US after 1979, EU after 1993
   when the third package had removed most of the remaining
   regulatory constraints on EU air tranpsort markets)
4=Liberalized markets (ie.North America and th EU after 1995)
5=Fully liberalized (eg. US by April 1997 and the EU from April
   1997, implementing full cabotage, operating the seventh and
   nineth freedoms)

Source: developed for this research

These specific market conditions are to be used in conjunction with the development of different types of strategic alliance, to examine whether a market condition has an effect on formation of airline alliances. Undertaking the analysis, the research develops a conceptual model, shown in Figure 2.

Figure 2 Conceptual model : Impact of market liberalization
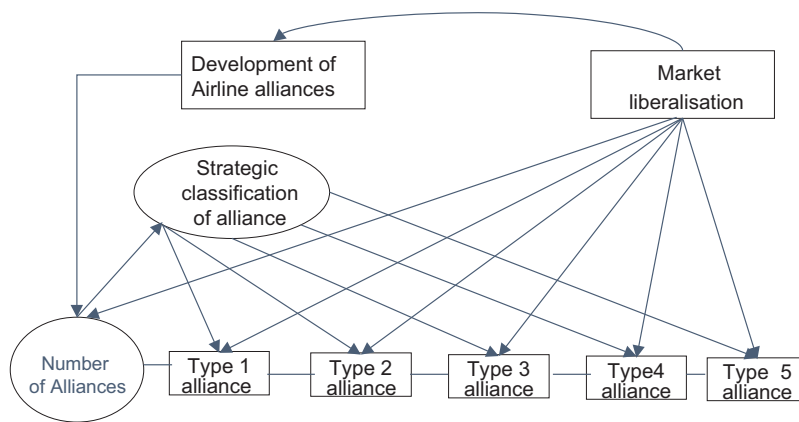
Source: developed for Research Issues

This model seeks to consider the impact of the market liberalization process of NA, the EU and the AP regions on the airlines entering number and types of strategic alliances, in that more liberal markets can lead to more number and integrated types of strategic airline alliances. Towards testing the research assumptions, some theoretical and structural equation models are developed, and described below.

First, the research presumes that there are differences between the number and types of alliances of the carriers. This presumption is expressed as

$$\sum (al)_i \neq \sum (al)_k \quad ....(3.1) \text{ i} =1,2,3 \text{ i} \neq k$$

$$\sum_{j=1}^{5} (al)_{ij} \neq \sum_{j=1}^{5} (al)_{kj}$$

where Σ *(al)* stands for the sum total of alliances, subscript *i* and *k* is a market, respectively, subscript *j* is an alliance specific dummy variable, and $\sum_{j=1}^{5}$ is the sum total of one type for the five types of alliances.

For testing the presumption expressed in equation (3.1), the research sets up a hypothesis as: *H 1: There is a significant difference in the number and forms of strategic airline alliances between the three aviation markets.*

The research also presumes that airlines with their aviation markets in different liberalization process have entered different number and types of strategic alliances. This is expressed in the equations as:

$$\sum (al)_{iz} \neq \sum (al)_{ig} \dots \dots \dots (3.2) \quad z = 1, 2, \dots 5, \quad z \neq g$$

$$\sum_{j=1}^{5} al_{iz} \neq \sum_{j=1}^{5} al_{ig}$$

where the subscript i is a carrier, z is a specific dummy variable of market conditions of i (z is not equal to g). $\Sigma(al)$ is a sum total of airline alliances, and $\sum_{j=1}^{5} al_{iz}$ is a sum total of j (one type) of the five types of alliances of i with the market condition as z.

Based on the presumption expressed in equation (3.2), the research sets up the hypothesis for tests as: *H 2: There is a significant difference between the airlines in involving strategic airline alliances with different market conditions.*

The research further presumes that the development of an airline alliance is the effect of the market liberalization, as well as other factors including year and passenger market size. It hence expresses the function of the development of an airline alliance in a structural equation model as:

$$Y_i = f(A_i, Z_i, T, Q_i, \omega_i) \dots \dots \quad \dots \dots (3.3)$$

where Y_i is the dependent variable, referring to carrier i's alliances, f includes a set of functional variables in that A_i is a specific-alliance dummy variable of i, Z_i is a specified market condition of i, T is year indices, and Q_i is the total passengers of i, and ω_i is a term of unobservable effects that may influence the development of i's airline alliances.

As an airline may have several types of alliances and experienced various market conditions in the period of 1989 and 1999, the structural equation model (3.3) is hence specified:

$$A = A(a_1, \dots, a_5),$$
$$Z = Z(z_1, \dots z_5), \quad \dots \dots \dots \dots (3.4)$$
$$T = T(yr_1, \dots yr_n)$$

where $a_1, \dots, a_5$ refers to Type 1 to Type 5 alliances, $z_1, \dots, z_5$ refers to the liberalization process of 1 to 5, $yr_1, \dots, yr_n$ refers to the year dummy variables of 1989 to 1999, and q is the number of passengers of market i.

For consistency of the functional structure and estimating the parameters of the development of airline alliances, we denote model (3.3) in the regression. The regression is expressed as:

$$InY_i = \beta_0 + \beta_1 A + \beta_2 Z + \beta_3 T + \beta_4 InQ_i + \varepsilon_i \ ....(3.5)$$

where Y is the aggregate annual alliance of i, A is the overall total alliance, including each specific type of alliances of i, Z is the specific market condition of i, T is a specific alliance dummy variable, Q_i is the total passenger traffic of i, and β is a parameter vector needs to be estimated.

Based on the structural equation model (3.3), a hypothesis is set up for the test as:

H 3: Market liberalisation leads to the development of strategic airline alliances.

The above examination presumes that market liberalization can impact on the formation and development of strategic airline alliance. The research initially also presumes that market liberalization and strategic airline alliance can affect airline performance. It hence predicts that airline performance of NA and EU markets may have been more enhanced than the AP market, due to the difference in numbers and scopes of airline alliances and market liberalization processes of the three markets. In testing these presumptions, the last two hypotheses set up for tests as:

H 4: There is a significant difference between airline performance of the three markets.

H 5: Airlines achieve better results of performance when aviation markets are more liberal.

In the next section, this research introduces statistical methods for testing these hypotheses.

STATISTICAL METHODS

The theoretical study in the above section identified five categories of market conditions that can be examined, representing the liberalization process of the three aviation markets as shown in Figure 1. The categories of market conditions in the ordinal scales from 1 to 5 are to be used in conjunctions with the development of different types of strategic airline alliances. This enables the analysis of how the market liberalization affects formation of strategic airline alliances. The alliance data used in the analysis are adopted from Wang (2001). In that the researcher identifies five major categories of current airline alliances, based on serious examinations on 11 years of the major airlines' alliance activities. The five types of alliances are seen in hierarchical ranges, from the simple affiliation

to more integrative forms of alliances, and hence can be treated as ordinal data variables in the analyses, shown in Figure 3. Several other dummy variables are also employed in the tests, and shown together in Table 3.

Figure 3 Hierarchical ranges of the five types of airline alliances
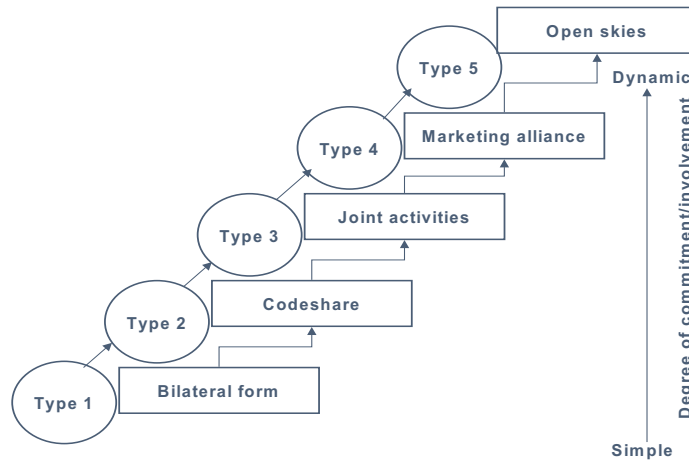
Table 3. Measures and variables employed by this research

VARIABLES	SPECIFICATIONS	
Types of alliances	Type 1	Bilateral
	Type 2	Code sharing
	Type 3	Joint activities
	Type 4	Market alliances
	Type 5	Open skies
Market conditions	Category 1	Being regulated
	Category 2	In the progress of deregulation
	Category 3	Deregulated
	Category 4	In the progress of liberalization
	Category 5	Being fully liberalized
Year indices (dummy variables)	1, …,11	1989-99
Phases of alliance development	1	1989-92
	2	1992-95
	3	1995-97
Markets	$i,…,g$ $i \neq g$	NA, EU, AP
Performance variables		Passenger numbers
		Passenger kilometres
		Passenger revenues
		Average price of per passenger kilometre

The examination focuses on three markets, NA, the EU and the AP region, as listed in Table 3. The samples used for the observation of airline

alliances are 27 major carriers in the three markets, described in Table 4. The 27 major airlines are the members of the International Civil Aviation Organization (ICAO). These airlines are also the major international airlines or flag carriers of the three markets. Further, they are where the critical issues raised by previous studies, and hence the focuses of this research began.

Table 4. The 27 major international airlines examined

NA AIRLINES	DESIGN CODE	EUROPEAN AIRLINES	DESIGN CODE	ASIAN AIRLINES	DESIGN CODE
Air Canada	AC	Air France	AF	Air India	AI
American	AA	Alitalia	AZ	Air NZ	NZ
Continental	CO	British Airways	BA	All Nippons	NH
Delta Airlines	DL	KLM	KL	Cathay Pacific	CX
Northwest	NW	Lufthansa	LH	Air China	CA
SAS	SK	Swissair	SR	Japan Airlines	JL
United	UA	Virgin Atlantic	VIR	Korean	KE
Canadian	CDN			Malaysia Airlines	MH
USAir	AL			Qantas Airways	QF
				Singapore	SQ
				Thai Airways	TG

The research hypotheses involve an analysis of variance, and hence ANOVA technique is employed. This enables the comparisons of the means of numbers and types of airline alliances between the five groups, and seeks whether there is a significant difference between the groups based on the likelihood ratios (F ratio) obtained. By the same technique and procedures, the research also tests the differences in airline performance between the different aviation markets. A *t*-test is also employed. Through *t*-test the researcher is able to further compare two sample means between before and after the liberalization. An ANOVA essentially answers the simple question of whether there is a difference between the groups. This is path analysis, which analyses indirect effects (Tabachnick & Fidell, 1996).

Some research issues study hypotheses and structural equation models (SEM). Thus regression together with testing SEM are further employed. SEM is rather a confirmatory test to seek direct effects (Tabachnick & Fidell, 1996). Some parts of the analyses also used curve estimation to show model fit by the recommended cut-off value ($p < .05$). Essentially, normality of data variables is required in estimations done by methods of maximum likelihood and generalised least squares (Bacon, 1997). The analysis therefore employs both normal plots and normality test, based on the Kolmogorov-Smirnov test and the critical ratio and modification of skewness and Kurtosis's statistic. Results of the analyses are reported in the next section.

RESULTS

Descriptive Results

First, the descriptive statistics are reported. Figure 4 shows that the airlines of the AP region introduced the largest number of new bilateral services from 1989 to 1994 and that these airlines also had the largest increase in the number of joint programs from 1989 to 1999. According to the total numbers of alliances formed during 1989 and 1992, the airlines of the AP region were at the head of the alliance activities.

The airlines of NA and the EU developed alliances by more dynamic forms, including code sharing, marketing alliances and open skies agreements. These airlines were more rapid in expanding the air route networks. Comparatively, the airlines of the AP region forged more joint activities but there were very few alliances signed under the US open skies regime during that period of time except for a few regional open skies agreements in the so called East Asia Triangle. There were a fewer airlines in the AP region entered global marketing alliances from 1996 to 1999.

Figure 4.

Involvement to the five types of alliance by the three markets: cases of 24 major international airlines (1989-99)

	NA (N=8)	EU (N=8)	AP (N=8)
■ Route specific	97	76	58
■ Codeshare	114	136	95
□ Joint programs	62	100	109
□ Marketing	100	117	32
■ Open skies'	29	21	7
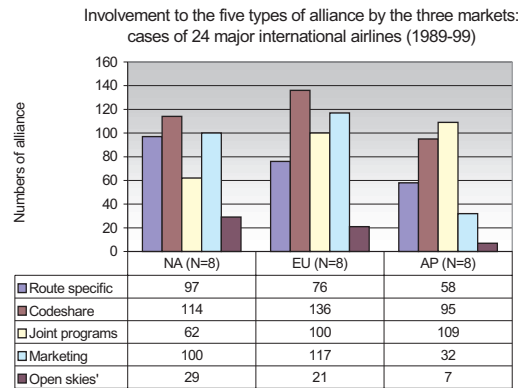
Data table

The descriptive examination on the development pattern of the airline alliance activities found that between 1989 and 1999 airline alliance activities were in three distinct growth phases. The results are shown in Figure 5. This figure first shows the wave appeared as a more flat up-growth between 1989 and 1992. The second wave occurred in the period of 1992 and 1995. In this period of time, the alliance activities had an increase,

and the increase became greater following the US signing of the first open skies agreement in November 1992. The third growth appeared between 1995 and 1999, and the growth was more rapid, showing more alliances formed during this period of time.

Results in Figure 5 also show that the airlines of the AP region were leading in strategic alliance activities between 1989 and 1995, followed by the EU. However, the AP airlines were generally slow in developing alliances from 1992 and 1999. On the other hand, the airlines of NA and the EU had more rapid progress after the 12 European countries had completed the liberalization in 1993, and the US established the open skies regime after 1992. As the growth trends show, after 1992 the airlines of NA and the EU became very active in developing alliances and the numbers of alliances had even merged together up with the airlines of the AP by 1995. Soon after 1995, both the airlines of NA and the EU markets took over the airlines of the AP region by a rapid development in the numbers of alliances.

Figure 5. Alliance involvement of the three markets 1989-99

The first period (1989-92)

	89	90	91	92
NA	3	20	38	53
EU	7	29	36	63
AP	22	43	86	98

Data table (Year 89-92)

The second period (1992-1995)

	92	93	94	95
NA	53	75	119	173
EU	63	109	131	176
AP	98	121	133	157

Data Table (Year 92-95)

The third period (1995-99)

	95	96	97	98	99
NA	173	201	266	340	402
EU	176	215	293	360	450
AP	157	172	211	258	301

Data table (Year 95-99)
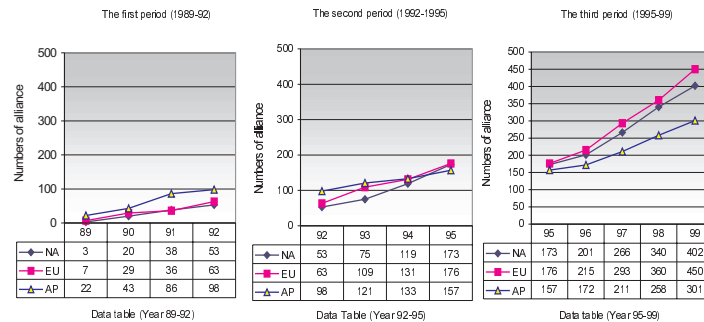
Note: These figures use accumulated data of alliances

Following the descriptive study, the research explored data distribution for normality, and results are shown below.

Test of Data Normality

Before testing the hypotheses, the analysis first explored the data normality since normal distribution is essential for estimations done by methods of maximum likelihood and generalised least squares. The criteria value for testing the normality is from a *z*-distribution, based on a significance level desired (Hair, Anderson, Tatham, & Black, 1995).

Following the guidelines the threshold value of standard score (*z*-score) is calculated, and a value exceeding ±3.5 is used as a critical ration for rejecting the assumption about normality of the distribution for this research. Also, if the data is normal distribution, its probability should be bigger than p <0.01 (Norusis, 1993).

In examining the data normal distribution, *SPSS Data Exploration* was used, through which skewness and kurtosis statistics were obtained, and then calculated. The *z*-score obtained by skewness statistics was then divided by the standard error. The *z*-score of kurtosis followed the calculation procedures of $z\text{-score} = \sqrt{kurtosisstatistic/std.error}$. These *z*-scores were then checked against the critical ratio desired (z-score = ±3.5). The test results show that all the alliance and performance data form a normal distribution, except open skies alliances where the skewness critical ratio is 2.5, satisfying the threshold value (see Tables 5a and 5b).

Table 5a. Results of normality test of the alliance data

	KOLMOGOROV-SMIRNOV		SKEWNESS	KURTOSIS
Variables	**Statistic**	**Df**	**(Critical ratio)**	**(Critical ratio)**
Route specific (bilateral)	0.16	286	1.10	0.56
Code share	0.20	286	1.60	2.60
Joint activity	0.17	286	1.40	1.90
Marketing	0.24	286	1.09	1.90
Open skies	0.38	286	2.50	6.70*
Total alliance	0.14	286	1.30	1.60

*departs from a normal distribution

Table 5b. Normality test results of the performance data

	SKEWNESS STATISTIC		SIG.	KURTOSIS STATISTIC	Pr	SIG
Variables	**Z score**	**Pr(Z≥0.49)**		**Z score**	**Pr(Z≥0.49)**	
Price p. p (US$)	-0.75	-0.29	0.19	1.17	0.38	0.28
P. revenue (US$ 000,000)	0.98	0.34	-0.24	-0.84	0.29	-0.19
Revenue p. kilom. (000,000)	0.98	0.34	-0.24	-0.95	0.34	-0.24
Revenue passenger (000,000)	0.27	0.12	-0.02	-0.84	0.29	-0.19

The following are results from examining the research hypotheses developed in the previous section through the analysis of variances, *t*-tests and the test of structural equation models.

Test of Hypotheses

This research initially predicted that the NA and the EU airlines could have engaged in more numbers and dynamic features of alliances than that of the airlines of the AP region, as outlined in the previous section. The results presented first are from testing ***Hypothesis 1: There is a significant difference in the number and forms of strategic airline alliances between the three aviation markets.***

The results in Table 6 show that there is a significant difference between the three markets in the numbers of joint activities (F = 5.05, df = 2, p < 0.007). The means show that the NA airlines on average engaged in more alliances (mean = 5.2) than the EU airlines (mean = 4.5), and the AP region airlines (mean = 3.3). Second, the results show that there is a significant difference between the three markets in numbers of joint activities (F = 6.2, df = 2, p < 0.002), marketing alliances (F = 17.4, df = 2, p < 0.000), open skies agreements (F=28.5, df=2, p < 0.000) and route specific services (F = 12.5, df = 2, p < 0.000). However, there is no significant difference in the number of code sharing activities between the airlines of NA, the EU and the AP region. The AP airlines, in fact, forged more numbers of joint activities than the airlines of the other two markets, as the means show. Test results corroborate the descriptive study to support *Hypothesis 1*.

Table 6. Different number and features of alliances between the three aviation markets

Variables	F	Df	Mean NA	EU	AP	Sig.
Annual new alliances	5.05	2	5.2	4.5	3.3	0.007
Route specific (bilaterial)	12.5	2	7.8	3.4	5.4	0.000
Code share	2.5	2	5.5	6.1	4.2	0.086
Joint activities	6.2	2	3.5	4.8	6.1	0.002
Marketing	17.4	2	4.5	5.6	1.7	0.000
Open skies	28.5	2	1.1	0.8	0.06	0.000

Since this research also predicted that, due to the differences in the liberalization process, the NA and the EU airlines could have engaged in more numbers and dynamic features of alliances than that of the airlines of the AP region, the examination also tested: *Hypothesis 2: There is a significant difference between the airlines in involving strategic airline with different market conditions.*

This test employed two statistical methods. Table 7 shows results from ANOVA, in that the means of several independent samples are compared in respect of the five market conditions. First, Table 7 shows that the mean of annual number of alliances was 2.81 if the markets were regulated, and the mean of annual number of alliances was 2.43 during the process of deregulation, and the number reached 3.29 when the market was deregulated. For the airlines in the process of liberalization the mean of annual number of alliances was 5.75, and soon it became 8.67 when the market was fully liberalized. The test results also show that there is a significant difference between the annual numbers of alliances ($F = 8.28$, df = 280, $p < 0.04$).

Table 7. Difference in alliances between market conditions

Variables	F	Df	Means					Sig.
			Z=1	Z= 2	Z= 3	Z= 4	Z= 5	
Annual alliance	8.28	280	2.81	2.43	3.29	5.75	8.67	0.04
Route spc. (bilateral)	44.2	280	0.98	0.72	1.15	0.53	0.14	0.00
Code share	8.22	280	0.48	0.77	1.10	2.50	2.04	0.04
Joint activities	31.6	280	1.04	0.65	0.74	1.65	1.73	0.00
Marketing	20.3	280	0.17	0.70	0.73	1.75	1.89	0.00
Open skies	75.3	280	0.00	0.04	0.23	0.50	0.50	0.00

$z=1,2,...,5$ the five stages of market liberalization process

The analysis also found that there is a significant difference between the means of bilateral services with the market conditions ($F = 44.2$, df = 280, $p < 0.00$). However, this test does not show the number of bilateral services increased in line with the process of liberalization. For example, the mean of bilateral services was 0.98 when the market was regulated, and the number became 1.15 when the market was deregulated. However, this number decreased to 0.53 while the markets were in the process of liberalization, and then dropped to 0.14 when the market was fully liberalized. These results suggest that the number of airlines' route-point specific services were generally decreased during this period of time. This suggests a bilateral agreement, as a reciprocal service agreement, can be forged between two countries regardless of whether a market is liberalized or regulated.

On the other hand, the number of marketing alliances and open skies agreement was increased in respect to each process of market liberalization as the means show in Table 7. These results indicate that bilateral service agreements, once the major means for airlines to access a new market, were

being replaced by other strategic airline alliances. For example, the mean of marketing alliances was 0.17 when the market was regulated, and this number became 0.73 when the market was deregulated, and increased to 1.15 while the markets were in the process of liberalization, and then arrived at 1.89 when the market was fully liberalized. The results from comparing the sample means also show that there is a significant difference between the numbers of codesharing ($F = 8.22$, $df = 280$, $p < 0.04$), and the number of joint activities ($F = 31.6$, $df = 280$, $p < 0.00$).

In order to focus on the three liberalization processes (regulation, deregulation and liberalization), a *t*-test is used. This test compared the means of the same carriers at two different stages in each analysis. Model 1 ($Z_1 \leq Z_3$) compares the number of alliances a carrier entered into when the market condition were at stage one (regulated) compared with when they were at stage three (deregulated). Model 2 ($Z_3 \leq Z_5$) compares the number at stage three with stage five (fully liberalized); and Model 3 ($Z_1 \leq Z_5$) compares stage one with stage five. The test results are shown in Table 8.

Table 8. Alliance development with market liberalization

Variables	Model 1 $Z_1 \leq Z_3$	Model 2 $Z_3 \leq Z_5$	Model 3 $Z_1 \leq Z_5$
Total alliances	(2.94)***	(2.99)	(7.08)***
Route specific (bilateral)	(2.25)	(1.92)*	(2.14)
Code share	(1.87)**	(1.64)**	(2.92)***
Joint activities	(2.74)*	(2.28)	(3.41)**
Marketing	(2.11)	(2.17)	(3.19)*
Open skies	(1.0)	(1.08)	(1.31)**

Z_1 = regulated, Z_3 = deregulated, Z_5 = fully liberalised
[b]The numbers in parentheses are means
*p <.05, **p <.01, ***p <.001

In Table 8 the results in parentheses are means, which indicate how the numbers of and types of airline alliances were different at the three stages. For example, the mean of the annual number of alliance was 2.94 when the market was at stage one, and became 2.99, then increased to 7.08 at stage three. The results also show that an airlines formed significantly larger number of joint activities when its market was liberalized than if regulated ($p < .01$). Also, an airline's number of code sharing and route specific services was increased significantly if the market was deregulated. For example, an airline's number of joint activities was significantly different ($p < .01$) with the market condition as stage five, compared with stage one. Generally, airlines obtained greater numbers coming from the increased integrative forms of alliances after the markets were liberalized. The results

from both ANOVA and t-test supported hypothesis 2.

The above tests find that there is a significant difference between the numbers of airline alliances in the different market conditions. It hence follows the question concerning the parameters of the increase in the numbers and types of airline alliances. The analysis further tested the structural equation model, to show empirical evidence of the causal-effect relationship between market liberalization and airline alliances. As the research initially presumed, more liberal markets led to more numbers of integrative alliances formed in the markets. As outlined in Section 3, it further tested *H 3: Market liberalization leads to the development of strategic airline alliances.*

Undertaking this hypothesis, three tests were conducted following the structural equation model (3.2) developed through the theoretical study in an earlier section. The first test took year as a parameter of airline formation and the results for $Y = \int$ (Year) in Table 5 show the coefficients of the estimations, in that the development of each type of alliances were significantly related to the year dummy variables. The second test took market conditions (liberalization process) as a parameter of alliance formation, and the results for $Y = \int$ (Z) showed that the dependent variables of the types of alliances were significantly related to the control variables of market conditions, and the market conditions significantly affected the development of code sharing (F = 45, p < .01), marketing alliances (F = 31. p < .001), open skies agreements (F = 31.5, p < .001), and total alliances (F = 87.2. p < .001).

The third test used three variables—market condition, year and passenger market—that tested the structural equation $Y_i = f (A_i, Z_i, T, Q_i)$; ω_i....(3.3). The results show the parameters of alliance development are market conditions, year dummy, and the passenger market (F = 87.2, Adj^2 = 0.62, p < 0.001). Additionally, this model showed a better fit, as the value of adjusted R^2 was 0.62, compared with the other adjusted R^2 as shown in Table 9.

Table 9. Development of alliances with market conditions (model tests)

Variables	Model 1 Y= ((Year) Coefficient	Model 2 Y = ((Z) Coefficient	Model 3 Y= ((Z,YR,Q) Coefficient (2 Stage least squares)	df
Total alliances	0.65*** (10.4)	0.65*** (14.3)	1.1*** (9.2)	162
Route specific (bilateral)	0.49*** (5.7)	0.43*** (7.9)	0.56*** (4.5)	160
Code share	0.59*** (7.33)	0.59*** (12.4)	0.44*** (3.3)	162
Joint activities	0.63*** (7.1)	0.27*** (4.7)	0.69*** (4.7)	162
Marketing	0.25*** (3.1)	0.65*** (14.6)	0.79*** (5.4)	162
Open skies	0.12** (1.5)	0.66*** (15.4)	0.76*** (5.1)	162
Model summary	**Model 1** **Adjusted ^{2}=0.39**	**Model 3** **Adjusted ^{2}=0.45**	**Model 3** **Adjusted R^2=0.62**	

**p <.01, ***p <.001
[ ] The number in parentheses are T value

Finally, model fit was examined. This examination predicts through curve estimation the value of the increases of alliances resulting from the markets being more liberal. The estimation used the predicted value and residual, and the upper and lower 95% confidence limits for the predicted value (Norusis, 1993). This estimation also plotted the curve based on observed and logarithmic value. Both the results form model prediction and fitting show that the model is fit. Due to space limits these tables are omitted from this paper.

Based on the results of the above examinations, it is concluded that the variables that have contributed to the development of airline alliances were market conditions, year dummy variables and passenger market growth. As the market conditions are specified in ordinal ranges and used as dummy variables, which measures whether a formation of alliance as a result of the market condition change, the results through the linear regression suggests that more liberal markets led to more integrative form of strategic alliances. The test results obtained through the multiple tests agreed with each other to show that hypothesis 3 is supported.

As the central research problem undertaken by this research is examining the impact of market liberalization, the analysis further attempts to explore whether there is a significant difference in airline performance between the three aviation markets as a result of market liberalization and airline alliances. The research finally was directed at answering the last research issue by testing hypothesis 4 and 5.

The test results (see Table 10) show that the airlines' general performance in NA, the EU and the AP regions are significantly different, with the exception of operation revenues. The estimated mean on average price of airlines of EU was twice of that of the airlines of the AP region. The results of $X2 = 49.8$, $p < .001$ show that the average price of airlines of the three markets are significantly different. The estimated means of passenger numbers and passenger kilometres of the airlines of NA were double the airlines of the AP region. The results show that the passenger numbers ($X2 = 55.7$, $p < .001$) and passenger kilometres ($X2 = 46.6$, $p < .001$) of airlines of the three markets are significantly different. Generally airlines of NA and the EU had larger profits and productivity than the airlines of the AP region and the average price of per passenger kilometres was much higher of the EU airlines (see Table 10). The results support *hypothesis 4*.

Table 10. Difference in airline performance between the three markets

Variables	US (1), EU(2), AP (3)	Number of observations	Mean Rank	Chi-square X^2	Asymp Sig
Passengers	1	62	111.57	55.7	0.00
	2	28	70.57		
	3	67	52.39		
Price of P.P.	1	67	95.75	49.8	0.00
	2	28	112.21		
	3	64	49.42		
Passenger klm	1	60	115.42	46.6	0.00
	2	38	75.58		
	3	67	58.18		
P. revenue	1	52	75.38	0.72	0.70
	2	31	67.58		
	3	60	71.35		

Results from testing *hypothesis 5* show that airlines achieved better results of performance when operating in more liberal market conditions. The results are shown in Table 11. These results show that there is a significant difference between the airlines' performance in different market conditions, with the exception of passenger operation revenues. Passenger number estimates are nearly three times more when the estimation with the market condition as 5 in contrast to 1. Also, the airline in the liberalized markets gained much larger passenger operation revenues than, in regulated market. Results show that generally, market liberalization contributed to better airline performance. Thus, *hypothesis 5* is also supported.

Table 11. Difference in airline performance between different market conditions

Variables	Z=1,...,5	Number of observations	Mean Rank	Chi-square (X^2)	Asymp. Sig
Passengers	1	32	35.44	38.2	0.00
	2	24	59.27		
	3	61	97.84		
	4	32	93.75		
	5	8	109.75		
Passenger klm	1	32	41.19	33.6	0.00
	2	29	68.89		
	3	62	97.00		
	4	34	99.24		
	5	8	123.88		
Price of P.P.	1	29	50.45	21.1	0.00
	2	24	76.50		
	3	63	80.52		
	4	34	98.71		
	5	9	110.28		
P. revenue	1	30	65.30	1.3	0.53
	2	24	69.71		
	3	46	73.50		
	4	34	72.75		
	5	9	90.00		

CONCLUSION

The research commenced with an attempt to address the research problems of the development of airline alliances and the critical factors involved in the development. The descriptive results show that the three distinct growth phases of the development of airline alliances corroborated the processes of the liberalization in the three aviation markets.

The tests of the hypotheses show that there is a significant difference between the development of airline strategic alliances with in different market conditions. Airlines in liberalized markets involve larger numbers and deeper scope of alliances than the airlines in regulated markets. Essentially, there is a positive relationship between the developments of alliances and the liberalization of air transport markets. Importantly, the results from the general examination on airline performance between the different markets with different market conditions show that there is a significant difference in airline performance between the three markets, and the airlines achieve better results of operation in the more liberalized markets.

These findings indicate that market conditions are significantly important for a formation of strategic alliances particularly for the dynamic

features of alliances. Market liberalization is also important for airline performance. Countries liberalizing the air transport markets enable their airlines to forge more numbers and integrative forms of alliance, towards building up global air transport networks. Based on the research findings, it can be suggested that airline alliances are an important strategy, particularly for the carriers of the AP region. Traditionally Asian businesses have frequently used joint activities. Airlines in the AP region have entered considerable numbers of joint activities and marketing alliances, including regional blocks, which have already benefited the airlines in term of performance.

It has been questioned that the US bilateral open skies agreements provide its carriers more access to the global market and countries that do not enter into such agreements with the US risk a loss of traffic (PC, 1998; Eleck et al., 1999). Consequently, open skies agreements may enable carriers who have the freedom to exercise market power to be dominant in the markets. Thus, regarding formation of strategic alliances, countries need to be cautious in policy making. It is essential for governments and organizations to protect developing markets and smaller carriers, to encourage competition, and also maintain necessary control over larger carriers so they its do not take advantage of the freedom to exercise power with the potential of becoming monopolistic. On the other hand, it is also important for government organizations to recognize that regulation can restrict not just the development of airline alliances but also the economic gains.

Due to the liberlization process of the Asian countries, strategic airline alliances crossing continents are still facing lots of impediments. Countries like China, due to market regulation and competitiveness, may not agree on open skies policy unless the air services are pooled with those of other goods and services (Oum et al., 2000). Thus intra-Asian open skies policy will allow the Asian carriers to compete effectively with the US carriers in their back yard (Oum, 1998). It will also allow major Asian carriers to set up an efficient multiple hub network covering the entire Asia continent effectively (Oum, 1998).

This research suggests that trade opportunities may be enhanced by an across-the-board approach, to enable a like-minded sub-group of countries to negotiate air transport and other goods and services trade together. The application of multilateral negotiations may be therefore encouraged where more than two counties take part simultaneously and broad categories of goods and services could be discussed more streamlined negotiations. A regional approach simultaneously resulting in to liberalizing all trades, including air transport, is likely to be more successful than negotiating air

transport matters separately from other goods and services trade matters (Oum et al, 2000).

The fact of economic growth and the tourism boom of the AP region will contribute to the passenger traffic growth, including passenger travel kilometers. However, the increasing rates of passenger operation revenue and average price of per passenger kilometers are not increased greatly, compared with the airlines of NA and the EU (Wang, 2001). This situation could also push the airlines of the AP region to be more involved in strategic alliances. Also, the external force of global alliances being formed by several major carriers residing in different countries is expected to strengthen over time (Eleck et al., 1999; Oum et al., 2000). This would also contribute to the promising future of the AP airlines entering more dynamic alliances.

While market entry or new service to a market is restricted, alliances will continue to be an important tool for airlines to seek in order to expand their own networks. The current regulatory system, including bilateral ASAs, poses impediments to structural changes in international aviation (Oum et al., 2000). The initiation of regional and more liberalised bilateral, or 'open skies, agreements has removed some of the impediments. This suggests that the coordination of regulatory alliances and the liberalization of international aviation reinforce each other and should therefore be pursed simultaneously.

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IMPACT OF FREQUENT FLYER PROGRAMS ON THE DEMAND FOR AIR TRAVEL

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ABSTRACT

Liberalization of the airline industry has lead to increased competition among the carriers for an expanding market of air travelers. This paper aims to identify the factors that affect the airline specific demand. The demand for the air services of Singapore Airlines (SIA) is examined in particular using binary choice models. The most important factor in influencing an individual's choice of SIA is the convenient schedule of SIA relative to other airlines. The other significant variable is membership in the Krisflyer frequent flier program (FFP), which has a small but positive (as compare to schedule convenience) impact on SIA's market. The sample is classified into different market segments: business versus leisure travel, long haul versus short haul travelers, Krisflyer FFP members versus non-Krisflyer FFP members, and FFP members versus non-FFP members. There seems to be an overall variation among the segments in each classification.

INTRODUCTION

As the global airline market inches towards liberalization, the forces of competition has lead to intense and constant realignments of loyalties between airlines, various forms of partnerships arrangements and cooperative schemes, such as code sharing agreements resulting in competitive fares, and changes in frequency of services and other attributes which are aimed at capturing market share and increasing profits. Frequent Flyer Programs (FFPs) is one such innovation introduced to induce and capture loyalty of travelers. FFPs offer free travel and upgrades as

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incentives to fly with an airline and is the most popular and successful marketing strategy devised to build customer loyalty and sell the high priced seats. The introduction of FFPs grew by 50% in less than half a decade (Bhagwanani, 2000). There are at least 100 airlines without FFPs but who have forged FFP links with one or more operators, particularly signing with at least one major airline partner. There are to date over 700 such FFP links.

FFPs are designed to achieve a high degree of brand loyalty particularly among business travelers, attract primary demand, effectively discourage new carrier competition, and give airlines direct and efficient communication links with their best individual customers (Brancatelli, 1986; Stephenson & Fox, 1987). The growth in air passengers will depend on the state of the global economy, population growth and the increase in income and wealth of individuals. Airline marketing officials claim that FFPs boost the carrier's business by 20 to 35 percent (Stephenson & Fox). However, traffic volumes can only increase across the board if total airline industry business traffic increases. Since corporate air travel is a derived demand business, it is highly improbable that FFPs will stimulate 20 to 35 percent growth. This is only possible if business travelers made billions of dollars worth of unnecessary air travel.

Unnecessary business trips can happen when a business traveler is a FFP member who gets to choose the airline and redeem the mileage earned on business trips for his or her private use while the company pays the fare. The business person might be better off choosing a regular air service that cost more due to a higher class of services or longer routes but saves on unnecessary travel under a FFP. It is also possible that an increase in traffic and revenue is a result of diverted travelers from other airlines. The relative impact of FFPs on traffic diversion and demand for air travel compared with other factors such as fare changes, a stronger economy, a growing population, and acquisition of another airline, have not been explored. One other interesting issue is whether FFPs are designed to protect (rather than expand) market share, revenues and profit erosion as a result of FFPs of other airlines. One way of ascertaining the impact of an airline's FFP on market-share is to examine the effect of FFPs on airline specific demand and choice. The following sections examine the literature on the demand for air travel and an empirical analysis of the impact of FFPs (its own and other airlines) on the demand for Singapore Airlines (SIA).

THE IMPACT OF FFPS ON AIR TRAVEL

Most surveys of individuals who belong to at least one FFP concerning airlines with FFP reveal that FFPs influence their choice of airline. For

example, Toh and Hu (1988) reported that 67% of FFP members agreed that membership in a FFP influenced their choice of airline. Morrison and Winston's (1989) model of joint airline and route choice using a sample of origin and destination data of individual trips showed that FFPs had a significant effect upon airline and route choice. Nako (1990) also found that FFPs had a significant effect on airline choice. However, FFPs are not the most important factor. The number of flights and the frequency of delays appear to have the strongest effect upon airline choice, followed by the percentage of direct flights, total travel time, FFPs, fares, and, finally, on-time performance. Except for on-time performance, the rankings in order of importance of these factors seem to be consistent with Toh and Hu (1988) findings where schedule convenience, on-time performance, low fare, and overall service by attendants are of greater importance in influencing their choice of airlines than FFPs. Business travelers gave a higher ranking to FFPs (Nako, 1990).

Factors Affecting the Demand for Air Travel

The growth in air traffic is accelerated by the falling price of air transport and an increase in economic activities. Falling airfares and rising personal incomes have also lead to an increase in the demand for leisure trips. Globalization, accelerated economic growth, liberalization of trade and the natural growth in population have had a positive impact on the demand for business travel. The demand for airline services is dependent on the volume of air traffic on a route. Factors affecting demand on specific routes include the relative attractiveness of tourist destinations, the relative price of goods, the relative cost of holidays, the exchange rates and the extent of migration, which can result in increased air travel to visit far-away friends and family. The nature of industrial and commercial activities at an airport's hinterland influences the volume of business traffic. The pattern and growth of demand of any route are affected by the economic and demographic characteristics of the markets at either end of the route.

Supply side factors such as frequency, seat availability, departure and arrival time, and number of en route stops influence the distribution of demand between competing carriers and play a significant role in affecting the airline specific demand. The demand for air travel is a function of the generalized cost of travel, that is, fare and time spent on utilizing the services. A carrier will attract passengers if it can offer a noticeable reduction in the elapsed time. This consists of (a) airport access time, (b) flight time, (c) waiting time and (d) boarding time. Other airline service attributes specific to the carriers that influence passengers' preferences include safety records, airline experience, in-flight service, fleet type and whether the airline is the flag carrier of the traveler's country of origin.

Factors Affecting the Effectiveness of an FFPs

Network coverage of air service provided

A business traveler will find it easier to accumulate FFP mileage if an airline covers most of his business destinations or has good coverage through alliances and partnerships with other airlines.

Airline's market share

Nako (1990) decomposed the effects of FFPs into an airline specific effect (which is measured by a membership variable, whose coefficients are positive and significant) and a hub effect (interactive term). The estimate of the interactive term indicates that an increase in an airline's airport market share by 10% enhances the value of the FFP by US $4.80. The effectiveness of a FFP is enhanced with the rise in the airline's presence in the city in which the participating members resides.

Duration and distance of flights

The effectiveness of a FFP increases with total travel time since travel time is positively correlated with the amount of mileage credit that may be earned on a specific trip. The positive sign of the coefficient of the interaction between fares and FFP membership provides some evidence that FFP members are less fare sensitive than non-FFP members.

Characteristics of an individual FFPs

The characteristics of the airline's services affect the effectiveness of its FFPs. However, FFPs are packaged differently. The success of a FFP grows in line with the number of members it can attract. It is not the absolute benefits but the relative gains compared to that of the other carriers that matter to individual travelers. In designing the awards scheme, one has to keep in mind the targeted group. The structure of the award and benefit system differs from airline to airline due to the difference in characteristics of the target group.

The first structural component lies in the ease in redeeming travel awards, this includes the class of service, the bonus for travel in first and business class, and the type of fares that qualify for point accrual. The second structural differentiator is the partner network inclusive of hotel, car rental and other retail chains. The third element centers on the terms and conditions that determine the flexibility of the reward system which consists of covering the validity of miles, booking procedures, blackout dates, transferability of awards and the capacity provided for award travel. The fourth element of the program is customer service. The last structural

factor is the elite program, catering to that essential customer segment of frequent high-yield travelers.

One rationale behind a FFP is to award free trips to the frequent flyers on seats that would not have otherwise been taken. This is to minimize revenue lost. This argument is weak because many FFP members do use the free tickets for trips they would have paid for. Other FFP members sell their free-ticket coupons to ticket brokers. In each case airlines lose revenue. The above revenue displacement phenomenon is prevalent in open-ended programs where the flyer does not have to use their mileage points by a certain date.

Most studies have focused on estimating the demand for the U.S., North Atlantic and European markets using aggregated data. This study estimates the demand for air travel by air travelers (foreign and local) in Singapore with the aid of disaggregated data. Factors affecting the demand include airfare, income, population, airlines' image, FFPs' quality of service in terms of frequency of flights, and load factors. The studies conclude that market share of the airline has an impact on the effectiveness of the airline's FFP on residents living near to an airport. However, does the FFP in turn affect the airline's market share? If so what is the impact?

FFPS AND AIRLINE CHOICE

Random surveys were conducted between December 18 and December 20, 2000, at several strategic locations in Singapore such as shopping centers, the financial district and popular tourist attractions. There were 192 successfully completed surveys. All respondents must have flown in the past twenty months with SIA within their choice set of airlines. A short haul traveler is defined as one whose origin or destination is any city in Asia, Australia or New Zealand to or from Singapore. If the traveler's origin or destination was further he or she would be classified as a long haul traveler. A business traveler is one who travels for the purpose of work regardless of who pays for the fare. Otherwise, he or she is a leisure traveler.

Descriptive Statistics

About 56% of the respondents are between the ages of 25 to 45 years old and are business travelers compared to only 35% of the leisure travelers who are 35 years old and younger. Business travelers (54%) earn more than S$9,000 a month as compared to leisure travelers (21%). Most business travelers are from the IT (12%) and banking and financial sectors (12.%), electronics (9%), manufacturing (6%), chemical (6%) and shipping (4.6%). Others include real estate, warehousing, food catering, legal, and

advertising. Table 1 shows that the 34% of travelers travel to or from Europe followed by 33% to or from Asia, Australia and New Zealand, Americas, Middle East and South Africa.

Table 1. Origin and Destination of Travelers Responding to FFP and Airline Choice Survey

Region	Percent
North & South America	10
Europe	34
Middle East & South Africa	4
Australia & New Zealand	19
Northeast Asia	14
Southeast Asia	11
West India	9

There were an equal number of long haul business (LB), short haul business (SB), long haul leisure (LL) and short haul leisure (SL) travelers. Over 50% of all business travelers surveyed were based in Singapore. This may be one of the reasons why 71% of the SB travelers chose SIA. Some travelers fly about 9 times a year with SIA. Half (50%) are members of the Krisflyer FFP. The average SB traveler is a member of more than one FFPs (1.7) and gave the highest rating of importance to FFPs (3.4 out of 5.0). The SB traveler sample has the largest proportion of members in the FFPs of other airlines (besides SIA, and Star Alliance and OneWorld carriers) and FFPs of the flag carrier of their own country of origin or residence. About 60% focus on just one FFP.

The highest proportion of LB travelers chose airlines recommended by their companies and fly with the flag carriers of their country of origin or country of residence. This group has the largest proportion of members in FFPs of a Star Alliance carrier (48%) and the flag carrier of their country of origin . A small number belong to FFPs associated with OneWorld carriers (16%). At least 79% of business travelers are FFP members while only 46% of leisure travelers belong to at least one FFP. These percentages are higher than Toh and Hu's (1988) estimate of 72% for business travelers and 23% for leisure travelers.

FFP Membership Profile

Of the 192 respondents, 127 belong to at least one FFP. About 60% of the FFP members earn more than S$84,000 annually while only 20% of non-members exceed this amount. Toh and Hu (1988) found that 72% of FFP members, compared to 34% of non-FPP members, earn more than US$40,000 (S$69,200) per year. A higher proportion of the FFP members

Table 2. Types of Airlines Chosen and Participation in Frequent Flier Programs (FFPs), by Type of Traveler

	Long-haul Business	Short-haul Business	Long-haul Leisure	Short-haul Leisure	All
Percent based in Singapore	58	52	13	25	37
Number of trips per year					
on Singapore Airlines	3.06	9.10	1.33	1.06	3.64
Choice of airline					
Singapore Airlines	38	71	50	38	49
Flag carrier of traveler's					
country of origin	44	23	31	28	31
Flag carrier of traveler's					
country of residence	44	50	33	31	40
Carrier recommended by					
employer or travel agent	52	27	29	20	32
Participation in frequent					
flier programs					
Concentrates in					
only one FFP	56	60	35	40	48
Number of FFP					
memberships	1.42	1.73	0.73	1.19	1.27
Importance of FFPs	2.7	3.4	1.7	2.3	2.5
Krisflyer member	35	50	15	19	30
STAR Alliance member	48	33	27	44	38
ONEWORLD member	17	35	19	46	30
Member of other FFPs	35	42	27	29	33

(32%) are either CEOs or owners of business. A higher proportion of FFP members (60%) compared to non-FFP members (31%) travel on business. This is similar to the findings of Toh and Hu. About 79% of business travelers are FFP members while 53% of leisure travelers are FFP members. This is higher than the 72% and 23% in the corresponding group estimated by Toh and Hu.

A higher percentage of FFP members (54%) make short haul trips compared to non-FFP members (47%) and have a higher average number of trips made per year (16; see Table 3). Only 30% of FFP members choose airlines recommended by travel agency or their company while 35% of non-FFP members took the advice. The average airfare of FFP members is S$2,354, which is higher than that of non-FFP members of S$1,835. Toh and Hu (1988) also found that FFP members tend to travel more often short distance (an average of 17 trips per year), pay higher fare and rely less on travel agencies. About 45% of all FFP members fly with the flag carrier of their country of residence as compared to only 29% of the non-members. The higher proportion of FFP members choosing SIA seems to positively

correlate with the higher proportion of FFP members living in Singapore 39% versus 32%, respectively).

Table 3. Characteristics of Travelers, by Frequent Flier Program (FFP) Membership

	FFP members	*Non-FFP members*
Business traveler	59	31
Long-haul traveler	46	63
Number of trips per year	16.02	3.21
Uses carrier recommended by travel agent or employer	31	35
Average price of airfare	S$2353.79	S$1834.71
Uses flag carrier of traveler's country of origin	31	31
Uses flag carrier of traveler's country of residence	45	29
Singapore Airline passenger	32	43
Singapore resident	39	32
Singapore resident and citizen	45	34

About 64% of the FFP members interviewed belong to two or more programs. This is marginally larger than 61% estimated in Toh and Hu's study (1988). About 30% (27% in Toh and Hu) participate in three or more FFPs. However, only 2%, as compared to 17% in Toh and Hu's survey, joined four or more FFPs. This is probably due to more domestic air travelers taking advantage of FFPs of U.S. domestic airlines. On average a FFP member in our sample belongs to 1.92 FFPs. FFP members on average give a rating of 3.81 (out of 5.00) to the importance of FFPs in affecting their choice of airline.

There is a positive correlation index of 0.15 between the number of FFPs enrolled in and the importance of FFPs. A similar correlation is observed between the strategy of concentrating in one FFP and rating the importance of a FFPs. This confirms Toh and Hu's finding that FFP members enroll in multiple programs but concentrate in one. The importance of FFPs will determine how FFP membership affects one's choice of airline. Over 40% of this sample do not belong to any FFP from either the Star Alliance or OneWorld, while 7% join FFPs of both the Star Alliance and OneWorld. A majority of FFP members belong to FFPs of at least one of the major alliance carriers. A large portion of the major alliance FFP members chose to concentrate their mileage among carriers within one alliance. This may

imply that a FFP member of a Star Alliance carrier has a higher likelihood to opt for a SIA flight than one belonging to another alliance.

Table 4. Characteristics of Travelers, by Membership in Frequent Flier Programs (FFPs)

	FFP member	Krisflyer member	FFP member but non-Krisflyer member	Non-Krisflyer member
Type of travel/traveler				
Business traveler	na	70	49	39
Long haul traveler	na	44	51	56
Number of trips per year	na	11.5	19.3	11.9
Singapore resident	na	49	23	29
Singapore resident and citizen	na	54	23	30
Choice of Airlines				
Singapore Airlines	na	7.00	2.63	2.24
Flag carrier of traveler's country of origin	71	68	75	34
Flag carrier of traveler's country of residence	70	74	65	38
Carrier recommended by employer or travel agent	na	32	32	32
Average price of airfare	**na**	**0.280702**	**0.338028**	**0.325926**
Participation in frequent flier programs				
Concentrates in only one FFP	72	74	73	38
Importance of FFPs	3.8	3.8	3.7	2.0
Number of FFP memberships	1.92	2.05	1.70	0.93
Star Alliance FFP member	57	86	60	30
OneWorld FFP member	43	39	39	25
Membership of other airlines' FFPs	50	40	55	30

The behavioral and attitudinal profile of Krisflyer members were analyzed with respect to three other groups of respondents, namely all FFP members, non-Krisflyer members and members of other FFPs except Krisflyer. Since the second group , non-Krisflyer members, includes many non-FFP members the percentage of this group differs with the rest of the three significantly (see Table 4). A Krisflyer member on average belongs to 2.05 FFPs, this is higher than the overall average of 1.92. A vast majority of Krisflyer members join at least one other FFP with 54% of the Krisflyer members joining two other FFPs.

Over 50% of the FFP members join FFPs of Star Alliance carriers. This percentage is larger than those who join the FFP of OneWorld (42%). A relatively lower percentage of Krisflyer members belong to the FFP of OneWorld compared to 42% of non-Krisflyer members. Almost 40% of

the sample that are members of Krisflyer belong to FFPs of other Star Alliance airlines but are not members of FFPs of OneWorld airlines, while only 15% of Krisflyer members belong to FFPs of OneWorld but not Star Alliance carriers. An overwhelming proportion of FFP members are members of FFPs of the flag carriers of their country of residence (69%). This percentage is approximately the same as those joining FFPs of the flag carrier of their country of origin. This percentage is higher among Krisflyer members. Being a resident of Singapore is an important factor in influencing an individual's decision to join the Krisflyer FFP.

A majority of FFP members felt that concentrating on one FFP would yield the best benefits (72%). This percentage is marginally smaller in Toh and Hu (69%, 1988). An overwhelming percentage of Krisflyer members are business travelers (70%). This is the highest among the three groups. A small proportion of Krisflyer members make short haul trips. Since a significantly larger proportion of Krisflyer members are either Singapore citizens or residents, the average number of SIA trips made in one year is higher than that in other categories.

Summary

The majority of respondents flew between Singapore and Europe and Singapore and Asia. About 35% of the respondents are stationed at Singapore, 50% of whom are business travelers. Over 50% of the business travelers chose to fly with SIA. However, a higher proportion of business travelers as compared to leisure travelers choose the flag carrier of their country of residence. Business passengers rate FFPs as being more important in affecting their choice of airline. A large proportion of short haul business travelers chose to fly SIA and to participate in the Krisflyer FFP.

About 66% of the respondents are FFP members and are short haul business travelers who take more flights and pay higher airfare. A higher proportion of FFP members, compared to non-FFP members, chose flag carriers of their country of residence and belong to FFPs of the Star Alliance rather than OneWorld. There is no significant difference between Krisflyer member and other FFP members in terms of FFP participating behaviour except that a higher proportion of Krisflyer members, compared to members of other FFPs, enroll in at least one other FFP that is a member of the Star Alliance. This implies there are more benefits to Krisflyer members if they join other FFPs. Most members of the Krisflyer FFP concentrate on one FFP.

THE DEMAND FOR AIR SERVICES

This section will propose several model specifications to explain the demand for air services with respect to the presence of SIA. The objective is to identify the relevant variables and estimate their relative importance in affecting travelers' choice of airline and ascertain the extent of Krisflyer membership in influencing a traveler's probability of choosing SIA, and the effect of the Krisflyer FFP on SIA's market share. The variations for each factor across different market segments are also examined.

Model Framework

Probabilistic choice theory is applied to the traveler's choice when making a trip. Binary choice models are specifically chosen since data attributes of only two alternatives are readily available for the entire sample. We specify individual i's indirect utility for choosing SIA's air services, U_{si}, as follows, $U_{si} = V_{si} + \varepsilon_{si}$ where V_{si} = deterministic component of individual i's utility and ε_{si} = SIA's specific error term. We specify individual i's utility for choosing any other airline j's transportation services as $U_{ji} = V_{ji} + \varepsilon_{ji}$ where V_{ji} = deterministic component of individual i's utility and ε_{ji} = j's specific error term.

An indicator variable defined as $y_{si} = 1$ if traveler i chooses SIA, and 0 if he or she chooses the another airline j. The probability of choosing SIA, that is, Prob($y_{si} = 1$) is defined as follows,

$$P_i(s) = \Pr (U_{si} \geq U_{ji})$$
$$= \Pr (V_{si} + \varepsilon_{si} \geq V_{ji} + \varepsilon_{ji})$$
$$= \Pr (\varepsilon_{ji} - \varepsilon_{si} \leq V_{si} - V_{ji}).$$

The net utility to individual of choosing SIA is given by $V_i = V_{si} - V_{ji} = \sum_{k=1}^{K} b_k x_{ki}$ where b_k = unknown parameter of the kth independent variable x_k; $x_k = f (z_{si}, z_{ji}, S_i)$ in which, z_{si} = the vector of SIA's attribute value to individual i, z_{ji} = the vector of airline j's attribute value to individual i and S_i = the vector of socio-economic variables which are included as SIA specific variables.

P_i will depend on the joint probability distribution function assumption for $\varepsilon_{ji} - \varepsilon_{si}$ and the specification of V_i. If $\varepsilon_i = \varepsilon_{ji} - \varepsilon_{si}$ is logistically distributed, then it would be a binary logit model. If the disturbances follow a normal distribution, it would be a binary probit model. Various specifications of V_i will be discussed throughout the section.

The likelihood function in terms of the set of coefficients b_k of k variables is $L(b_1 \, b_2, \ldots . b_k)$

$$= \prod_{i=1}^{I} P_i(s)^{y_{si}} P_i(j)^{y_{ji}}$$

The maximum logarithm of the likelihood function, denoted by, L (b_1, b_2,...b_k) is used to estimate the vector of coefficients, b. If all individuals in the market have the same deterministic component (attributes and weights) and the stochastic components (ε_{ji}, ε_{si}) from either a Gumbel distribution or a normal distribution, the aggregate SIA's market share is the same as the average individual forecast under the logit or probit assumption respectively.

Model Specifications

V_i is specified first in terms of the variables, which are believed to have an impact on the travelers' choice of airline. E-views and Limdep are used to run regression on the data under the assumptions of binary logit (b-logit) and binary probit (b-probit). The deterministic utility for SIA and that of airline *j* is specified as:

$V_{si} = b_1 + b_2\text{SCHEDULE}_{si} + b_3\text{LG(FARE}_{si}) + b_4\text{LG(TIME}_{si}) + b_5\text{RES}_i + b_6\text{RECOM}_i$
$+b_7\text{IMPT}_i*\text{KRIS}_i +b_8\text{CONCENT}_i*\text{FFP}_i +b_9\text{STAR}_i +b_{10}\text{LG(INCOME}_i)$,
$V_{ji} = b_2\text{SCHEDULE}_{ji} + b_3\text{LG(FARE}_{ji}) + b_4\text{LG (TIME}_{ji})$.

Since it is the difference in utility that matters the difference in attribute value between alternatives is expressed in one term. Thus V_i is given as,

$V_{si} - V_{ji} = b_1 + b_2(\text{SCHEDULE}_{si} - \text{SCHEDULE}_{ji}) + b_3\text{LG(FARE}_{si} - \text{FARE}_{ji}) + b_4\text{LG(TIME}_{si} - \text{TIME}_{ji}) + b_5\text{RES}_i +b_6\text{RECOM}_{ji} + b_7\text{IMPT}_i*\text{KRIS}_i +b_8\text{STAR}_i +b_9\text{CONCENT}_i*\text{FFP}_i +b_{10}\text{LG(INCOME}_i)$ is expressed as the following models.

MODEL 1: Basic model

$V_{si} - V_{ij} = b_1 + b_2\text{SCHEDULE} + b_3\text{LG(FARE)} + b_4\text{LG(TIME)} + b_5 \text{ RES} + b_6\text{RECOM} + b_7\text{IMPTKRIS} + b_8\text{STAR} + b_9\text{CONFPP} + b_{10}\text{LG(INCOME)}$

MODEL 2: Modified basic model

$V_{ii} = b_1 + b_2\text{SCHEDULE} + b_3\text{LG(FARE)} + b_6\text{RECOM} + b_7\text{IMPTKRIS} + b_9\text{CONFFP}$

MODEL 3: Impact of travel type—Business versus leisure travel

$V_{si} - V_{ji} = b_1 + b_2\text{SCHEDULE} + b_3\text{LG(FARE)} + b_6\text{RECOM} + b_7\text{IMPTKRIS} + b_9\text{CONFFP} + b_{11}\text{BIZ}$

MODEL 4: Impact of length of travel—Long haul versus short haul travel

$V_{si} - V_{ji} = b_1 + b_2 SCHEDULE + b_3 LGFARE + b_6 RECOM + b_7 IMPTKRIS + b_9 CONFFP + b_{12} LONG$

MODEL 5: Impact of length and type of travel—Comparing between market segments of LB, SB, SL and LL

$V_{si} - V_{ji} = b_1 + b_2 SCHEDULE + b_3 LG(FARE) + b_6 RECOM + b_7 IMPTKRIS + b_9 CONFFP + b_{11} BIZ + b_{12} LONG$

MODEL 6a: Impact of FFP—Krisflyer members versus non-Krisflyer members

$V_i = b_1 + b_2 SCHEDULE + b_3 LG(FARE) + b_6 RECOM + b_7 IMPTFFP + b_9 CONFFP$

MODEL 6b: Impact of FFP—Krisflyer members versus non-Krisflyer members (modified)

$V_i = b_1 + b_{2S} CHEDULE + b_8 STAR + b_{13} QFFPCON + b_{10} LG(INCOME)$

MODEL 7: Impact of FFP—FFP members versus non-FFP members

$V_{si} - V_{ji} = b_1 + b_2 SCHEDULE + b_3 LG(FARE) + b_6 RECOM + b_{14} NO$

Where,

1. Coefficient b_1 is the alternative specific constant (SIA here) is $\varepsilon_{si} - \varepsilon_{ji}$. It reflects the difference between the utility of choosing SIA and that of any other airline *j*, other things remaining constant.

2. SCHEDULEni s , j (n (s: SIA, j: all other airlines) is respondent's ordinal rating of the schedule of airline n for the specific trip discussed on a 5-point scale (where 5 stands for Excellent and 1 stands for poor). This often refers to the quality of air services measured by frequency stochastic delay.[1]

3. $LG(FARE_{ni})$ s , j $\in$ *n* which is the natural logarithm (log) of the airfare respondent *i* faces for the particular trip discussed expressed in terms of Singapore dollars. This generic[2] variable of monetary cost represents payments by foreign visitors for their airfare in foreign currency.[3]

4. $LG(TIME_{ni})$ is the log of trip duration on airline *n* measured in terms of hours. TIME*ni* obtained from flight time connecting time

and stop over time, which includes the waiting time at the airport to get transit onto a connecting flight but excludes time spent outside the airport. This time variable is meant to capture the time required to complete the trip. Time spent in activities to gain utilities should be as far as possible excluded from the measurement.

5. RES_i is the dummy variable that equals 1 when individual *i* chooses the flag carrier of his or her country of residence and 0 otherwise. This will also equal 1 if the airline chosen is the flag carrier of the traveler's country of origin.

6. $RECOM_i$ is a dummy variable that equals 1 when individual *i* chooses the airline upon recommendation of the travel agency or corporate travel policy and 0 otherwise.[4]

7. $IMPTFFP_i$ is an individual i's 5-point scale rating (in which 5 = very important and 1 = not at all important) of the importance of an FFP in influencing his or her choice of airline.

8. $KRIS_i$ is a dummy variable that takes a value of 1 if the individual *i* is a member of Krisflyer and 0 if not.[5] The individual specific weight $IMPT_i$ is multiplied by $KRIS_i$ to obtain $IMPTKRIS_i$.

9. $CONCENT_i$ is a dummy variable taking the value of 1 when the individual *i* thinks that concentrating in one FFP will yield him the largest benefits and 0 otherwise. This also equals 1 if the rating is three or greater and 0 if the rating is less than three.

10. $JFFP_i$ is a dummy variable that equals 1 when individual *i* is a member of airline *j*'s FFP (i.e., a member of any other FFP besides or in addition to the Krisflyer FFP) and 0 otherwise. $CONFFP_i$ is the product of $CONCENT_i$ and $JFFP_i$ to examine the interactive effect.[6]

11. $STAR_i$ is a dummy variable equals to 1 if an individual *i* is a member of a FFP of a Star Alliance airlines other than SIA and 0 otherwise. If the FFP belong to airlines in the Star alliance, then $STAR_i$ will take the value of 1 and 0 otherwise. This reflects the impact of membership in the Star Alliance FFP on the demand for SIA's service. This does not include Krisflyer membership, which has been captured by the variable $IMPTKRIS_i$.

12. $LG(INCOME_i)$ which is the natural log of individual *i*'s monthly income measured in terms of Singapore dollars. This measures the impact of income on the variations and relative utility of flying SIA.

13. BIZ is a variable equal to 1 if the traveler is categorized as a business traveler, and equal to 0 if the traveler is categorized as a leisure traveler.

14. LONG is a variable equal to 0 if the traveler's origin or destination is any city in Asia, Australia or New Zealand to or from Singapore;=, and 1 if the origin or destination was further.

15. QFFP is the five point rating of Krisflyer or SIA services minus the corresponding rating of any other airline's FFP or services.

16. QFFPCON is the product of IMPTFFP*CONCENT.

17. NO is the difference between the average number of SIA flights per annum minus the average number of other airlines' flights.

Empirical Results

Models 1 and 2: Deriving the basic model

The b-logit model[7] is significantly different from the intercept only hypothesis ($b_1 = c$ and $b_2 = b_3 = ... = b_{10} = 0$) as shown by the likelihood ratio (LR) statistic of about 52 which is significant in a χ^2 distribution with a degree of freedom (df) = 11. Only three out of ten variables are significant at a 10% level of significance for a two-tailed t-test.[8] The ρ^2 is only 0.20 with adjusted $\bar{p}^2$ significantly smaller at 0.13. This implies that too many variables have been included in the regression equation and that multicollinearity is present. Given the presence of an insignificant estimated coefficient $\hat{b}$, the final specification of V_i is given by Model 2 (see Table 5). The results of b-probit is presented and given higher $\bar{p}^2$, compared to the b-logit model. Only SCHEDULE and IMPTKRIS have significant coefficient estimates. The estimated b_2 is almost twice the estimated b_7 indicating that an increase in the schedule rating by one unit will increase the probability of choosing SIA by a larger amount as compared to a one unit increase in the rating of importance of FFPs.

Model 3: Impact of travel type—business versus leisure travel

The airline market is segmented by purpose of travel and distance of trip. Thus the observed different proportion of passengers in each segment may be due not only to the different average value of attributes across segments but also to the different weights placed on each attribute. Model 2 is used as the base equation to analyze various market segments by different categories of travelers. The analysis on trip type gives Model 3 and includes the addition of the variable BIZ. This resulted in a higher $\bar{p}^2$ (0.111961 >

Table 5. Significance of variables on choice between using SIA and any other airline, by type of traveler

Variable	All travelers		All travelers		Business traveler		Leisure traveler		Long haul traveler		Short haul traveler	
	Coeff	Prob	Coeff	Prob	Coeff	Prob	Coeff	Prob	Coeff	Prob	Coeff	Prob
No differences	-1.663451	0.1588	-0.12117	0.419	0.10098	0.7008	-0.23590	0.2049	-0.3336	0.128	0.05461	0.7966
Quality of schedule	0.295960	0.000*	0.262028	0.00*	0.34794	0.0000	0.179473	0.0225	0.38769	0.000	0.18909	0.0055
Price of airfare	-0.104883	0.5078	-0.14593	0.369	-0.0124	0.9653	-0.16094	0.4750	-0.0308	0.847	-0.2903	0.3271
Length of trip duration	0.591069	0.1508	-	-	-	-	-	-	-	-	-	-
Airline is flag carrier of traveler's country of origin or residence	0.636024	0.003*	-	-	-	-	-	-	-	-	-	-
Recommendation of travel agent or employer	-0.260546	0.2298	-0.23459	0.266	-0.3934	0.1947	-0.05524	0.8528	0.19882	0.504	-0.7317	0.0246
Importance of Krisflyer FFP membership	0.098515	0.0924*	0.1336	0.013*	0.11483	0.1200	0.107689	0.2454	0.13024	0.132	0.13366	0.0633
Strategy of concentrating in one FFP	-0.496367	0.045*	-0.29304	0.204	-0.4938	0.1345	-0.17711	0.6002	-0.4985	0.164	-0.1304	0.6815
Membership in Star Alliance FFP	0.070428	0.7550	-	-	-	-	-	-	-	-	-	-
Traveler's income	0.154162	0.2546	-	-	-	-	-	-	-	-	-	-
Summary statistics												
$L(\hat{b})$ [i]	-107.0648											
$L(c)$ [ii]	-133.043											
LR [iii]	51.95554											
ρ^2 [iv]	0.195259											
$\bar{\rho}^2$ [v]	0.127612											

(*continued*)

Table 5 - continued

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* Significant at the 10% level

i. $L(\hat{b})$ is the value of log likelihood function: at its maximum

$$:L(\hat{b})=\sum_{i=1}^{I} \{y_{si} \log P_i(s) +(1-y_{si})\log[1-P_i(s)]\}$$

ii. $L(c)$ is the value of the log likelihood function when all the parameters except for an alternative specific constant are included. $L(c) = \sum_{g=1}^{2} I_g \ln \frac{I_g}{I}$

Where n is the number of alternatives (in this case, 2), I_s is the number of individuals choosing SIA and I is the total number of respondents in the sample.

iii. The likelihood ration statistics is used to test the null hypothesis that all the parameters except the alternative specific constant are zero. It is asymptotically χ^2 distributed as with K- 1 degree of freedom in binary choice models, where K is the number of parameters in the model.
LR statistic $= -2[L(c)-L(\hat{b})]$

iv. ρ^2 is an informal goodness of fit index for a binary model with an alternative specific constant ρ^2 must be between zero and one. $p2 =1 - \dfrac{L(\hat{b})}{L(c)}$ 13

v. ρ^2 is another goodness of fit measure corrected for the K number of parameters calculated as follows $\bar{p}^2 = 1 - \dfrac{L(\hat{b}) - k}{L(c)}$

0.111886) indicating a slightly better fitting model[9] but does not alter the $\hat{b}$ and statistical significance much. The test of equity shows that there is no significant difference in the value of $\hat{b}$. However, the test for parameter difference between the business and the leisure travel market shows that variations exist across them (see Table 6).[10]

The SIA-specific constant is positive for business travelers but negative for leisure travelers. One possible reason is that SIA offers the best schedule of flights to and from Singapore. Business travelers who rank convenience of schedule high generally prefer SIA in spite of a higher airfare. It is on average 1.19 times more expensive than other airlines. Leisure travelers are more price sensitive as shown by the higher $\hat{b}^3$ = -0.161 as compared to $\hat{b}^3$ = -0.0123 for business travelers. However it is not the difference in the average value of the attribute in each group that determines the value of b but the perceived value attached to an airline's reputation that will affect the alternative specific constant.[11] Krisflyler FFP membership is an important factor affecting the probability of choosing SIA for business trip; but is not an important factor for leisure trips. The sensitivity of the variable SCHEDULE, which is the only significant factor influencing the choice of airlines for a leisure trip is smaller compared to that for a business trip ($b_2^{lei} < b_2^{biz}$: 0.18 < 0.35).

The coefficient of SCHEDULE is larger than that of IMPTKRIS and LG(FARE). Nako's (1990) results confirm that the number of flights and the presence of direct flights (as a proxy for schedule convenience), followed by FFPs and then airfare, have a large impact on the choice of airline. Hoffman's (1985) found that business travelers' choice of flight is not determined by brand loyalty but entirely by schedule convenience. Business people are willing to pay a premium because of tight business schedules. This explains the smaller absolute value of LG(FARE)'s coefficient of the business travelers as compared to the leisure travelers.

Model 4: Impact of length of travel—Long haul versus short haul travel

There is no significant difference in the value of $\hat{b}$ for distance except for RECOM. The absolute value of $\hat{b}$ for the variable LONG is small and insignificant, but the negative sign imply that long haul travelers are not in favor of SIA fights. The inclusion of LONG in the travel market segment using b-probit resulted in a better fit than the b-logit for the short haul travelers ($\bar{p}^2$: 0.056 < 0.057), but the b-logit model seems to be better in explaining long haul travelers ($\bar{p}^2$: 0.15 > 0.14).[14]

The $\hat{b}$ shows significant differences between the coefficients of SCHEDULE and RECOM in the two market segments (see Table 6). The long haul passenger's probability of choosing SIA is more responsive to a

Table 6. Impact of the length and type of travel on choice between using SIA and any other airlines, by type of traveler

Variable	Long haul business		Short haul business		Long haul leisure		Short haul leisure	
	Coeff	*Prob*	*Coeff*	*Prob*	*Coeff*	*Prob*	*Coeff*	*Prob*
No differences	0.00161	0.9965	0.534535	0.2547	-0.546865	0.1061	-0.057956	0.8895
Quality of schedule	0.47190	0.0034	0.336169	0.0047	0.471250	0.0040	0.061315	0.6903
Price of airfare	0.68661	0.1280	-1.12880	0.1463	-0.321376	0.4665	-0.148473	0.8549
Recommendation by travel agent or employer	-0.202	0.6310	-0.64963	0.1730	0.514966	0.3329	-2.141455	0.0702
Importance of Krisflyer membership	0.05388	0.6415	0.138705	0.2240	0.283939	0.1477	-0.065555	0.7798
Strategy of concentrating on one FFP	-0.9268	0.0775	-0.42372	0.4000	0.022382	0.9678	-0.450983	0.5816
$L(\hat{b})$	-24.1885	-20.6844	-23.1537	-29.1758				
$L(c)$	-31.755	-28.9746	-33.2711	-31.755				
ρ^2	0.238277	0.286119	0.304088	0.081223				
$\bar{\rho}^2$	0.080822	0.113554	0.153808	-0.07623				

Note: See notes in Table 5 for an explanation of symbols.

change in the ranking of SCHEDULE. As the distance between hub city pairs increases, the number of airlines providing direct flights declines. An increase in flight frequency may induce a greater positive impact on SIA's market share of the long haul market than on that of the short haul travel market where there are more alternatives available.

To minimize the discomfort of long haul flights, direct flights with the shortest duration and the most convenient schedule is chosen. The relative higher explanatory power of IMPTKRIS in the short haul travel market is due to a larger proportion of of Krisflyer members (66%). The difference in sign specific constants indicates that the short haul travelers have a positive preference for SIA, while the long haul travelers seem to prefer other airlines more.

Travel agents seem to favor SIA for long haul travel as indicated by the positive sign. It is not favored for short haul travel. Membership in the Star Alliance FFP will enhance this position and lead to a greater impact on its long haul flight market share. SIA is usually recommended in addition to airlines in the Star Alliance for long haul tour packages. Although the value of RECOM's coefficient is estimated to be larger in the long haul market, the significance level of its estimate is much higher in the short haul market. Short haul travelers have more alternative choices of airlines offering direct flights. Given that SIA's airfares are relatively more expensive, travel agencies tend to avoid it when given cheaper alternatives fares. Travel agencies tend to have more contracts with other airlines than SIA for short haul flights. The lower p-value for CONFFP in the long haul market indicates that the market for long haul flight service is more competitive than that for the short haul service, especially at the high end of the market characterized by good quality service. This is probably due to more long haul travelers who are mainly from developed countries traveling on flag carriers with more established FFPs compared to Asian airlines.

Model 5: Impact of length and type of travel—comparing between market segments of LB, SB, SL and LL

The addition of dummy variables LONG and BIZ gives Model 5 improved overall fit. B-probit models gave a better fit than b-logit, which is why only the table of coefficients estimated under the b-probit models is presented. A test of variation across the four market segments was significant at the 10 % level.[14] The logs of the maximum likelihood function indicate that SB respondents have a higher probability of choosing SIA followed by LL, LB and then SL travelers.

Model 5a: Long haul business (LB) travelers

Two significant factors that determine long haul business travel are SCHEDULE and CONFFP. Over 35% of LB travelers are FFP members of other airlines and hence there is a higher chance of a LB traveler concentrating his mileage with another airline's FFP. A high proportion of LB travelers are members of the FFP of the flag carrier of their country of residence (56%). This makes sense, since the flag carrier is probably the LB traveler's most frequently used airline due to schedule convenience. Many of these LB travelers come from developed countries with well-established flag carriers providing established international air service. Hence the relative large absolute value of $\hat{b}$ of CONFFP which is significant and implies more intense competition from well-established FFPs of foreign international air carriers. This will have an adverse effect on SIA's share of the long haul market. Thus CONFFP has significant negative effect that probably offsets the positive effect of IMPTKRIS (see Table 6).

The positive sign of b_{3^*}, the airfare coefficient, is probably due to the overriding positive effects of SCHEDULE and FFP. One other possibility is that since the fare is paid by the employer the incentive to search for a lower fare is absent. Published airfares were used for respondents who did not know the true fare of the flight in question, however business travelers might receive a much lower fare because of their company's bulk discount arrangements with a travel agency. Also LB travelers take more flights than LL travelers. This may explain the large negative effect of CONFFP on a LB traveler's higher probability of choosing SIA than a LL traveler's segment.

Model 5b: Short haul business (SB) travelers

Airfare seems insignificant but $\hat{b}$ has the expected negative sign. The only significant estimate is that of SCHEDULE. Though the estimate of the coefficient of airfare is not very significant, its largest absolute value may imply that SB travelers have the highest fare sensitivity. The SIA specific constant in the SB market is about 500 times than that in the LB market with a smaller p-value (see Table 6) indicating that SB travelers prefer to travel by SIA as compared to LB travelers. Further the absolute value of $\hat{b}$ of IMPTKRIS is larger and more significant for SB travelers. This is consistent with the observation that more Krisflyer members travel short haul. On the other hand, $\tilde{b}$ of CONFFP is smaller in absolute value and has a larger p-value in the SB market than in the LB market. This may imply that SIA and/or the Krisflyer FFP has a niche in the market of regional travelers where there are fewer competitors providing the same high standard of service.

Table 7. Impact of Frequent Flier Programs (FFPs) on choice between using SIA and any other airline: Krisflyer members versus non-Krisflyer members

	Krisflyer Member		Non-Krisflyer Member		Krisflyer Member		Non-Krisflyer Member	
	Coeff	*P-value*	*Coeff*	*P-value*	*Coeff*	*P-value*	*Coeff*	*P-value*
No differences	0.22964	0.75850	-0.1209	0.52593	-2.39157	0.336756	-1.0791	0.423365
Quality of schedule	0.372821	0.00081	0.22810	0.00017	0.427127	0.000300	0.24763	6.2e-005
Cost of airfare	-0.21065	0.63979	-0.1622	0.37024	0.282602	0.496704	0.17831	0.543469
Recommendation by travel agent or employer	-0.22579	0.58084	-0.2413	0.33683	0.039111	0.081029	0.03017	0.039216
Importance of Krisflyer membership	0.058283	0.74496	-0.0057	0.93568	0.275634	0.310292	0.10345	0.515182
Strategy of concentrating in one FFP	-0.56692	0.20929	-0.1700	0.615				

Model 5c: Long haul leisure (LL) travelers

LL travelers are as sensitive to schedule convenience as LB travelers even though they are less fare sensitive, as shown by the smaller absolute value of $\hat{b}$ of LG(FARE) of 0.32 compared to that of 1.10 for SB travelers. Given that 37% of the SB travelers are either CEO or sole proprietor of their business, choosing the lowest available airfare will minimize business cost. Since the principal and the agent is the same person there is no moral hazard problem. LL travelers who fly less frequently than SB travelers may be unaware of the lowest available airfare at their desired departure time or variation of airfare over time and across different distribution outlets. Moreover, LL travelers probably have fewer choices of airlines providing direct flights than do SB travelers.

LL travelers with a tighter budget are more responsive towards FFPs, which offer rewards in terms of free trips that reduce the implicit cost of each trip. This is confirmed by the larger $\hat{b}$ of IMPTKRIS (of 0.20) in the LL market as compared to the LB and SB markets. The p-value is also lower in the LL market. A few long haul trips will contribute a significant amount to the mileage bank. LL travelers try, as far as possible, to choose airlines with FFPs they belong to in order to concentrate mileage under one program in order to maximize rewards.

However $\hat{b}$ of IMPTKRIS is still smaller than that of SCHEDULE and LG(FARE), indicating the latter two variables are more important than a FFP in their choice of airline. About 29% of LL respondents chose airlines recommended by the travel agency, which explains the positive sign for $\hat{b}$ of RECOM. Being infrequent travelers they may not be fare sensitive and thus fare differentials may not make a difference to their budgets. Convenience of schedule may not be important since tours come in a package.

Model 5d: Short haul leisure (SL) travelers

SCHEDULE, which is an important factor in the above three market segments, is insignificant here. A large number of airlines offer services of higher frequency to nearby hub cities as opposed to destinations further away. This implies a smaller difference in the attribute of schedule between alternative choices. Holiday-makers who book a tour package will perceive this small difference but it will not have an adverse effect on their choice. In contrast, LB travelers do care about schedule convenience. RECOM seems to be the only other significant factor in affecting SL travelers' choice of airline.

Models 6a and 6b: Impact of FFP—Krisflyer members versus non-Krisflyer members

We divide the population into two market segments, those who are Krisflyer members and those who are not Krisflyer members (non-Krisflyer members) and compare these groups on the importance of FFPs on their choice of airline (IMPTFFP). There does not seem to be a large variation between Krisflyer members and non-Krisflyer members. The only significant variable in both cases is SCHEDULE. Krisflyer members are more sensitive to a change in the SCHEDULE, given that a majority of them are business travelers with tight schedules. SIA provides the most number of direct flights to and from Singapore. This accounts for the large proportion of Krisflyer members as compared to non-Krisflyer members choosing SIA (63% versus 49%, respectively). The $\hat{b}$ of IMPTFFP is positive for Krisflyer members but negative for non-Krisflyer members.

Model 6b: Impact of FFP-Krisflyer members versus non-Krisflyer members (modified)

The inclusion of LG(INCOME), QFFPCON and QFFP increases the $\bar{p}^2$ from 0.08 and 0.04 to 0.14 and 0.07 (see Table 7).[15] The significant variables are SCHEDULE and QFFPCON. Krisflyer members are more sensitive to the difference in rating than non-Krisflyer members as shown by $\hat{b}$ (0.40 > 0.25). Note that the coefficient values are close to those estimated in Model 6a, indicating stability of the coefficient estimate across various specifications.

QFFPCON has a smaller impact than SCHEDULE on one's probability of choosing SIA. QFFPCON's coefficient is marginally larger for Krisflyer members. This confirms the importance attached to the relationship between FFP membership and the traveler's strategy of concentrating on one FFP and how that relationship has an impact on a traveler's probability of choosing a specific airline. This is partly due to the limited choice set. The $\hat{b}$ of LG(INCOME) is insignificant at the individual t-test level but contributes to the overall significance of the model. A Krisflyer member's probability of choosing SIA is twice as income sensitive as a non-Krisflyer member's probability. SIA is reputed for providing high quality for a price. Thus an increase in income is likely to increase one's probability of choosing SIA. It also indicates their relative preference for SIA.

STAR is positively related to the probability of choosing SIA, implying that mileage for the Star Alliance FFP can be earned from SIA flights, however its insignificance may be due to ease of mileage transfers across FFPs. The impact of FFPs has a smaller impact on the choice of airline for the group of non-Krisflyer members that do not belong to any FFP.

Model 7: Impact of FFP—FFP members versus Non-FFP members

The sample is split into two segments: non-FFP members (respondents who do not belong to any FFP) and FFP members (respondents who are members of at least one FFP). About 65% of the respondents are FFP members of which 52% of them choose SIA. The absolute values of $\hat{b}$ of SCHEDULE is larger than that of LG(FARE), and IMPTKRIS (see Table 8). This is consistent with Toh & Hu (1988) survey's finding of FFP members rating schedule convenience, fare and then FFP in descending order of importance. One possible explanation for the relatively large absolute value for the coefficient of RECOM is that business travelers do not always decide on the airline used for business trips. Corporate travel policies may require employees to take one specific airline or choose from one restricted list. The impact of membership in the FFPs of other airlines may help explain the large but insignificant estimate.

The only significant variable is SCHEDULE. There is no variation in terms of SCHEDULE across the two subsamples. The SIA specific constant has a significant estimate with a larger positive value in the market of non-FFP members (0.90 > 0.20). The $\hat{b}$ of LG(FARE) has a large absolute value of 1.10 in the market of non-FFP members, as compared to that of 0.91 in the FFP member group (see Table 8). Non-members are more fare sensitive. One possible reason is that FFP members in redeeming do not mind paying a higher fare or choosing business or first class. There is probably a net gain from the FFP rewards system that induces them to incur the present cost or investment relative to higher airfare.

The higher but negative coefficient for RECOM of 0.69 for non-FFP members as opposed to 0.20 in the FFP member group suggest that non-FFP members do not have any incentives to stick to any particular airline. The infrequent flyer non-FFP member who averages three trips a year (as compared to 16 made by FFP members) may not have much information about the available choices and service attributes. They simply rely on the advice of travel agencies. The negative sign indicates that travel agencies are not in favor of using SIA.

Model 7b: Importance of service factor

When the variable NO was introduced (see Table 8) the positive sign of LG(FARE)[16] is really surprising because FFP members pay for the service and receive accumulated points to be redeemed for potential free trips or upgrades. The higher airfare expense (either from longer distance trip or from a higher fare class) will result in more travel awards being earned within a shorter period of time and hence resulting in a lower cost per flight taken.

Table 8. Impact of Frequent Flier Programs (FFPs) on choice between using SIA or any other airline: FFP members versus non-FFP members

	FFP Member		Non-FFP Member		FFP Member		Non-FFP Model 7b	
	Coeff	*P-value*	*Coeff*	*P-value*	*Coeff*	*P-value*	*Coeff*	*P-value*
No differences	0.229642	0.75850	0.09726	0.70339	0.008267	0.97655	0.07996	0.764621
Quality of schedule	0.372821	0.00081	0.35905	0.00147	0.365455	0.001378	0.30972	0.012144
Cost of airfare	-0.21065	0.63979	-.12661	0.066522	0.305547	0.49413	-0.96454	0.127686
Recommendation by travel agent or employer	-0.22579	0.58084	-0.6945	0.071159	0.024876	0.955348	-0.673	0.124552
Importance of Krisflyer membership	0.058283	0.74496	-	-	0.110508	0.027824	-	-
Difference in number of flights on SIA and other airlines							0.13196	0.008172
Strategy of concentrating in one FFP	-0.56692	0.20929	-	-	-	-	-	-

The coefficient of RECOM is positive in the sample of FFP members and negative in the sample of non-FFP members. A larger proportion of FFP members are traveling on business and thus choose airlines recommended by their companies due to schedule convenience. On the other hand travel agencies may capture a large proportion of non-FFP members who are more fare sensitive and opt for airlines with lower fares. FFP members' probability of choosing SIA is more than twice as sensitive to the difference in the number of trips made. The higher the number of times one flies with any one specific airline the greater the potential benefits.

Estimation of SIA's Market Share

Drawing upon the results from b-probit models and assuming market homogeneity (i.e., every individual in the population is identical) this section attempts to analyze SIA's market share and the probability of an average individual choosing SIA. This is estimated by the exponential of the average log likelihood, where Ave Log is equal to the maximum log likelihood divided by the total number of respondents in the sample. Given Model 2 and the respective specification of V_i the Ave Log is -0.58933 and market share is 0.5547.

Classification Approach of Aggregation Across Market Segment

The market segmentation approach estimates SIA's market share by using the explicit integration approach within each segment and the classification approach across all the market segments. Ave Log estimates SIA's market share in each segment. Given the probit assumption, SIA's total market share will be the weighted average of all market shares in each segment. SIA's market share for business versus leisure and long verse short haul markets is estimated to be 0.56 and 0.57,[17] respectively. In the case of the four market segments of LB, SB, LL & SL, SIA's weighted average market share is estimated to be higher at 60%. The same method is applied to the market segmentation of Krisflyer members versus non-Krisflyer members and FFP members versus non-FFP members with the weights 57/192, 135/192, 126/192 and 66/192 respectively (see Table 9).

Given the four market segments or groups, SIA is estimated to have the largest market share (65%) of short haul business travel. It seems to have captured a larger share in the market of non-Krisflyer members (38%). SIA is believed to have a much larger share of FFP members (54%) as opposed to non-FFP members (20%). This resulted in a significantly larger estimate of 74% under market segmentation based on FFP membership. Intuitively, this implies that Krisflyer membership is more effective in enhancing the

Table 9. Estimation of SIA's market share for different types of travelers

	Business traveler	*Leisure traveler*	*Long haul traveler*	*Short haul traveler*
Ave log likelihood A=L($\hat{b}$)/48	-0.5137	-0.63994	-0.53481	-0.5992
Each segment's Market share Exp (A)	0.598281	0.527325	0.585782	0.549251
Each segment's weighed Market share Exp (A)/2	0.29914	0.263662	0.292891	0.274625
Total SIA market share	0.562803		0.567516	

demand for SIA's services in market segments where FFP membership is prevalent. This highlights the importance of attracting business travelers who also belong to other FFPs especially FFPs of major alliance carriers (see Table 10).

Krisflyer membership and the availability of a wider range of flight schedules will increase a traveler's probability of choosing SIA. Hence, increasing loyalty through an attractive FFP can increase the demand for its services especially from repeated patronizing of increased number of customers. FFPs of other airlines with a good service network similar to that of SIA will affect SIA's market share when mileage points are not transferable. Transferability and mileage trading within an alliance or partner will enhance its position. Other factors such as airfare, income, flight duration and recommendation of travel agencies seem to be relatively insignificant in explaining the demand for SIA. This may be due to SIA's position as the dominant operator in Singapore and the lack of comprehensive schedules offered by other carriers.

Variations across different market segments are also observed. However there is no significant difference in the weight placed on each variable across market segments. Generally, schedule convenience and Krisflyer membership can explain the demand for SIA's services in all of the market segments except that of short haul leisure travel. A large proportion of long haul travel is business travel with an estimated market share of 60% while short haul travel have a share of 55%. No significant variations were observed across Krisflyer members and non-Krisflyer members.

There appears to be significant differences in $\hat{b}$ of LG(FARE) between FFP members and non-FFP members. The demand for air services by FFP members is positively related to airfare while that of non-FFP members is inversely related with airfare. This is because the cost of air service to FFP members does not discount the potential benefits credited to mileage accumulation. The number of trips made per year is an important

Table 10. Estimation of SIA's market share for different types of travelers

	Krisflyer Member	*Non-Krisflyer Member*	*FFP Member*	*Non-FFP Member*	*Long haul buisness traveler*	*Short haul business traveler*	*Long haul leisure traveler*	*Short haul leisure traveler*
$A = L\,(\hat{b})/48$	0.609242	0.5467896	0.820871	0.574097	-0.503928	-0.43093	-0.48237	-0.60783
Exp(A)	0.180869	0.3844614	0.538697	0.197346	0.6041529	0.649908	0.617319	0.544532
Total SIA market share	0.5653302		0.736043		0.60364			

determinant of demand. Krisflyer membership increases one's probability of choosing SIA marginally. However the Krisflyer FFP does not have a significant effect on SIA's total market share.

STRATEGIES AND TRAVELER SATISFACTION

Does the generalized cost of travel matter with FFPs?

The insignificance of travel time and airfare is apparent in this study. Further there is not much variation in the magnitude of the coefficients of the variables compared to that used in the time series analysis. Most respondents are unaware of the significant differences in airfare between airlines, let alone gather information on airfares of other airlines for a given schedule. A reason for this is that the fare difference is too small to yield significant benefits for the decisionmaker to invest time in information gathering. In addition, most travel takes place within the conditions set up between the respective companies and travel agent with whom long term contracts are established. Even if the individual has a choice of airlines the fares quoted are either often discounted or not made available to him since the employer is paying for the trip. Thus schedules and gains from a business deal is often more crucial than the monetary cost of travel.

Moreover over half of the long haul business travelers choose airlines recommended by their employer. Corporate travel policies may include cost controlling measures that restrict the employee's choice of airlines. Under such restrictions, there may not be a great difference between the attributes of the given choices.

The estimated coefficient for travel time, LG(TIME), is surprisingly positive for all samples of market segments and is significant for short haul business travel. The reasons for this are similar to that for the apparent lack of importance of fares. Most respondents did not seem to detect significant differences between flight times for direct flights across airlines. The marginal difference in time due to flight delays seems to be immaterial to travelers who were prepared to incur delays of up to a couple of hours. The general perception is that most of the airlines are on time. The estimated coefficient of the variable measuring on time performance is also insignificant in Nako (1990) and Toh and Hu (1988). Large differences arise between direct versus indirect flights, but passengers prefer their choice set to direct flights. Indirect flights are chosen only when all the direct flights are fully booked or in situations where the traveler could use the delay for shopping or sight seeing. Since this is voluntarily time to participate in benefit yielding activities, it cannot be included in the time cost component of air travel. Excluding transit time yields no large difference in the time duration between direct and indirect flights. If no

benefits are incurred, the time cost of indirect flights is still greater than direct point-to-point flights. A positive relationship between travel time and the choice of airline seems to arise for reasons not specified in the model. One explanation for this is the possible correlation between travel time and variables such as NO.

Schedule Convenience and FFPs

Krisflyer membership does have a significant positive impact on an individual's probability of choosing SIA's services and a positive impact on market share. However the magnitude is smaller than that for schedule convenience. This is consistent with previous studies, which indicate that an airline's market share is very elastic to the frequency of flight services provided. Frequency of flight service is often used as proxy for schedule convenience. These studies confirm that the effectiveness of a FFP is enhanced with a large presence at an airport. This is supported by the finding that FFP members, most being business travelers, place great importance on schedule convenience while choosing an airline.

The implications for this on consumer targeting is important. There are slight variations between various market segments consisting of business versus leisure travelers, long haul versus short haul travelers, and Krisflyer members versus non-Krisflyer members. However none of these variations are large enough to result in a significant impact on SIA's dominance. FFP members are observed to have a preference for SIA's services. The overall quality of its services relative to other airlines is the most important factor determining a traveler's choice of airlines. An individual's decision to join the Krisflyer seems to be insensitive to the number of SIA flights taken.

Variables reflecting the joint benefits from alliance of FFP have a significant impact on the probability of joining Krisflyer. This seems to be in line with previous studies that observed that travelers are members of many FFP but concentrate on one. Thus targeting members of the Star Alliance FFP is advantageous to increasing SIA's market share. The Krisflyer FFP is more effective in increasing the demand for SIA's services within the group of FFP members than among non-FFP members. As such, SIA should target FFP members who are willing to pay a premium for high quality air services.

A larger proportion of frequent flyers from developing countries compared to those from developed countries seem to prefer SIA. Many of the regional travelers residing in the neighboring countries are members of Krisflyer given the preference for high quality service in the form of frequent flights to major hub cities. This is prevalent among the short haul business travelers. However, SIA seems to have a lower share of the regional leisure market that is made up of fare sensitive leisure travelers.

Competition with the Krisflyer FFP comes from European, American and Australian airlines with an established pool of loyal FFP passengers. Good repute and high quality air services have attracted a considerable portion of the long haul business and leisure markets but these comprise mainly of residents of developed nations. However, the difference in attribute of service quality has marginal effects on SIA's overall market share. An airline's global market share is determined by its service network that is very much restricted in a regulated environment. Penetrating markets lies in forming alliances and partnerships and remains the second best effective way open to SIA.

Enhanced schedule convenience arrangements such as code sharing and FFP alliance are important. Fostering direct contracts with large companies and Multi National Corporations (MNCs) will further guarantee a large share of business travel. Enlarging one's market share through joint maximizing of revenues is one strategy. On the regulatory front, the recent step toward multilateralism, between the U.S., Brunei, Chile, New Zealand and Singapore, seems encouraging but does not consider issues of cabotage and ownership. However, shifting from bilaterals to multilaterals is progress.

ENDNOTES

1. Although subjective rating may not be as reliable as objective facts such as flight frequencies or load factors, it captures information specific to each decision making process. Different individuals experience different frequency delay for the same flight schedule. In one instance, the respondent flew with an airline that was not his usual choice due to the unavailability of seats on his preferred airline at the time of booking. This is simply stochastic delay on the part of the preferred airline. An airline which offers infrequent flights between a city pair may just happen to offer a service at the time desired by this particular traveler and this explains his choice of the airline. This effect is not captured when aggregate data of the frequency of flights between two city pairs is used as a proxy for frequency delay. Moreover past studies pointed out that regressing the demand for air service upon the product of frequency of flights and load factors is regressing the independent variable upon itself.

In most cases respondents only include direct flights (if available) in their choice sets. Thus there are few cases where SIA is offering a direct flight while the alternative airline does not. Moreover respondents usually filter the presence of direct flights into their rating of SCHEDULE. Thus the dummy variable of direct flight is excluded from the specification due to the few observed differences in this attribute and its high correlation with the variable of SCHEDULE. Air service here refers specifically to schedule convenience, which differs from the layman understanding in terms of cabin crew service. This general notion of service is probably taken into account by the alternative specific constant.

2. Assume that one Singapore dollar has the same marginal (dis)utility regardless of whether it is used to pay for SIA service or another airline's services. Thus the coefficient for $FARE_{ni}$ is the same b_3 in both utilities, U_{si} and U_{ji}.

3. It is converted to Singapore dollars based on the exchange rate prevailing in early January 2001. The class in which the passenger travels is not taken into consideration, as the

difference among airfare of the same class across airlines is the concern. The difference in airfare between airlines is assumed to be independent of the class of travel.

4. In many instances, an airline is chosen just because it has been recommended by the travel agency or by company travel policy. For around-the-world holiday trips, the travel agencies normally offer their customer a package of air services (usually provided by airlines within an alliance) consisting of trips to different countries. From another point of view, it seems to become a comparison of alternative alliances instead of individual airlines. This is classified as long haul leisure trip as the price paid is for a package of air service instead of individual airfares. This price is compared with that of other similar packages. To a leisure traveler, schedule and time are not the top considerations, thus they may not even bother to gather information that differentiates between the alternative airlines' schedule and flight duration from one point to the other. Believing that paying a packaged price for a bundle of services is more economical in terms of monetary cost and information collecting cost, these holiday travelers will just choose among the available packages instead of individual airlines. The decision to fly from one point to another throughout the journey is made by the travel agencies who would usually purchase seats from major airlines in order to gain bulk discounts. And major airlines usually provide service of the same general quality. Hence the differentiating factor among airlines will lie in their network of marketing outlets and their membership in major alliance. A business traveler may be required to choose from the list of airlines recommended by his company. Schedule is his top priority. Hence recommendation is the conditional, if not the critical factor, in the choice of airline for business trips.

5. There are Krisflyer members who meet the membership requirement at the margin, but are not enjoying benefits significant enough to make him or her put much weight on FFP membership in their choice of airline. Due to the different trip frequency and travel behavior, FFPs will benefit different individuals at varying degrees. Hence, FFP members place varying weights on the importance of FFPs in their choice of airline.

6. If the FFP member's strategy is to concentrate his or her mileage on one FFP which happens to not be the Krisflyer FFP, he or she will probably prefer the airline(s) associated with the other FFP over SIA This assumes that mileage earned on SIA cannot be easily transferred over to the other FFP, which seems to be the case in spite of the airlines' claim of transferability. Thus the maximum strategy is to earn the mileage, as much as possible, from the airline from whose FFP one desire to redeem benefits.

7. The coefficient estimated under the b-logit instead of the b-probit assumption is displayed due to the slightly better fit of its index, under the logit model.

8. As the sample size becomes larger the t-statistic approaches the z-statistic. And the p-value gives the probability of a type one error. A p-value of less than 0.1 indicates that the estimate is significant at a 10% level.

9. Reject null hypothesis $b_{11} = 0$. Test statistics of 2.02 is significant at the 10% level.

10. The likelihood ratio estimated statistics (5 df) = 127.6846 is χ^2 distributed. It is significant at the 10% level.

11. Discounted SIA airfare may be cheaper. The perception by travelers that SIA is a premium airline commanding premium fares may deter them from including SIA in their choice set. This may help explain the negative specific constant for SIA.

12. Test of overall variation across the long and short haul markets with a test statistics of (5 df) = 8.5844 which is χ^2 distributed. It is significant at the 10% level.

13.	The above definition is more useful in comparing two specifications developed from the exact same data. $[K/OK-1)][\rho^2/(1-\rho^2)]$ is approximately F distributed with (K-1, K) degree of freedom under the null hypothesis that B = C.

14.	Test statistics (15 df) = 31.90914 which is χ^2 distributed.

15.	$\bar{p}^2$ increases further to 0.17 and 0.08 when only two variables SCHEDULE & QFFPCON are specified.

16.	$\bar{p}^2$ Increases from 0.08 to 0.19 for FFP members and from 0.14 to 0.25 for non-FFP members.

17.	For each segment (type of travel and length of travel) the weights will be half as there are equal number of respondents surveyed for each segment. When divided into four segments (LB, BB, LL,SL) the weight will be one quarter.

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ELECTRONIC TECHNOLOGY AND SIMPLIFICATION OF CUSTOMS REGULATIONS AND PROCEDURES IN AIR CARGO TRADE

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ABSTRACT

One of the biggest barriers to air cargo trade is cumbersome customs regulations and procedures that have failed to keep up with the rapid development of the sector. This paper attempts to contribute to a better understanding of (a) the issues surrounding the application of electronic technology and the simplification of customs procedures to air cargo trade and (b) why the issues are important. The current measures and practices are discussed, both generally and in the Asia Pacific Economic Cooperation (APEC) context particularly. The paper further examines regulatory lag and reforms. Finally, the requirements and factors that would affect a successful application of e-technology to customs and related administrative practices are discussed.

INTRODUCTION

With the successful reduction of typical trade barriers such as tariffs and quotas, countries are now in a position to turn their attention to other practical obstacles to the free flow of goods and services across borders. Administrative barriers, which include barriers arising from customs and related administrative procedures, seem particularly prominent for the Asia Pacific Economic Cooperation (APEC) region, given the diverse character of its member economies and their different levels of development in regulative and administrative systems and in technology. In order to effectively expand trade in the region, APEC economies must take full

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advantage of the recent advancement in information technology and simplify customs regulations and procedures.

At the same time, with individual shipments decreasing in volume but increasing in value and with more frequent shipments as a result of globally integrated, just-in-time (JIT) systems, a greater move towards the use of airfreight and air express services eventuates. In effect, for the last decade, the JIT process has made air cargo in general, and air express in particular, the fastest-growth area in the dynamic cargo industry. The international air cargo volume has grown faster than the international trade volume; consequently, it has grown at about twice the rate of worldwide GDP (gross domestic product) growth. Average annual growth in freight-ton kilometers on international scheduled services during the last decade is 7.9%. In addition, both the JIT pressures and the vertical integration of the logistics industry, along with the increasing trend towards outsourcing distribution, have led to much faster growth in the air express market than the total air cargo market. Annual growth in international express has averaged nearly 24% since 1992 (Zhang & Zhang, 2001). Finally, e-commerce is likely to generate further increased demand for air cargo, particularly the time-definite, express market.

While continuing to fulfill their legal duties (tackle drug smuggling or collect value-added tax and duty), customs administrations need to react to this development by facilitating faster customs clearances. Studies have shown that delays as a result of customs procedures was the biggest problem faced by the integrated air express industry in Association of Southeast Asian Nations (ASEAN) countries (ASEAN, 2000). Integrators, airlines and a number of general cargo handlers identified time-consuming customs clearance procedures of several APEC economies as a key constraint on the development of freer and more efficient APEC trade (Ching, Kao, Leung, Wong & Zhang, 2000; Bridges, 2001). For instance, trans-shipment goods are in general still subject to the usual import-export procedures during transfer, unnecessarily increasing the turnaround time of trans-shipment business. Another obstacle to the integrated express industry was the restrictions on investment in ground transport operations, resulting in higher costs of doing business. The primary reason for these obstacles is because integrated, door-to-door express service as a way of movement is still relatively new in Asia. On the other hand, customs regulations or procedures are set mainly in the context of traditional ways of cargo movement, in which customs played a relatively passive role.

This paper attempts to contribute to a better understanding of (a) the issues surrounding the application of electronic technology and the simplification of customs procedures to air cargo trade, and (b) why the issues are important. The current measures and practices are discussed,

both generally and in the APEC context particularly. The paper further examines regulatory lag and reforms. Finally, the requirements and factors that would affect a successful application of e-technology to customs and related administrative practices are discussed.

CUSTOMS ADMINISTRATION AND NEW DEVELOPMENTS IN TRADE AND PRODUCTION

One of the biggest administrative barriers to trade is cumbersome customs regulations and procedures that have failed to keep up with the expansion and increased complexity of trade. Customs regulations or procedures may not directly impede services trade. However, some service sectors, such as distribution and transport, are very much contingent upon customs regulations and procedures. As indicated above, customs simplification and harmonization have become a major issue for companies that find their operations and profits severely affected by administrative delays at borders. Small and medium-sized companies (SMEs) are among the most affected.

Customs administrations perform two basic functions: trade facilitation, and customs control. The latter includes prevention of the infiltration of illicit drugs or other hazardous substances, intellectual property rights protection, and in particular, tariff collection. Historically, tariff collection (revenue raising) was a major function. For developing countries, revenue-raising appears still the main function of customs. Correspondingly, manifest acquittal prior to delivery remains the norm for their cargo clearance process. As a consequence, their customs suffer from information overload, with its consequential delays.

However, as tariff barriers come down, the customs revenue-raising function has diminished in relative importance, especially for developed countries. Since customs regulations or procedures are no longer tied closely to the revenue objective, streamlining customs procedures, via the application of modern electronic technology, becomes predominantly a measure of trade facilitation. If doing so generates net social benefits, the governments would have an incentive to undertake it.

Apart from the continuing reduction of tariff, another important development is the emergence of globally integrated, JIT production and distribution systems. Specifically, companies manufacture to order and have to source their raw materials. They need to reduce inventories and cut down the time it takes to move a product to the market. Product life spans are also shortening in many industries (e.g., computers, pharmaceuticals, and designer clothes). While some companies have turned to virtual warehousing—keeping goods in transit as a substitute for holding goods in

storage—a growing community of e-commerce retailers have begun to rely on strategically located fulfillment centers to enable speedy and economical delivery of goods bought on-line. Furthermore, as a result of continuous declines in tariffs and other trade barriers, *international fragmentation*, that is, outsourcing various production blocks to countries that possess a comparative advantage in that type of productive activities, becomes a major economic force for firms to remain competitive. These increase the demand for international service links, in the form of distribution, logistics and transportation services.

For these international service links, customs becomes an increasingly important component. It is important in many ways, such as, including clearance time, predictability, and transparency (ICC, 1999). Any customs administration that can provide reliable, timely customs clearance, or immediate release based on pre-clearance, creates a competitive advantage in attracting foreign direct investment and foreign manufacturing/distribution/transportation and third-party logistics companies. Arbitrary or unpredictable customs clearance delays are incompatible with efficient manufacturing and distribution. Arbitrary or unexplained changes in classification or valuation of goods also can disrupt logistical flows.

In addition to distribution, transport and logistics services, efficient customs services are imperative to electronic commerce. E-business, that is, transactions involving electronic information exchange, has been growing exponentially for the last ten years and has fundamentally changed the way in which companies do business. For example, the booming e-procurement enables buyers to source distant suppliers and SMEs, and to choose the best suppliers (based on low price, high service level). Another growing e-commerce market is one where goods are ordered on-line and imported through normal channels, often involving inter-modal transport and distribution services. Demand for speedy and efficient logistics and transportation services is much greater in such e-commerce trade than in traditional trade. Since these goods need customs clearance, customs administration remains one component of the supply chain of the e-commerce firms.[1] Application of e-technology to the simplification of customs procedures-shipment, customs clearance, and so on-is therefore imperative for these firms to optimize functions over the supply chain. The streamlined e-customs procedures will also help alleviate the negative trade-diverting effect arising from the current asymmetric treatments for e-commerce products (see footnote 3; Mattoo & Schuknecht, 2001).

AGREEMENTS AND MEASURES ON
CUSTOMS AND RELATED PROCEDURES

Given the importance of an efficient customs and administrative system to international trade, significant efforts have been expended on establishing multilateral agreements that deal with barriers related to customs and other administrative procedures. Examples include the following General Agreement on Tariffs and Trade/World Trade Organization (GATT/WTO) agreements.

Agreement on Sanitary and Phytosanitary Measures

In order to harmonize sanitary and phytosanitary measures on as wide a basis as possible, WTO members are encouraged to base their measures on international standards, guidelines, and recommendations where they exist. It is expected that WTO members would accept the sanitary and phytosanitary measures of others as equivalent if the exporting country demonstrates to the importing country that its measures achieve the importing country's target level of health protection. The agreement includes provisions on control, inspection, and approval procedures. Governments must provide advanced notice of new or changed sanitary and phytosanitary regulations and establish a national enquiry point to provide information.

Agreement on Technical Barriers to Trade

The agreement encourages countries to use international standards where appropriate. Innovative features of the agreement are that it covers processing and production methods. The coverage of conformity assessment procedures is enlarged, and disciplines are made more precise. Notification provisions applied to local government and non-governmental bodies are elaborated in more detail. A Code of Good Practice for the Preparation, Adoption, and Application of Standards by standardizing bodies is included.

Agreement on Pre-shipment Inspection

The obligation placed on pre-shipment inspection (PSI) by user governments include non-discrimination, transparency, protection of confidential business information, avoidance of unreasonable delay, the use of specific guidelines for conducting price verification, and the avoidance of conflicts of interest by the PSI agencies. The obligations of exporting members towards PSI users include non-discrimination in the application of domestic laws and regulations, prompt publication of such laws and regulations, and the provision of technical assistance where requested.

Agreement on Import Licensing Procedures

The revised agreement strengthens the principle of transparency and predictability. With respect to automatic licensing procedures, the agreement sets out criteria to reduce trade restrictive effects. As for non-automatic licensing procedures, administrative burdens for importers must be limited to what is absolutely necessary. It also sets a maximum of 60 days for applications to be considered.

Customs procedures have been covered by the disciplines of GATT from its inception. Given the recent developments outlined in the previous section, governments, firms, and users have become increasingly aware of the urgency of customs modernization. The first ministerial conference of the WTO in Singapore in 1996 marked a breakthrough when governments for the first time placed customs facilitation on the agenda of the WTO. In addition, member customs administrations of the World Customs Organization (WCO) invested four years in updating and modernizing the Kyoto Convention, a comprehensive set of practices that should characterize all modern customs administrations. In June 1999, all 151 WCO members unanimously adopted the revised Convention (Kyoto, 2000). Furthermore, the International Chamber of Commerce (ICC), which represents the business community, and the WCO have been working together under a formal cooperation agreement since 1996. One of the ICC efforts is to develop the ICC International Customs Guidelines (ICC, 1997).

At their 1994 meeting in Bogor, APEC leaders declared the target of achieving free trade in the region by 2020, with an earlier date of 2010 for the developed economies. The next year in Osaka they agreed on the Action Agenda and in 1996 adopted the Manila Action Plan for APEC (MAPA). Parallel with the Collective Action Plans (CAPs), individual APEC members announced their liberalization and facilitation plans (Individual Action Plans, or IAPs) unilaterally, and implemented IAPs according to their domestic legislatures. A quantitative assessment of 1997 IAPs and CAPs has been done by Yamazawa (1998).

In the area of customs and related administrative procedures, the Osaka Action Agenda set nine concrete objectives for CAPs: (a) Harmonization of tariff structure with the Harmonized System Convention; (b) Transparency of customs procedures, including information on customs laws, regulations, administrative guidelines, procedures and rulings; (c) Simplification and harmonization on the basis of the Kyoto Convention; (d) Adoption and support for the UN/EDIFACT, using the standard UN electronic messaging format for automated reporting systems; (e) Adoption of the principles of the WTO valuation agreement; (f) Adoption of the

principles of the WTO Intellectual Property Agreement; (g) Introduction of clear appeals provision, in case of potentially erroneous or inequitable customs decisions; (h) Introduction of an advance classification ruling system; and (i) Provisions for temporary importation, for example, acceding to the A.T.A. Carnet Convention or the Istanbul Convention (Yamazawa, 1998).

In 1997, the APEC Sub-Committee on Customs Procedures (SCCP) added the following three objectives to the list: (a) Harmonized action of APEC data elements in order to develop a comprehensive directory supported in United Nations Rules For Electronic Data Interchange for Administration, Commerce and Transport (UN/EDIFACT); (b) Focusing risk management techniques and customs enforcement efforts on high risk goods and travelers (of high probability of inappropriate reporting); and (c) Introduction of guidelines on express consignments clearance (Yamazawa, 1998).

These twelve objectives aim for promptness, transparency, predictability, and harmonization in customs and related administrative procedures. They differ in their difficulty of actual implementation. Many are setting rules and procedures, while some require technology and administrative capability of individual customs.

APPLICATION OF ELECTRONIC TECHNOLOGY

These agreements and action plans have so far yet been fully implemented in APEC economies. Barriers arising from customs delays and red tape involve cross-sector, horizontal issues such as standardization of administrative procedures, coordination among government agencies of different economies, transparency of laws and regulations, and timely and accurate provision of information on regulations and administrative procedures. These are complicated issues that touch upon a number of areas. A useful way is to treat customs and administrative barriers as a trade facilitation issue; as such, they should be included in the broader agenda on trade facilitation of the General Agreement on Trade in Services (GATS) Services 2000 Round.

The discussion in this paper is narrower in scope, however. It examines the application of the full benefits of modern information technology to customs and related administrative procedures. As the role of customs administrations evolves more towards trade facilitation, the focus is on how to improve the speed of goods and services across borders. For instance, they need to rely more on pre-clearance of shipments, scanning of source documents such as airway bills, and greater utilization of risk management techniques for targeted examinations and audits. Here, the recent

advancement of electronic technology has provided important opportunities and tools. As discussed earlier, e-business has made possible global transactions in a seamless environment, and has revolutionized the way we trade and do business. Many government agencies, including customs administrations, have become important users of e-business based facilities. They will continue to take their place alongside larger multinational organizations at the leading edge of developments in electronic communications media.

An important form of e-business is computer-to-computer exchange of business information, or Electronic Data Interchange (EDI). EDI consists of standardized electronic message formats (transaction sets) for business documents such as requests for quotations, purchase orders, purchase change orders, bills of lading, receiving advises, and invoices. These transaction sets allow computers in one organization to talk to computers in another organization without producing paper documents. EDI is important because it enables organizations to exchange information faster, more cheaply, and more accurately than is possible using paper based systems.

Governments in the APEC economies have been quick to understand the potential benefits and importance of e-technology to their work and are developing EDI-based administrative systems. In Hong Kong, for example, the Government has been proactive in promoting EDI through a partnership approach with private business. One initiative is the Community Electronic Trading Service (CETS), which is a joint venture between the Government and Tradelink Electronic Commerce Limited (Tradelink) to introduce public service EDI for the handling of trade transactions.[2] Typically the trading and cargo industries are driven by high information demands of government agencies, banks, handling agents, port and airport companies, shippers and carriers, with much of the work being undertaken via fax, e-mail and, in more developed economies, EDI-enabled computer systems.

As part of the CETS project, Tradelink and the Hong Kong Government's Trade Department jointly launched, in 1999, an EDI service—Electronic Visa Information System (ELVIS)—for textiles exports subject to U.S. visa requirement. ELVIS is a system whereby the key data on export visas are electronically transmitted from the exporting authority of the U.S. customs for the purpose of customs clearance. By replacing the paper visa copy with electronic message under ELVIS, textiles traders exporting to the U.S. can save time and avoid any possible loss of visa copy during transit or postal delay. Other textiles exporting APEC economies such as China, Singapore, South Korea, Malaysia, Indonesia and the Philippines have also implemented ELVIS.

ELVIS is just one example of the e-technology based initiatives undertaken by individual APEC governments. Of various government

agencies, customs administrations have, in particular, responded vigorously to the challenges and opportunities of EDI, and are today some of the leading users of EDI technology in the trade area. A number of intra-regional EDI pilot initiatives are under way between selected participants under the APEC and Asia EDIFACT Board umbrellas. It is noted, however, that some of the initiatives have simply been developed to prove that the concept of international exchange of clearance information is a possibility. Much work remains to be done for the extensive commercial use of such systems in the next few years.

REGULATORY LAG AND REFORM

The recent advancement of electronic technology provides governments a good opportunity to re-engineer and simplify their administrative procedures. In this regard, it serves as a catalyst for change. The aim of the change is to have e-technology enabled administrative procedures that can fulfill the need for an easily accessible and efficient trading system.

When e-technology is applied to customs and other administrative procedures, a regulatory lag occurs. To illustrate, consider paper-based customs operations: customs clearance must wait until the paper documents arrive at border offices, sometimes at about the same time of cargo arrival. In some economies, a physical signature is required on customs declaration documents, and manual approval is required for customs clearance. In China, for instance, customs clearance requires manual approval (customs chop). Customs brokers and customs often have offices in the same building. Brokers can connect their computers to the customs' system via EDI. For every deal, they are required to first send an electronic form for the statistics of cargoes. Then their staff needs to take all the documents to the customs office. Customs staff check whether the value reported conforms to the specification of the cargo and then verify the documents. If there is no problem (including duty and foreign exchange payment), then customs officials sign and chop the bill of entry/exit. In the case of airfreight shipments, customs clearing must be finished during a working day (from Monday to Friday) before the flight. With paperless, electronic customs procedures, early arrival of cargo information ready for customs pre-clearance, electronic signatures, and automated customs clearance are all possible. But some countries still view paperwork as creating jobs. This is narrow and short-sighted, because it ultimately reduces jobs as it discourages trade and foreign investment.

More generally, e-customs, together with the developments outlined in a previous section, call for customs procedure reforms. Customs administrations and other organizations involved in the movement and

clearance of international freight have historically adopted transaction-based processing philosophies and procedures. The increased airfreight shipments, with individual shipments decreasing in volume but increasing in value, have put much more work pressure on customs clearance procedures at airports (as compared to ports), mainly because such historical clearance procedures remain transaction based. Furthermore, it is noted that many historical customs activities are typically performed at the border, when such activities can be better handled after the event, as part of post-event company audits (TLIAP, 2000). Tasks such as valuation, classification, testing or sampling, are all capable of being undertaken as part of a regular post-entry audit program. By removing some of these activities from front-line operations, and supported by appropriate computer-based systems capable of providing details about past shipments, customs clearance procedures can be simplified, become system based, and help ease pressure on existing facilities and resources.

In fact, as indicated in the previous section, e-technology (in the form of EDI and e-commerce) has already become an important tool for customs administrations as they seek to reconcile the two seemingly contradictory trends between more facilitation to traders, logistics companies and shippers, and more control. If the benefits of e-technology applications were to be maximized, a fairly detailed review of national customs legislation would be required. Such a review is useful in determining the extent of flexibility that exists for the procedural reforms to take place without the need for further legislative rewrite.

Often such legislation is found to be rigid and very specific in relation to document contents, duty payment prior to delivery, examination prior to de1ivery, hours of operation, and other issues (TLIAP, 2000). In many economies, local customs management remains unable to implement procedure reforms, such as clearance prior to arrival, clearance on minimum or no paper documentation, deferred payment of duty, and other risk management initiatives, without first obtaining some form of legislative amendment. In our context and for illustration, the following two points should be accommodated to ensure maximum flexibility for future e-technology based simplification initiatives. First, reference to the extent of supporting documentation should be avoided so that customs can reduce the volume of documents required in support of each shipment, while retaining the authority to call for further documentation on a selective risk management basis (TLIAP, 2000). Second, any specific requirement for a physical signature on a customs declaration and requirement for manual approval should be abandoned. The elimination will then enable future systems to be introduced that support use of bulk clearance of multiple low-risk shipments, use of periodic returns, developments of high

technology clearance systems using scanners with minimum human intervention, use of electronic signatures, and other e-commerce based initiatives.

The application of e-technology to customs and other administrative practices may quickly expose internal weaknesses and constraints. Dealing with them may mean sweeping changes to historical procedures. Such an environment demands that senior government officials ensure the implementation team is adequately empowered to implement organization-wide changes and that the team leaders and project managers are also experts in managing changes. For instance, there are many architectural variations to the implementation of e-commerce trading systems. Each implementation is different. There are different drivers, different circumstances, different expectations, and different investment sources. They all require active participation and support of government agencies such as customs, immigration service and information technology (IT) service to ensure the success. It is also important for governments to smoothly manage the transition from historical procedures to new procedures. Installation of appropriate administrative and management reporting and evaluation capabilities and interfaces to existing systems are often needed.

REQUIREMENTS FOR BETTER APPLICATION OF E-TECHNOLOGY TO CUSTOMS PROCEDURES

There are several factors that affect the application of e-technology and the simplification of customs and other administrative procedures. Some examples are discussed below.

Private Sector Initiative and Government-Business Partnership

Private investors can lead the way in bringing innovation and change at customs procedures. The ICC has a long history of promoting the benefits of trade facilitation and customs modernization on behalf of the global business community. One of the ICC efforts is to develop the ICC International Customs Guidelines (ICC, 1997), which set up some of the international best practices. The Guidelines particularly encourage customs authorities to use automation and e-information systems as extensively as possible (Cattaui, 1998).

In the air transportation industry, leading integrated express operators and International Express Carriers Conference have been active in bringing innovation and change at customs procedures. For example, a study cited earlier was conduced in cooperation with United Parcel Service (UPS), Federal Express, and DHL International Ltd. (DHL), as well as express

service shippers in the ASEAN region (ASEAN, 2000). The study was very comprehensive and made constructive recommendations for changes. Another case is one where DHL went paperless with its customs clearance at Changi Airport Free Trade Zone checkpoint in 1998. The new customs clearance procedure was the result of the joint efforts by Singapore Customs and the air express industry to streamline and enhance Singapore's import procedures and improve its competitiveness.

Close collaboration between government agencies and business community is essential for achieving the objective. On one hand, governments need to know about state-of-the-art business technology and needs and thereby develop compatible automated customs and administrative systems. On the other hand, when governments are investing in the modernization and automation of their national customs administrations, significant future capacity exists for using electronic documents in all aspects of trade (either in goods or in services). However, not only must government agencies be willing and legally able to accept and process such documents electronically, but the commercial sector must also be prepared to make the necessary investment and commitment to introduce complementary process reforms to operate in such an e-environment. Both aspects require a strong partnership between government and business, including, among others, mutual trust and all parties working to agreed time schedules and receiving additional support when needed.

It is also noted that many smaller organizations in the cargo industry appear fearful of customs administrations introducing e-commerce based initiatives as they believe their corporate viability would suffer as a result (TLIAP, 2000). When such systems are contemplated, therefore, they should be preceded and/or accompanied by extensive public education campaigns so as to reduce industry concerns and ensure maximal industrial participation, if successful implementation of the system is to be assured.

The following is an example of a productive public-private partnership. At the beginning of 2001, China's southern Guangdong province, following the suggestions/proposals of business communities in Hong Kong and the Pearl River Delta (PRD) region, introduced a new customs system for vehicles coming overland. Cross-border trade in Guangdong province has been developing rapidly for the last decade. A significant portion of such trade is part of Hong Kong air cargo flows. In fact, about 78% of Hong Kong air cargo business is traffic originating from, and/or destining to, the PRD region. About 25 thousand trucks cross Guangdong-Hong Kong borders each day and the figure is increasing by 15 to 20 percent each year. In the past, trucks coming from Hong Kong had to be inspected at every customs checkpoint they passed before reaching their

destination. Now firms can use a 24-hour computer system to make their customs declarations rather than having to renew their declarations at every checkpoint they pass. The twelve step customs procedure has also been reduced to five steps. Cars are also scanned electronically and drivers no longer need to stop to be checked. Customs transfer, a job that used to take more than an hour to complete, has been reduced to a two- or three-minute process. The reform has greatly increased the customs' efficiency and boosted the province's cross-border trade.

Coordination Among Domestic Government Agencies

Although tariff barriers have come down over the years, there appears a continued expansion of non-tariff trade barriers that typically involve some form of quota control, additional license/permit requirement, or an increased level of surveillance activity. Such barriers bring additional burdens on clearance procedures. Often they require customs administrations to rely on other government agencies to issue appropriate documentation before clearance can be effected. However, these agencies often do not apply the same degree of urgency to the issuance of such documentation, or they are located some distance away from border control points, resulting in delays in the clearance of shipments. E-technology enabled clearance methods, while ensuring adequate safeguards, require constructive relationships between customs and other government agencies.

Adequate Infrastructure and Funding

Successful implementation of e-technology administrative systems requires basic infrastructure such as communications capabilities, significant process reforms and other support expertise. It also requires active participation of business community and local e-business community. For instance, if e-technology makes quality information arrive prior to physical cargo shipments, then customs authorities will be able to analyze the information and conduct risk assessment analysis with respect to whether to inspect the shipments when they pass through customs. This practice can shorten the boarder crossing time significantly. This, however, requires that logistics agents (traders, forwarders, etc.) be IT equipped. Many of these companies are SMEs that still employ totally manual and paper-based historical systems. Where such organizations have invested in some form of automation, it is often only for administrative and financial activities together with international e-mail. Furthermore, the compatibility of their systems is likely to be a problem. Since SMEs may not have enough financial resources especially at the beginning stage of systems

development and standardization process, some form of governmental support (subsidy) and coordination may be required.[3]

In these situations, the implementation of a nationwide cargo community system typically involves substantial investment of public funds in telecommunications, computerization, process reform, extensive public and staff education programs and marketing. However, for developing and emerging economies, typically funding is limited, basic infrastructure is lacking and technical expertise is scarce. A more likely solution for these economies would be to rationalize administrative procedures in one or two isolated areas first. In addition, technical assistance and support from developed economies, coordinated through the APEC, may be required.

Coordination Between National Governments

By streamlining procedures and improving transparency, standardization improves the efficiency of government administrations. Here, the advantage of an e-technology based administration system is that the technology can facilitate standardization. But standardization of policies and procedures requires close coordination among governments of different jurisdictions: for example, they need to agree on common standards, processes and technology to be used. Coordination between customs administrations in exchanging information on the track record of shippers and traders would allow expedited clearance to low-risk shippers and maximize the efficiency of the trading process.

Significant effort is now being made by some countries to develop systems and procedures whereby customs administrations in exporting countries can receive import clearance notification from the importing country prior to granting approval for export. If import clearance is denied due, for example, to quota restrictions, then approval to export should also be denied. Such close cooperation between nations is obviously time sensitive, and will eventually change the way in which certain export consignments are processed in the future. Again e-technology can play a very useful role in facilitating such cooperation.

Standardization and cooperation would also ensure an active participation from the business community. When commercial organizations are multi-national in nature, the introduction of information processing systems must be viewed on a global basis. In such situations the pace of change to core business systems is typically slower and the cost of initiating such change is significantly higher if countries adopt different systems. For governments to successfully influence the private sector participation, it is necessary to ensure that multi-nationals are offered standardized, coordinated and simplified facilities and administrations in a

number of economies concurrently, to justify the significant investment involved by firms in changing their information processing systems. In short, only when the modernization of administrative procedures is conduced by all trading partners, can the full realization of negotiated trade benefits be ensured.

International Organizations

As indicated in an earlier section, a number of initiatives have already been taken at the international level, including work by the WTO, WCO, and ICC on customs. International organizations can do a lot more in reforming and standardizing customs (and other administrative) procedures. Binding rules on trade facilitation should be established in the current round of WTO negotiations and be administered by the WTO. Naturally, such rules would draw upon relevant facilitation work undertaken by other international organizations such as the WCO, the United Nations Center for Trade Facilitation and Electronic Business, the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO) and ICC. In particular, the WCO's revised Kyoto Convention should be adopted and may be given obligatory and enforceable status.

Regarding developing countries, both the WTO and the World Bank now recognize how essential efficient customs and transport regimes are for trade facilitation and sustainable development, and are incorporating these concerns into their core policy objectives. The World Bank, which lends funds to developing countries with the goal of achieving sustainable development, has established a Global Facilitation Partnership, with the objective of disseminating customs and transport expertise and establishing public-private logistics liaisons in World Bank client countries. Measurements of customs efficiency, transport improvement, and integrity are proposed conditions for future lending programs.

Other international forums, such as APEC and Asia-Europe Meeting (ASEM) also play an important role. For example, in the third ASEM attended by ministers for economics, trade and industry from 10 Asian and 15 European countries in September 2001, the ministers agreed that in 2002 they would focus on customs reform toward the paperless customs procedure. An action plan will simplify customs procedure and create favorable conditions for goods circulation between the two regions.

ENDNOTES

1. Note that this is in contrast to another e-commerce market, in which goods are bought and delivered on-line. These goods do not go through customs. In effect, electronic delivery of products is at the moment exempted from customs duties.

2. Tradelink, a consortium involving a number of Hong Kong's leading banks, trading houses and transport companies, was granted seven years exclusivity in operating the Government EDI gateway.

3. Given that they create positive external effects, these supports can be viewed as national investments.

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DEVELOPMENT OF AN INTELLIGENT AGENT FOR AIRPORT GATE ASSIGNMENT

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ABSTRACT

The Aircraft-Gate Assignment Problem (AGAP) is a well-known Non-deterministic Polynomialtime (NP)-hard problem for optimization. During daily airport operations the arrival and departure times of flights may vary compared to their original schedules. This may require reassignment of gates to capture the dynamics of flights and gate status to enhance the level of services provided to passengers. For busy airports with high numbers of arrivals/departures, the assignment decisions must be made within a short time to capture all the changes. To satisfy this requirement, an intelligent agent for airport gate assignment (InGates) is being developed for this purpose for the management and assignment of gates at an airport for daily operations. The agent is aimed at performing the gate assignment for every flight, taking into consideration gate and flight dynamics, transfers, requirements of the airlines, aircraft types, airport operation rules, etc. A knowledge-based expert system forms the cores of the system and is connected to external databases for flight and passenger information. Real-time changes on airport gates and flights can be made through a graphical user interface, with the capabilities of performing real-time updating of the results and information. Data obtained at Singapore's Changi Airport is used to examine the performance of the system. Results obtained from the scenario analysis have shown that the system provides an enhanced way to assign gates at an airport. In the development of the next stage, InGates will be integrated with an optimization model to provide an integrated solution for planning and assignment of gates at an airport.

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INTRODUCTION

Airports around the world continue to face pressure to expand their capacities to handle increasing numbers of flights due to increases in air travel demand. The airspace will be more congested, and it will be increasingly difficult to site new airports or expand existing airports to cater to the growing demand for air travel. Therefore, efficient gate assignment is increasingly important because it would allow an airport to increase the capability of existing passenger terminal facilities and resources, as well as to cope dynamically and proactively with sudden changes which often take place in real-time operations. Through proper planning of gate assignment, level of service offered by airports can be enhanced.

Gate assignment is a complicated task involving the consideration of many factors. The assignment usually needs to be completed within a short time frame, and under such constraint an overall optimized utilization of airport gates is difficult to achieve. In technical terms, the gate assignment problem is combinatorial in nature, NP-hard, and cannot be optimized easily within a practical time frame. Past approaches have seen the use of simulation, mathematical programming, and artificial intelligence techniques. Results have not been satisfactory due to the uncertainties that could happen in real operations, where the necessary quick modifications to the gate assignment plan are needed.

Assigning aircraft to gates is an important task in airport operations. Although these activities may take only a small part of the direct cost of airline operations compared to flight operations, they might have a major impact on maintaining flight schedules or even the flight networks. Normally, based on the flight schedules, the airport has an established assignment that allocates aircraft to gates as well as specifies the apron time of aircraft at gates. Nevertheless, in daily operations, it is usually unavoidable for the airport scheduler to handle some unforeseen delays caused by various factors. Thus, there are usually needs to reassign the aircraft to gates for a specific period in future based on the real-time dynamics and special requirements from aircraft and airlines. This has to be accomplished in a short time period. On the other hand, in order to enhance the productivity and service level, the real-time assignment of gates is expected to be optimal in terms of minimizing passenger walking distance, baggage transferring distance, aircraft taxi distance, and the like. In this sense, the problem becomes a very difficult combinatorial optimization problem. As a result, an efficient Decision Support System (DSS) would be very helpful for daily operations. In this paper, the development of an intelligent agent for airport gate assignment by providing real-time decision support will be presented. With the limitations on real-time

performance in mind, a hybrid framework is adopted to provide the needed efficiency and optimality of the solution at the same time. The core of the system is a knowledge-based intelligent agent incorporating a quadratic optimization model to achieve optimality of the solution.

The paper is structured in the following manner. The next section gives a review of literature on past studies and different approaches taken to solve the airport gate assignment problem. The methodology for the research is presented next, followed by the discussion on the structure of the intelligent agent. Knowledge represented in the intelligent agent will subsequently be discussed and then the validation of system performances will be presented. Finally, conclusions will be drawn based on the discussion in this paper.

REVIEW OF LITERATURE

Tosic (1992) gave a comprehensive review on modeling the Aircraft-Gate Assignment Problem (AGAP), which is normally formulated as a Quadratic Assignment Problem and is a type of well-known, difficult problem. Various researchers including Bihr (1990), Haghani & Chen (1998), and Mangoubi & Mathaisel (1985) have applied OR techniques to solve AGAP directly. These approaches have better assurance in terms of the optimality of the solutions, but substantial computation time is needed in obtaining the solutions due to the complexity and scale of the problem. In addition, these approaches also have weaknesses in handling uncertain information and multiple performance criteria. Xu and Bailey (2001) reported solving a test-case problem using the tabu search technique, which resulted in a significantly shorter time in getting the solution.

To overcome the shortcomings of OR-based approaches, knowledge-based expert systems were developed to solve the problem, such as Brazile & Swigger (1988), Gosling (1990) and Srihari & Muthukrishnan (1991). A knowledge-based approach is ideal for solving ill-defined problems through the use of heuristics reasoning. By using a knowledge-based system, the knowledge of experienced apron controllers in the airport, that is, the heuristics, can be captured in the form of production rules. A recognize-action cycle that uses information held in the rules will search for the right actions through either backward or forward chaining of the rules, thus allowing the consideration of multiple objectives and constraints in the gate assignment problem. Such a system can also be used to obtain an optimized gate assignment due to unforeseen events such as bad weather, mechanical failure, late arrivals and other unexpected events that would interrupt the original flight schedule. This type of approach can capture well the operation features, handle uncertain information, meet needs of

real-time decision support, and more, but it has less assurance in terms of optimization.

In this paper, a hybrid approach, which combines both the knowledge-based expert system in the form of an intelligent agent, and an optimization model to obtain optimal gate assignment solutions is presented.

METHODOLOGY

Combining the intelligent agent and OR techniques, the development of an Intelligent Airport Gate Assignment System (called InGates) is discussed in this paper. A framework of InGates is designed based on the analysis of a real-time AGAP. Taking into account the complexity of the problem, the DSS consists of an intelligent agent module and an optimization module, as illustrated in Figure 1.
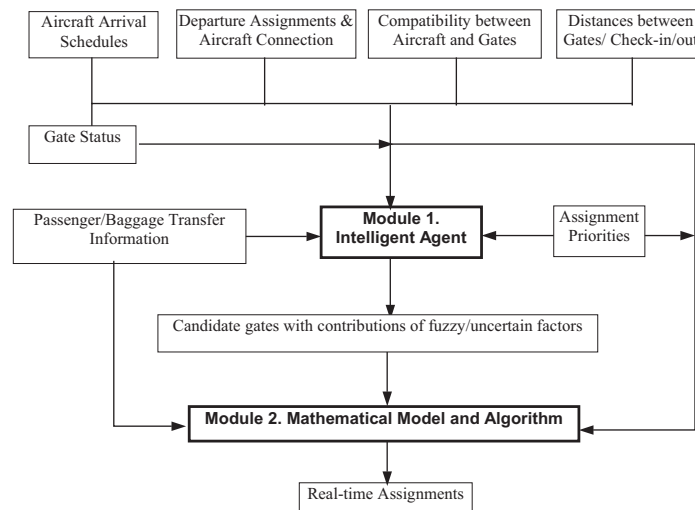
Figure 1. Flow chart of the system

The intelligent agent is developed to determine the candidate gates for every aircraft. These gates are selected through the consideration of criteria such as passenger and baggage transferring distance, operation rules as well as requirements from the airlines. The criteria are implemented in the form of production rules. This module aims to reduce the scale of the problem to make it easier to determine a final optimal assignment. With this approach, available gates will be assigned to aircrafts through consideration of factors such as the compatibility of the gates and aircraft,

passenger walking distances, baggage handling distances, and conflicts between adjacent gates as well as aircraft passenger capacity. These are rules implemented in the expert system. The multi-objective function implemented in InGates is a combination of minimum delays to arriving aircraft, maximum use of contact gates with aerobridge facilities, minimum passenger walking distances and baggage handling distances, and minimum changes to a pre-established assignment.

The candidate gate list generated in the intelligent agent module will be passed to the optimization module to obtain an optimal assignment within the size limited by the intelligent module. This ensures that the solution will not be worse than any one concluded directly by the intelligent agent. In this paper, the emphasis will be placed on the intelligent agent module.

STRUCTURE AND DEVELOPMENT OF INTELLIGENT AGENT

An object-oriented approach is used to model the entities in the system. These include flights and gates. Each entity contains attributes that are mapped into the attributes of relevant objects, which inherit characteristics and values from their parents, that is, classes. The attributes are placeholders that contain values of specific characteristics associated with different objects. The class-object structure provides an easy way to add or delete objects in the structure as well as sharing of common characteristics and values.

Gate Class and Objects

Information such as gate number, gate group number, operation time, and aircraft type compatibility are the attributes used to describe the gate class of objects. To reflect the real-time changes in real operations, the system offers an interface, as shown in Figure 2, for users to set gate features whenever they need to. With this interface, users can set the operation time of the gate and limits for the gate to hold various types of aircraft if there is a need. Note that there are some aircraft types named as not assigned (NA), those are pre-set places for users to add new aircraft types.

Figure 2. The stand information window

Flight Class and Objects

The flight class represents the information about all arriving or departing aircraft. For each flight, the information such as the flight number, arrival and departure times, terminal used, type of aircraft used, type of gate required, and any pre-assigned gate. In the flight information interface, as shown in Figure 3, users can set the flight features they need, such as arrival or departure time, arriving terminal, aircraft type, and expected gate type (remote or bridge), and current assignment for the flight (shown in the last line). This will allow the possibility of real-time modification of the flight information and allow the system to perform the optimal assignment based on the new information.

Figure 3. The flight information window

Based on the class-object structure shown in Figures 2 and 3, knowledge can be represented using production rules in the generic format of: A (and B) C.

The rule structure of production rules effectively captures essential cause-effect situations. These rules were developed based on the normal operation rules-of-thumb applied at the example airport used in this research. This information was obtained from interviews with apron managers and controllers, as well as documented domain knowledge from company records and operational manuals. For the rule given above, A and B represent conditions to be satisfied and C represents actions to be taken once the conditions are fulfilled.

Through the use of a graphical interface, the values and behaviors of objects can be modified at any time. Rules can be modified, inserted, or deleted during run time. The users can monitor the gate assignment progress and override recommended gates by InGates, if desired. The following are examples of how this can be done.

KNOWLEDGE REPRESENTATION BY RULES

The rules are implemented to capture the knowledge retrieved from domain experts. Production rules with if-then structure were used. To cater to the easy customization of applications in different airports, the rules interface was developed to allow users to make changes to rules during run-time and to avoid the needs of modifying the program. For instance, the rule "*Prohibit parking aircraft with sizes larger than A300 side by side among Gates C41, C43, and C45*" may be specific to an airport. Since the relationships among gates C41, C43, and C45 may be different from airport to airport, or even if there is no gate with such a name, rules like this need to be revised or even deleted when applying the system to a new airport. Even for the same airport, sometimes there is a need to revise the rule when changes occur, such as changes in configuration or airline requirements for example. As shown in Figure 4, this can be achieved by using a module that provides the users with an interactive interface to revise, enable or disable and add or delete rules on the run-time level.

Some rules are aimed at setting limits for gates and flights, as in the rule, "*Do not park B737 and smaller aircraft at gates F75, F77, and F79.*" This type of rule can be revised in a similar manner by setting gates and flight information as presented previously. Rules can be turned on or off, or simply deleted, from the knowledge base. The conditions of rules can be changed easily. As shown in Figure 4, the object attributes of aircraft and gates can be used in the left-hand side (the IF portion) of the rules. The action of rules can be abidance, preference, avoidance, or prohibition, to reflect the necessary requirements due to the real operations. In the example given in Figure 4, the rule indicates that if the aircraft type is B747, the gates C41, C43, C45, D51, D53, and D53 should be avoided in the

allocation. While these represent specific gate names given at a particular airports, in this example, at Changi Airport similar rules can be adopted easily to the real situation at different airports.

Figure 4. Interface of Rules Editor

Rules such as "*Wherever possible assign aircraft arriving between 0100/0500 at Gate Groups 1 and 2,*" as shown in Figure 5, are used for situations where preferences are to be satisfied as much as possible.

Figure 5. Edition results of Rule-2

To ensure the safety and operational separation of aircraft, the following type of rule is applicable. "*For aircraft with sizes larger than A300 and time interval of departure/arrival within 10 minutes, prohibit parking them side by side among Gates C41, C43 and C45.*" This situation can be captured easily by utilizing the side-by-side restriction rule for gates C41, C43, and C45, as shown in Figure 6.

Figure 6. Edition results of Rule-3

In some situations, the system variables are defined as V1, V2, and so on, and are included in the rules. These variables can be used effectively to help control the logical relationship between rules. For example, as shown in Figure 7, users need only to key in the serial numbers of the ghost variables. This will allow the system to reinforce the pre-determined gate assignment by users, for example, for VIP arrivals at the airport.
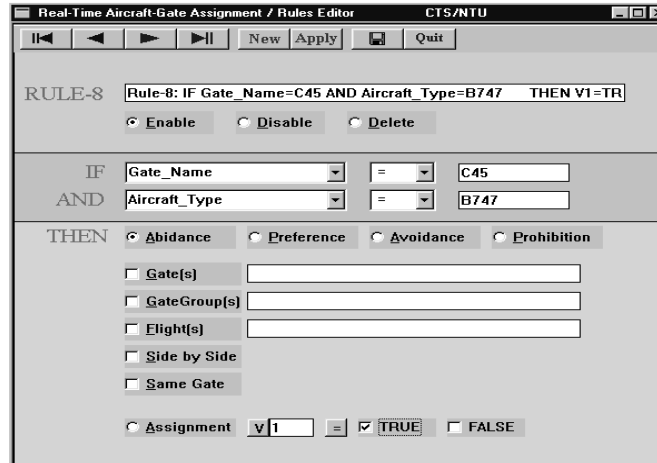
Figure 7. Assignment of system variable

VALIDATION OF SYSTEM PERFORMANCE

Thorough testing of model logic has been performed using a data set collected in a typical day of operations at Singapore's Changi Airport, with two terminals and almost 100 gates. The data set consists of more than 200 flights in a 24-hour period. The test performed on the data set has allowed the debugging and fine-tuning of the system. A comparison of the results from InGates and those obtained from manual assignment has shown that InGates is able to assign the gates in a manner similar to that of the human experts. The results illustrate that the objectives and the constraints stated above were satisfied. The computing time taken is just a few seconds on a mid-range PC.

The results of gate assignment can be displayed in either an airport map, as shown in Figure 8, or a Gantt chart, as shown in Figure 9. With the use of a Gantt chart, one can easily view the scheduled use and assignment of gates for different flights. The pictorial display of such assignment results is represented by an airport map, which provides the gate and flight information, as well as the availability of gates and assignment results, at any time of the day through the clicking of appropriate buttons on the menu.

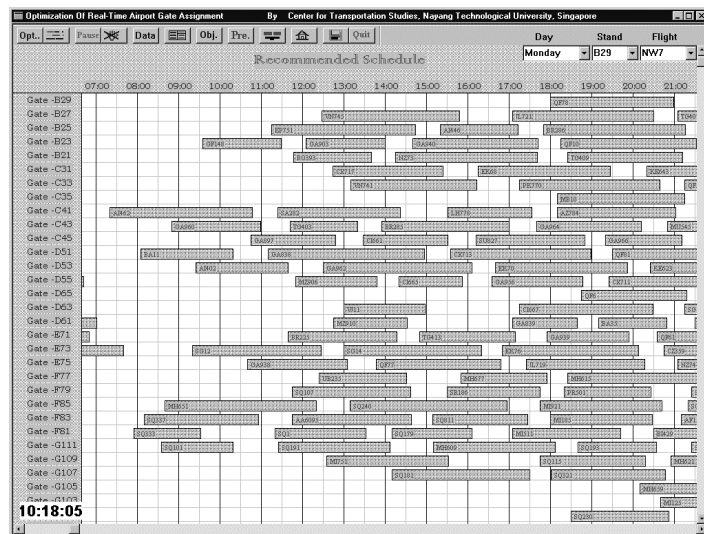**Figure 8. The airport base map showing the gates (aircrafts of flights allocated to gates are shown in red)**

Figure 9. The Gantt chart showing the allocation results

CONCLUSIONS

In this paper, an intelligent agent for airport gate assignment (InGates) was presented. The structure and special features of the system were discussed, as well as applications to perform gate allocations to a set of data obtained from Singapore's Changi Airport. The results show that InGates is able to allocate gates to aircrafts of flights in a reasonably large and busy airport within a short time. Together with systems and tools designed to allow for real-time adjustments to data and settings used by InGates, it has the capability to function as a real-time decision support system for airport gate assignment. The results obtained from the intelligent system module of InGates will be used as input to facilitate the search for an optimum solution for the airport gate assignment program as the next step of the development.

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METHODOLOGY FOR ASSESSING SUSTAINABILITY OF AN AIR TRANSPORT SYSTEM

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ABSTRACT

Assessment and operationalisation of the concept of a sustainable air transport system have been recognised recently as an important but complex research, operational and policy tasks. In the scope of the current academic efforts to properly address these problems, this paper develops methodology for assessing the sustainability of an air transport system. The methodology is based on the indicator systems of sustainability defined for the operational, economic, social, and environmental dimensions of the system performance. The measures are defined for each indicator to express the system effects (benefits) and impacts (costs) for particular actors such as the system users—air travellers, air transport operators, aerospace manufacturers, local community members, local and central government. They are assumed to evaluate the system sustainability with respect to the values of selected indicators. Generally, for all of them the system will be sustainable if the indicators representing effects (benefits) are as high as possible and increase with increasing system output, and the indicators representing impacts (costs) are as low as possible and decrease with increasing system output.

INTRODUCTION

What is sustainability? Different definitions related to sustainable society have been developed. The generic one provided by the Word Commission on Environment and Development (1987), considered a

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sustainable society as one that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987, p. 14). This definition has been frequently modified. For example, Daly (1991) defined a physical sustainable society as one proposed to fulfil basic conditions in terms of limiting rates of using renewable and non-renewable resources, and quantities of air pollution emissions. Recently, the United Kingdom (UK) government has defined sustainable development popularly as a better quality of life, now and for generation to come (DETR, 2000, p. 3).

When strictly applied to transport, the above definitions generally indicate that transport (as a system) has not been sustainable primarily due to the permanent and intensive consumption of mostly non-renewable energy resources (fossil fuels) and emissions of greenhouse gases despite the fact that the sector has managed to reduce energy consumption and air pollution rates by using new technologies and alternative energy sources (Whitelegg, 1993). Nevertheless, air transport has acted as a strong driving force of economic development and welfare. Therefore, in order to deal fairly with both aspects of transport influences, the concept of a *sustainable air transport system* has been introduced. In the scope of this concept, *sustainability* has meant continuity of the sector growth combined with limitation (or mitigation) of the harmful effects for both the short- and long-term. Such balanced development has thought to be achieved by establishing inter- and intra-balance (trade-offs) between the full social benefits and costs of the various transport modes. However, numerous theoretical and practical problems have emerged as barriers to operationalisation of this concept. One of the most important theoretical problems has shown to be the complexity of quantifying of the full social benefits and costs of particular transport modes. The main practical problem has shown to be the generalisation and operationalisation of the policies designed to internalise costs of the environmental damages throughout the air transport system worldwide (DETR, 2001; EC, 1997; ECMT, 1998; Hewett & Foley, 2000; Levison, Gillen, Kanfani & Mathieu, 1996).

This paper develops methodology for assessing the sustainability of an air transport system. The methodology is based on definition of indicator systems each consisting of a set of indicators related to different dimensions of the system performance: operational, economic, social and environmental (FAA, 1996). In the scope of each indicator system, separate sub-sets of indicators are defined to express the objectives and sometimes very conflicted interests and preferences of the various actors involved in

the system. These actors include air travellers, air transport operators, aerospace manufacturers, local community members, and local and central government. The methodology is expected to be able to scan current and future sustainability of an air transport system and its components with respect to particular indicators (EC, 1999).

In addition to this introductory section, this paper consists of three sections. The second section describes the concept of a sustainable air transport system. The third section develops the methodology for assessing the sustainability of an air transport system in the form of the indicator systems relevant for particular actors involved in dealing with sustainability of the system. The last section contains some conclusions.

THE CONCEPT OF A SUSTAINABLE AIR TRANSPORT SYSTEM

The concept of a sustainable air transport system is based on the identification, analysis and assessment of three linked dimensions of its performance: economic, social, and environmental. As well, they all are linked and highly dependent on the operational dimension of performance, which should also be taken into account. Analysis and assessment of the sustainability of an air transport system can be carried out by developing the indicator systems of sustainability for each dimension of performance. Each such indicator system consists of the sub-sets of individual indicators relevant for particular actors involved in dealing with the air transport system. The indicator systems constitute the methodology for assessing the sustainability of an air transport system.

The objectives of this paper is to develop this methodology through following steps: (a) Understanding the basic principles of sustainability, including identification of particular dimensions of the air transport system performance and groups of actors involved; (b) Designing the indicator systems of sustainability consisting of individual indicators for each group of actors involved and each dimension of the system performance; and (b) Quantification of particular indicators and evaluation of the main directions of their development with respect to the basic principles of sustainability.

The first two steps are presented in this paper. The last step should be the subject of further research. In addition to contributions to the academic research, achieving the above objectives could help in establishing the scientific base for negotiations between particular groups of actors concerning setting up the thresholds or acceptable ranges of values for particular indicators as policy targets, which in turn should provide medium- to long-term sustainable development of an air transport system.

Dimensions of the System Performance

Sustainability of an air transport system can be considered with respect to four dimensions[1] of the system performance: operational, economic, social, and environmental. They are linked and dependent on each other as it is shown in Figure 1. The operational dimension is the basic one. It relates to elements such as demand and capacity, quality of service, and safety and security. The air transport demand has been mostly driven by the external forces, of which the gross domestic product (GDP) has dominated at the global level. Figure 2 shows one such characteristic example. Capacity has been always adjusted (i.e., expanded) in order to satisfy demand at any given level of efficiency and effectiveness (i.e., quality of service). Safety and security have inherently been included in the system planning, operation and management at both the local (i.e., the system component) and global level.
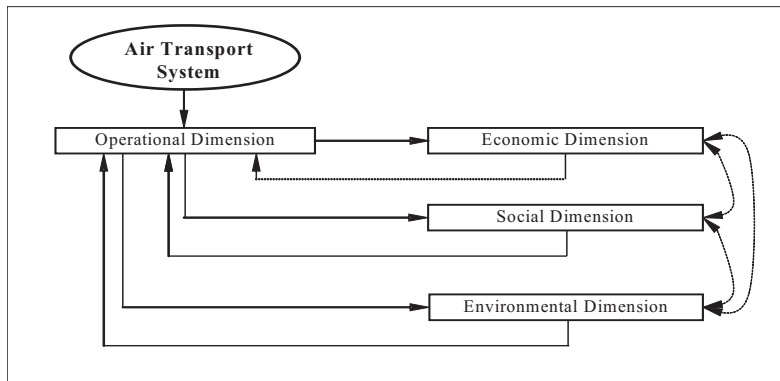
Figure 1. Dimensions of air transport system performance and their linkage

The operational dimension influences the economic dimension, which consists of the elements such as the system operational costs, revenues, profits, and productivity (Hooper & Hensher, 1997). Costs are imposed on the system operators while providing capacity by using inputs, generally in terms of capital, labour and energy, at given prices. The revenues are obtained by charging users for services. Profits are the differences between revenues and costs. The size and scope of the economic dimension mostly depends on the size and scope of the supply (capacity), which is adjusted to present and prospective demand. The economic dimension increases with the increasing of the operational dimension, and vice versa.

Figure 2. Air transport growth vs. economic growth: development of the U.S. domestic traffic - period 1960-1999 (compiled from BTS, 2001)

The social dimension represents the social effects of the system such as direct, indirect and induced employment at the local and regio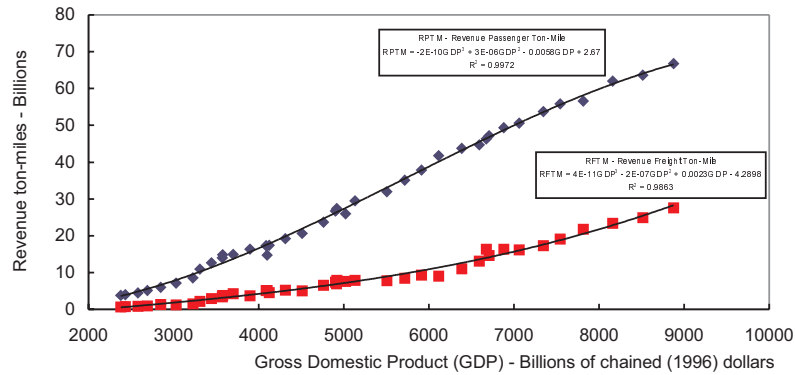nal level, and contributions to local and regional GDP (Button & Stough, 1998; DETR, 1999, 2000). In addition, contributions to globalisation and internalisation of business and leisure activities (e.g., international trade, investments, tourism) may also be considered in the scope of the social dimension. The social dimension depends on the operational dimension. Generally, the social dimension increases with the increasing of the operational dimension, and vice versa.

The environmental dimension contains the physical impacts on peoples health and the environment. In general, local (airport) and global (airspace) air pollution, airport noise, aircraft accidents, congestion and delay, generation of waste, and land use can be considered as the most common and noticeable impacts. Most of these impacts are directly dependent on the operational dimension, that is, the environmental dimension increases with the increasing of the operational dimension, and vice versa (Janic, 1999).

The economic, social and environmental dimensions of performance also influence each other. For example, implementation of measures for protecting the environment in the scope of the environmental dimension may influence the economic and operational dimension by imposing extra costs on the air transport system operators and by limiting the scale and scope of their activities, respectively. In addition, limitation of activities may affect the system's social dimension through reduction of positive

social contributions. On the other hand, favouring of employment as an element of the social dimension may negatively influence the elements of the economic dimension such as profitability and productivity.

Groups of Actors Their Objectives and Preferences

According to the vertical organisation of air transport services, different groups of actors may be involved in dealing with sustainability of air transport system as follows (ATAG, 2000; INFRAS, 2000):

1. Users—air travellers, freight (air cargo) shippers, and mail constitute air transport demand;

2. Air transport operators—airports, Air Traffic Management/Air Traffic Control (ATM/ATC), and airlines constitute the system service (capacity) providers;

3. Aerospace manufacturers produce and deliver the aircraft (airframe, engines, avionics), ATM/ATC and airport facilities and equipment to the system operators;

4. Local community members live in vicinity of airports, and benefit and suffer from air transport operations;

5. Local and central government mainly play roles in creating policies to regulate the system operations at the local (community) and regional (national) level, respectively;

6. Aviation organisations coordinate the system development at the global (international) level;

7. Lobbies and pressure groups organise and articulate the interests of people who usually oppose the expansion of the air transport system infrastructure; and

8. The public is interested in particular aspects of the air transport system from time to time.

Sustainability of an air transport system may have different meanings and contexts for different groups of actors depending on their specific the very often conflicted objectives and preferences.

1. The users—air travellers and freight shippers—usually prefer frequent, easy accessible, relatively cheap, punctual, reliable, safe and secure door-to-door service in which air transport plays the major role.

2. The air transport operators provide services according to their business objectives in terms of profitability and safety on one side, and the users' satisfaction on the other.

3. The aerospace manufacturers prefer business success to be achieved through selling their products. In general, they are mainly focused on the quality of products in terms of reliability, safety, efficiency and profitability.

4. Local community members usually tend to maximise potential benefits and minimise costs of air transport system operation at the local level. Opportunity for direct and indirect employment and use of the efficient air connections to other distant communities can be considered as obvious benefits. The costs are regarded as exposure to airport noise, air pollution, and risk of damage of property, injury or loss of life due to potential aircraft accidents.

5. Local and central governments are mostly interested in the overall benefits and externalities of the system operation. The direct benefits embrace the system's contributions to the GDP. Indirect benefits include contributions to internalisation and globalisation of businesses (international trade and investments) and tourism. Creation and implementation of the policies to protect people's health and the environment at both the local and global level is intended to keep the externalities under control.

6. International aviation organisations [for example, International Civil Aviation Organization (ICAO), International Air Transport Association (IATA), European Civil Aviation Conference (ECAC), Association of European Airlines (AEA), Airports Council International (ACI)] provide the framework and guidelines for sustainable development of air transport systems at both the regional (national) and global (international) level.

7. Different lobbies and pressure groups campaign against global harmful effects of polluting systems on the peoples health and environment. In such context, they also intend to prevent further contribution of air transport to global warming by strong opposition to any further physical expansion of the system infrastructure, that is, airports.

8. The public is informed about the air transport system from media such as radio, television, internet, and newspapers. However, media report mostly about the cases of severe system disruptions such as aircraft accidents, terrorist attacks, congestion (delays), massive cancellation of flights, and significant rises of airfares since such disruptions may directly affect wide population of users and non-users for a long time. Generally, the public wants to be objectively informed.

Figure 3 shows a scheme of the vertical organisation of an air transport system developed for defining the indicator systems of sustainability.
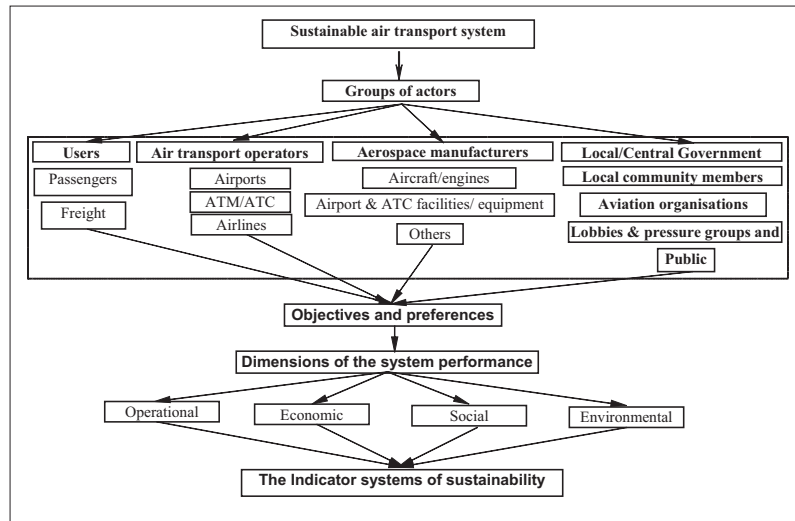
Figure 3. Scheme of the air transport system vertical organisation for developing the indicator systems of sustainability

The Basic Principles of Sustainability

It can be said that an air transport system develops in a sustainable way if the net benefits of its operations expressed either in absolute (total) or relative terms (per unit of output) increase in line with the increasing of the system output. This can be achieved by establishing a balance (i.e., trade-off) between the system's positive effects (benefits) and negative impacts (costs). Generally, such trade-offs may be established at the global (intercontinental), regional (continental, national) and local (community) level (INFRAS, 2000).

Global Trade-off

At the global level, the growth of economy and air transport demand have strongly driven each other with the evident negative consequences such as increased energy consumption and increased emission of greenhouse gases. A trade-off between positive effects and negative impacts of such growth may eventually be established by using one among the following scenarios.

Setting up a cap on the impacts. According to this scenario, a cap on total energy consumption and related air pollution, and consequently growth of air transport demand in absolute terms, would be set up. However, despite a lot of efforts, development and implementation of such a global scenario—based on the worldwide consensus of particular actors involved in air transport operation and business—seems unlikely to take place in the short- to medium-term future (Hewett & Foley, 2000).

Decomposing the growth of air transport demand and the overall economic growth. This scenario consists of weakening the strong links between the air transport demand and the GDP as its main external driving force. Figure 1 shows the very strong dependence. Under such circumstances, it seems that such decomposition can only be carried out by stimulating people to change their habits of using air and other transport modes (EC, 1999). However, this is a long-term process with unpredictable success.

Trading-off between global effects and impacts. In this scenario, long-term conditions to guarantee faster growth of the systems global positive effects rather than the negative impacts should be established. In general, this can be achieved by adequate technological improvements of aircraft and engines, and ATM/ATC procedures, as well as by more sophisticated global use of land for expanding the systems infrastructure. At present, this scenario seems to be the most acceptable. Figure 4 shows a generic scheme
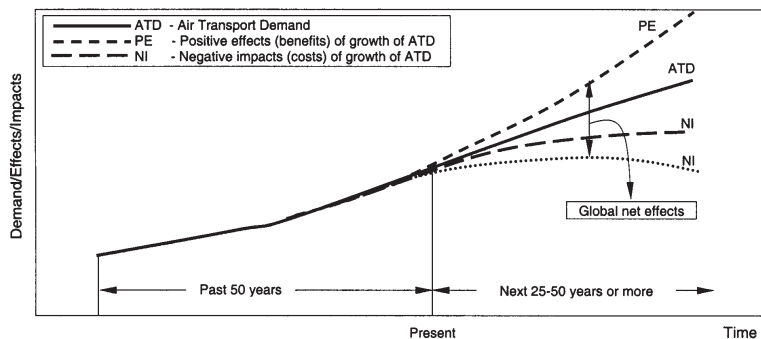

Figure 4. Long-term sustainable development of air transport system according to compromise scenario

of the systems possible long-term development according to a compromise scenario.

Regional Trade-off

At the regional (national, continental) level, particularly in the United States (US) and western Europe, the growth of air transport demand has been driven by liberalisation of already matured air transport markets as well as by higher productivity and lower prices of services. At the same time, this growth has been confronted with the limited capacity of airports and ATM/ATC, which has increased congestion and delays and thus deteriorated the expected quality and efficiency of service. This has given rise to the question of establishing of an appropriate trade-off between demand and capacity at the regional level in order to maintain the desired quality of service and hinder its further deterioration. Three scenarios are available.

Changing regional factors. This scenario assumes changing of the regional factors—liberalisation, market competition, productivity, and airfaresin a way to discourage further growth of air transport demand. If it did happen, previous positive development and progress achieved so far would be annihilated. However, the present trends indicate that this scenario is not likely to take place (Boeing, 2001).

Constraining the infrastructure expansion. This may be called the do-nothing scenario, in terms of further expansion of the air transport infrastructure in some mature markets, for example, those in western Europe and the US. If such a scenario takes place and if air transport demand continues to grow, the system infrastructure will come to saturation, which will cause widespread and severe deterioration of the quality and efficiency of service and thus deter the existing and prospective demand from using the system. Such a scenario has already taken place at some the very congested European airports and airspace, but still without any noticeable evidence of a significant effect on demand (EUROCONTROL, 2001).

Utilising the available resources more efficiently. This scenario consists of more efficient utilisation of the existing air transport infrastructure—airports, ATM/ATC—and aircraft. This can be achieved by using new technologies and innovative operational procedures, appropriate modification of the airline hub-and-spoke practice, and cooperation with other transport modes (particularly railways) through provision of integrated services. Some elements of this scenario have already been implemented at particular congested European airports (Arthur, 2000).

Local Trade-off

At the local level, trade-offs between the positive effects and negative impacts of airport growth on the local community and environment may eventually be established by using two scenarios:

Constraining the airport growth. This scenario assumes that the growth of a particular airport should be limited to the capacity of the existing infrastructure, both airside and landside. On one side, such limits will prevent further escalation of the negative impacts on local people and the environment in terms of noise, local air pollution, and acquisition of land. On the other, it will constrain the positive direct and indirect effects on the local economy. This scenario has already taken place at particular congested airports in Europe.[2]

Managing the airport growth. This seems to be a reasonable scenario for development of most airports under present circumstances, which assumes that their growth will be managed to provide higher rates of benefits than costs to the local area.

Figure 5 shows how this scenario would work at London Heathrow airport. As can be seen, under conditions of growing demand and current use of two parallel runways (alternating mode) to mitigate noise, the airport will come to saturation in the near future with negative consequences such as severe congestion and delays. In order to reduce these negative social consequences and to increase the positive economic and the environmental consequences of previous development, different options for increasing the runway system capacity should be considered. One of the options consists
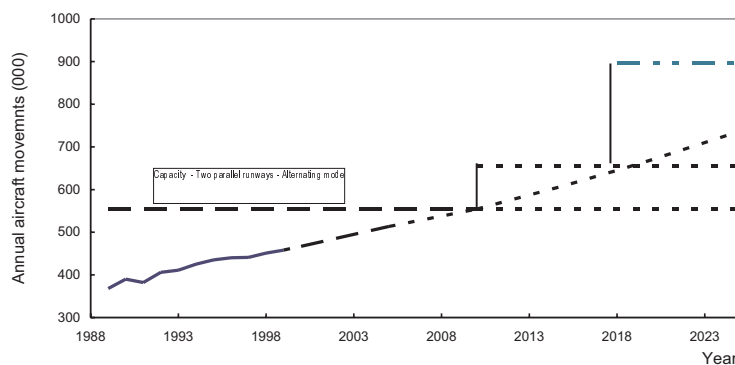

Figure 5. Options for increasing of airside capacity at London Heathrow airport

of more efficient utilisation of the existing runway system, which can be carried out by changing the present mode of runway use from alternating to mixed (BA, 2001). Another option consists of building a third parallel runway. However, both options will likely increase aircraft noise and air pollution. Therefore, a trade-off between these two effects should be established and evaluated.

METHODOLOGY – THE INDICATOR SYSTEMS OF SUSTAINABILITY

Assumptions

Development of the indicator systems of sustainability of an air transport system is based on various assumptions introduced to easier define, understand and quantify the individual indicators of sustainability. These assumptions are as follows:

1. The indicator systems of sustainability are developed for particular groups of actors involved in dealing with the sustainability of an air transport system. Thus, the number of these systems corresponds to the number of different groups of actors involved. Each indicator system consists of four sub-systems corresponding to different dimensions of the system performance (operational, economic, social, environmental). The particular sub-system of indicators consists of the individual indicators and their measures.

2. The individual indicators are defined to measure the effects (benefits) and impacts (costs) of an air transport system operation in either absolute or relative monetary or non-monetary terms, as functions of the relevant system output. Within the same sub-system of indicators, if a benefit indicator increases and a cost indicator decreases or is constant with the increasing of the relevant output, the system will be considered as sustainable. Otherwise, the system will be considered as unsustainable. When a threshold value is set up for an indicator, it can be used as a target value for achieving sustainability. Figure 6 shows a generic example.[3]

3. For all individual actors within the same group, the indicator system and sub-systems are unique.

4. The individual indicators are assumed to be independent across given indicator systems and sub-systems.
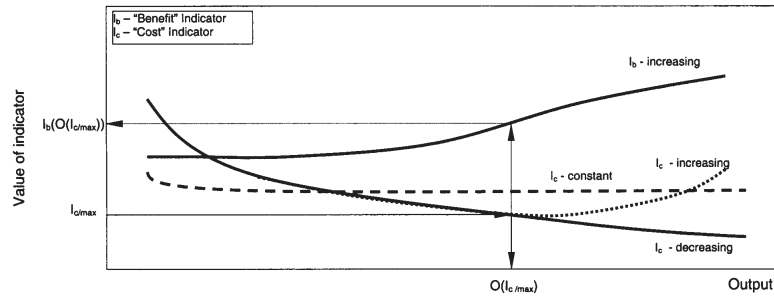
Figure 6. Generic relationships between indicators of sustainability and the system output

5. The particular indicators should be sufficiently convenient to be applied either to the system as a whole or to its individual components. As well, they should be easily transformable to be applied to other transport modes for comparative purposes.

6. The indicator systems should be updateable depending on the specific objectives and preferences of particular groups of actors.

7. Indicators should be convenient for an initial assessment of the direction of the system's development with respect to sustainability.

8. The data for quantifying particular indicators should be available from existing statistical databases. Regression least-square technique seems to be the most appropriate analytical technique for estimating dependence of particular indicators on the system output. In such a case, the value (i.e., measure) of the indicator is assumed to be the dependent variable and the relevant system output is the independent variable.

Definition of the Indicator Systems

According to their specific objectives and preferences, different actors may use different indicator systems for assessing sustainability of an air transport system. Therefore, separate indicator systems are defined to express each systems specific objectives and preferences with respect to the four dimensions of system performanceoperational, economic, social, and environmental. Tables 1A-7A in the appendix provide list of these systems.

The Indicator System for Users

The indicator system for users, that is, the air travellers, consists of eight individual indicators. Five indicators are defined for the operational dimension and one indicator each for the economic, social and environmental dimensions of performance. These indicators mainly relate to airline and airport services and can be quantified for individual airlines, routes and/or airports, as well as for the airline industry and airport network of the region as the whole (see Table 1A).

Operational Indicators of the User Indicator System

The five indicators of operational performance are experienced punctuality of service, experienced unreliability of service, lost and damaged baggage, safety and security.

Experienced punctuality of service refers to the users' perceptions of a chosen airline's ability to carry out flights and services on- time. This assessment can be carried out either by experience or by using airline information. In the later case, two measures may be convenient. First is the probability that an airline flight is on time. This probability can be calculated as the ratio between the number of on-time flights and total number of flights carried out for a given airline during a given period of time. Another measure is the average delay per flight, which may include arrival delay, departure delay or both. Both measures are relevant when choosing the airline, air route and air transport mode itself, and are components of the Airline Quality Rating system (AQR) in the US (Headley & Bowen, 1992; BTS, 2001). Users usually prefer the probability of on-time flights to be as high as possible and average delay per flight to be as low as possible under conditions of increasing number of flights.

Experienced unreliability of service reflects the users' perception of a chosen airline's ability to fulfill the schedule. This indicator can be assessed either by experience or by using airline information. In the later case, the number of cancelled (or diverted) flights to total number of flights during a given period of time ratio can be used as a measure. This measure is also a component of the AQR in the US (BTS, 2001). Independent of the causes of cancellations or diversions of flights, it is preferred the ratio be as low as possible and to decrease with an increase in the number of flights.

Lost and damaged baggage expresses potential loss or damage of the users' baggage while within the air transport system. In addition to experience, information from a chosen airline can be used to assess this indicator. This indicator is also a component of the AQR. The number of

lost (or damaged) baggage to total number of passengers served during a given period of time ratio can measure it. The ratio is preferred to be as low as possible and to decrease with an increase in the number of passengers served.

Safety emerges as a relevant indicator for users while choosing one airline among the other airlines as well as while choosing the air transport mode itself among the other alternative transport modes. This indicator measures perceived risk of death or injury of an individual while onboard. Again, in addition to subjective judgements, airlines and/or the national and international aviation authorities can provide information about this measure, which is usually expressed by the number of deaths (or injuries) per unit of output as measured by revenue passenger kilometer or revenue passenger mile (RPK/RPM). The users prefer this ratio to be as low as possible and to decrease with an increase in system output.

Security relates to the perceived risk of an individual's exposure to threat from illegally carried weapons or other dangerous devices (e.g., bombs, firearms, and guns) while at an airport or onboard. Airport security services can provide information on this indicator for individual airports or for an airport network. The number of detected illegal dangerous devices to the total number of passengers screened ratio can measure this indicator. Users prefer this ratio to be as low as possible and to, independent of the causes,[4] decrease with an increase in the number of screened passengers.

Economic Indicator of the User Indicator System

Economic convenience of air travel is the economic indicator important to an air traveller while choosing the air transport mode among the alternative transport modes (Janic, 2001). This indicator reflects the total generalised cost of a door-to-door trip. Air transport generally has the highest cost as compared to other travel modes. The average airfare per passenger can be used as convenient measure. Users always prefer airfares be as low as possible and to decrease over time.

Social Indicator of the User Indicator System

Spatial convenience is the only social indicator relevant for users. It reflects the users' opportunity to travel from a given airport by a selected airlines to other medium and long distant places. The number of destinations served from an airport (or region) by a given airline can be used as a measure. In addition, connectivity by non-stop, one-stop or multi-stop flights with respect to trip purpose (business, leisure) can be

considered to refine this measure. Recently, this measure has become a global competitive tool of both airlines and airports. In general, users prefer the number of opportunities to be as high as possible and to increase over time.

Environmental Indicator of the User Indicator System

Comfort and health is the user's indicator for the environmental dimension. Air transport users consider travelling comfort and healthiness of the airport and aircraft environment while assessing the quality of the transport environment. This indicator relates to the users' feeling of comfort while at an airport terminal and onboard. Different measures can be used. At an airport, in addition to a subjective judgement, passenger density (the number of passengers per unit of space) and the average queuing time can be used to measure passenger comfort and discomfort as a component of the airports quality of service. In addition to the individual experience, the airport operator can provide information on these measures (Hooper & Hensher, 1997; Janic, 2001). Configuration and size of seats in economy class and the quantity of fresh air delivered to the aircraft passenger cabin per unit of time seem to be the most relevant measures of passenger comfort and healthiness of the environment while onboard. The measures of airport comfort and discomfort are preferred to be as low as possible and to decline with an increase in the number of passengers served. Both measures of comfort while onboard are preferred to be as high as possible and to increase over time.

The Indicator System for Airports

The indicator system for airports consists of eleven indicators. Four indicators are defined for the operational dimension, two for the economic dimension, and five for the environmental dimension of airport performance. There are no indicators for the social dimension. The indicators can be quantified for the individual airport or the airport network as the whole (see Table 2A).

Operational Indicators of the Airport Indicator System

Demand, capacity, quality of service and integrated service are regarded as the main airport operational dimension indicators.

Demand indicates the scale of an airport operation. The number of passengers and Air Transport Movements (ATM) measured by arrivals and departures, and the volume of freight accommodated during a given period

of time can measure this indicator. Sometimes, it is more convenient to use Workload Unit (WLU) where one unit equals one passenger or 100 kg of freight (Doganis, 1992). The airport operator prefers these measures to increase over time.

Capacity reflects the maximal physical capability of an airport to accommodate demand during a given period of time. Commonly, two measures are used: airside capacity in terms of the maximum number of ATM, and landside capacity in terms of the maximum number of WLU. Both measures are preferred to be as high as possible and to increase over time in order to cope with increasing demand.

Quality of service reflects the relationship between airport demand and capacity. Generally, the average delay per ATM or WLU during a given period of time can be used as a measure. This delay occurs whenever demand exceeds capacity. The measure is preferred to be as low as possible and to decrease with an increase in demand.

Integrated service is when an airport has the opportunity to improve utilisation of their capacity by substitution of some short-haul flights with adequate surface transport, usually high-speed rail services, and by using such freed slots for more profitable long haul services.[5] A measure of this indicator can be the ratio between the number of substituted flights and total number of feasibly substitutable flights carried out during a given period of time. Airport operators prefer this ratio to be as high as possible and to increase with an increase in the number of feasibly substitutable flights.

Economic Indicators of the Airport Indicator System

In addition to the operational dimension, airports, as business enterprises look strictly after the economic dimension of their performance. Profitability and labour productivity are defined as the most convenient indicators of the economic dimension.

Profitability usually reflects the airports financial success. It can be measured by operating profits (the difference between operating revenues and operating costs) per output measured by WLU (Doganis, 1992). This measure is preferred to be as high as possible and to increase with an increase in airport output.

Labour productivity reflects the efficiency of labour use at an airport. The output in terms of the number of WLU (or ATM) carried out during a given period of time per employee can be used as a measure of this indicator (Doganis, 1992; Hooper & Hensher, 1997). Only direct

employment is taken into account. This measure is preferred to be as high as possible and to increase with an increase in the number of employees.

Environmental Indicators of the Airport Indicator System

Five indicators—energy inefficiency, noise inefficiency, air pollution inefficiency, waste inefficiency and land use inefficiency—are defined to represent the environmental dimension of airport performance. These indicators relate to the physical impacts of an airport on the health of the local people and the environment and get relevance while undertaking mitigation measures.

Energy inefficiency relates to the quantity of energy used by an airport for day-to-day operation of the airport itself. This energy obtained from different sources is used for lighting, heating, and other airport infrastructure. A measure for this indicator can be the quantity of energy consumed per unit of WLU accommodated during a given period of time. The measure is preferred to be as low as possible and to decrease with an increase in the volume of output.

Noise inefficiency relates to the noise energy generated by the number of ATM during a given period of time. A measure for this indicator can be the area determined by a certain equivalent long-term noise level (L_{eq}) expressed in decibels [dB(A)]. The affected area is expressed in square kilometres (DETR, 2000, 2001). This indicator is preferred to be as low as possible and to diminish with an increase in output.

Air pollution inefficiency relates to total air pollution generated by an airport during a given period of time. The quantity of all or specific air pollutants can be considered. In addition to that from air traffic-aircraft, the air pollution from landside airport road traffic and by airport handling operations can be taken into account (EPA, 1999). Generally, the quantity of air pollutants per polluting event—defined by ICAO (1993a) as a landing/take-off (LTO) cycle—can be used as a measure of this indicator. Airport operators prefer this quantity to be as low as possible and to decrease with an increase in the number of LTO cycles.

Waste inefficiency relates to waste generated by an airport excluding airline in-flight waste (BA, 2001). A convenient measure can be the quantity of waste generated per WLU during a given period of time. This measure is preferred to be as low as possible and to decrease with an in crease in the airport output.

Land use inefficiency relates to utilisation of land taken for building the airport infrastructure—both airside and landside. Once the infrastructure has been constructed, the intensity of use of land where it is accommodated is dependent on the demand. However, this intensity is always limited by the capacity of the infrastructure. A convenient measure for this indicator can be WLU accommodated during a given period of time per unit of acquired airport land. This measure is preferred to be as high as possible and to increase with an increase in land taken by the airport infrastructure.

The Indicator System for Air Traffic Management/Air Traffic Control (ATM/ATC)

The indicator system for Air Traffic Management/Air Traffic Control (ATM/ATC) consists of eight indicators of performance: four for the operational dimension, two for the economic dimension, and two for the environmental dimension. There are no social indicators defined for this system. These indicators can be quantified for a part of the ATM/ATC sector or for the whole system (e.g., airspace of a country or continent) (see Table 3A).

Operational Indicators of the ATM/ATC Indicator System

Demand, capacity, safety and punctuality of service are defined as the operational indicators of the ATM/ATC indicator system.

Demand is measured by the number of flights accommodated (i.e., controlled) in a given ATM/ATC airspace during a given period of time (Janic, 2001). This measure is preferred to be as high as possible and to increase over time.

Capacity expresses the maximum capability of ATM/ATC providers to serve demand under given conditions. It can be measured by the maximum number of flights served in a given airspace per unit of time (Janic, 2001). This indicator is preferred to be as great as possible and to increase over time to cope with the increase in demand.

Safety expresses probability of occurrence of an air traffic accident because of ATM/ATC operational error. This accident may take place at an airport or in airspace and while an aircraft is on the ground or airborne. Some convenient measures of this indicator can be the number of individual aircraft accidents or the number of Near Midair Collisions (NMAC) per unit of the ATM/ATC output measured by the number of controlled flight. These measures are preferred to be as low as possible and to decrease with an increase in the number of flights.

Punctuality of service is a surrogate for the quality of service provided by ATM/ATC to its users—flights and aircraft. This indicator can be measured for a given period of time by two measures: percent of non-delayed flights due to the ATM/ATC restrictions, and the average delay per delayed flight. The percent of non-delayed flights is preferred to be as high as possible and to increase with an increase in the number of flights. The average delay per delayed flight is preferred to be as low as possible and to decrease with an increase in the number of flights.

Economic Indicators of the ATM/ATC Indicator System

Two indicators are defined to reflect economic dimension of performance of ATM/ATC providers: cost efficiency and labour productivity.

Cost efficiency[6] relates to the ATM/ATC operating costs. It is measured by the average cost per unit of output—controlled flight—for a given period of time. This measure is preferred to be as low as possible and to decrease with an increase in the number of controlled flights (Janic, 2001).

Labour productivity reflects efficiency of the ATM/ATC providers in terms of labour use. A convenient measure can be the number of controlled flights per employee. This indicator is preferred to be as high as possible and to increase with an increase in the number of employees.

Environmental Indicators of the ATM/ATC Indicator System

Two indicators are defined to express the environmental dimension of ATM/ATC performance: energy efficiency and air pollution efficiency.

Energy efficiency relates to the extra fuel consumption due to deviations of flights and aircraft from the prescribed (fuel-optimal) trajectories dictated by the ATM/ATC safety requirements. This indicator can be measured by the average extra fuel consumption per flight. The measure is preferred to be as low as possible and to decrease with an increase in the number of flights.

Air pollution efficiency relates to the extra emission of air pollutants due to extra fuel consumption resulting from deviations of flight and aircraft from prescribed trajectories. The indicator is measured by the average quantity of emitted pollutants per flight. It is preferred to be as low as possible and to decrease with an increase in the number of flights.

The Indicator System for Airlines

The indicator system for airlines consists of eleven indicators: five for the operational dimension, two for the economic dimension, and four for the environmental dimension of performance. There are no social indicators for airlines. These indicators can be quantified for an individual airline, an airline alliance or the whole airline industry of the region (see Table 4A).

Operational Indicators for the Airline Indicator System

Airline size, load factor, operational punctuality, unreliability of service, and safety are defined as indicators of airline operational performance.

Airline size reflects the volume of airline output carried out during a given period of time. Several measures can be used to quantify this indicator: total number of passengers, total volume of freight and total volume of Revenue Ton-Kilometre or Revenue Ton-Mile (RTK/RTM) (Janic, 2001). As well, RPK/RPM and Freight Ton-Kilometre or Freight Ton-Mile (FTK/FTM) can be used separately instead of the aggregate RTK/RTM. In addition, the size of available resources in terms of the number of aircraft and staff deployed to carry out the output can be used to measure the airline size. All of these measures are preferred to be as high as possible and to increase over time.

Load factor indicates dynamic utilisation of the airline capacity during a given period of time. Usually, it is measured in aggregate form as total RTK/RTM to Available Ton-Kilometre or Available Ton-Mile (ATK/ATM) ratio. As well, load factor can be determined separately for passengers and freight. In each case, this measure is preferred to be as high as possible and to increase with the increase in airline output (Janic, 2001).

Operational punctuality and *unreliability of service*, and *safety* indicators for the airline indicator system are analogous to those same indicators of the users indicator system in terms of how they are measured and their preferences. The airlines use them as competitive tools when applied to the user indicator system and as indicators of operational efficiency when applied to their own system (Janic, 2001).

Economic Indicators of the Airline Indicator System

Two indicators are defined to express the economic dimension of airline performance: profitability and labour productivity.

Profitability relates to the airlines financial success. It is measured by the average profits, defined as the difference between operating revenues and costs, per unit of output measured by RTK/RTM. This indicator is

preferred to be positive, as great as possible, and to increase with an increase in airline output.

Labour productivity reflects the airlines efficiency in using its workforce. It is measured by the average output, measured by RTK/RTM, per employee for a given period of time. The preference for this measure is to be as great as possible and to increase with an increase in the number of employees.

Environmental Indicators for the Airline Indicator System

Four indicators are defined to express the environmental dimension of airline performance: energy efficiency, air pollution efficiency, noise efficiency and waste efficiency.

Energy efficiency and *air pollution efficiency* relate to the rate of modernisation and efficiency of utilisation of the airline fleet in terms of energy and fuel consumption and associated emissions of air pollutants. These indicators are measured during a given period of time by the average quantity of fuel and air pollution, respectively, per unit of output measured by RTK/RTM, distance flown (D) or flying hour (FH). Both measures are preferred to be as low as possible and to decrease with an increase of airline output.

Noise efficiency indicates the rate of modernisation of an airlines fleet in terms of the use of aircraft of the Stage 3 and Stage 4 type, rather than older Stage 2 type (ICAO, 1993; BA, 2001). Once an airlines fleet is completely modernized by replacing all aircraft of Stage 2 type by aircraft of Stage 3 and Stage 4 type, this indicator will become irrelevant. This indicator can be measured by the proportion of the aircraft of Stage 3 and Stage 4 type in the airlines fleet. This proportion is preferred to be as great as possible and to increase with the growth of the airline fleet.

Waste efficiency indicates generation of airline in-flight waste (BA, 2001). This indicator can be measured by the average quantity of in-flight waste per unit of airline output measured by RTK/RTM (BA, 2001). This measure is preferred to be as low as possible and to diminish with an increase in airline output.

The Indicator System for Aerospace Manufacturers

The indicator system for aerospace manufacturers consists of eight indicators: three for the operational dimension, two for the economic dimension, and three for the environmental dimension of performance. There are no social dimensions. These indicators can be quantified for an individual manufacturer or for the sector as a whole (see Table 5A).

Operational Indicators of the Aerospace Manufacturer Indicator System

Innovations of aircraft, innovations of ATM/ATC and airport facilities and equipment, and reliability of structures are defined as indicators of the operational dimension.

Innovations of aircraft reflect the technological progress in terms of aircraft speed, capacity and cost efficiency (RAS, 2001). The progress in speed and capacity can be measured by technical productivity measured by the product of ton-kilometres or ton-miles per hour. Technical productivity of commercial aircraft has generally increased by introducing larger aircraft flown at higher subsonic speeds (Arthur, 2000). Aircraft cost efficiency is usually measured by the average operating cost per unit of capacity measured by Aircraft Seat-Kilometre or Aircraft Seat-Mile (ASK/ASM). This cost generally decreases with an increase in aircraft capacity (Janic, 2001).

Innovations of ATM/ATC and airport facilities and equipment express technical and technological progress in developing avionics, ATM/ATC and airport facilities and equipment. Progress in developing avionics and ATM/ATC equipment can be measured by the cumulative navigational error of aircraft position, which has significantly reduced over time (Arthur, 2000). This has brought gains in airspace capacity and safety. Progress in development of airport facilities and equipment can be measured by increased capacity of processing units in both airport airside and landside areas (Janic, 2001). This measure is preferred to be as high as possible and to increase over time.

Reliability of structures reflects the feature of the particular system components to operate without unexpected failures. This indicator can be separately measured for different components, but, in any case, the average number of failures per unit of operating time for a given period of time can be used as a measure. Because of safety and operational reasons, this measure, independent of the indicator system, is preferred to be as high as possible and to improve with technological progress over time.

Economic Indicators of the Aerospace Manufacturer Indicator System

Profitability and labour productivity are defined as indicators of the economic dimension of performance of aerospace manufacturers.

Profitability, similarly as in the airport and airline indicator systems, expresses financial success or failure of an aerospace manufacturer. It is measured by the average operating profits measure by the difference between operating revenues and costs per unit sold. As with any type of

manufacturer, this measure is preferred to be as great as possible and to increase with an increase in the number of sold units.

Labour productivity expresses the efficiency of aerospace manufacturers in using workforce. Like in case of airlines, airports and ATM/ATC providers, the average number of units produced per employee can be used as a measure. This measure is preferred to be as high as possible and to increase with an increase in the total number of employees.

Environmental Indicators of the Aerospace Manufacturer Indicator System

Three indicators are defined for the environmental dimension of performance. They primarily relate to performance of new aircraft and engines in terms of energy efficiency, air pollution efficiency and noise efficiency.

Energy efficiency, *air pollution efficiency* and *noise efficiency* reflect reductions of fuel consumption, associated air pollution and noise energy generated by new aircraft and engines, respectively, in both absolute and relative terms. They can be measured by the absolute or relative decrease in the quantity of fuel consumption, air pollution and noise energy, respectively, per unit of engine power or aircraft operating weight. These measures are preferred to be as low as possible and to decrease with the increase in the engine power and/or aircraft operating weight.

The Indicator System for Local Community Members

People living permanently or temporarily in tourist residential areas near the airports represent the group of local community members. Usually, they are mostly interested in the social and environmental dimension of the air transport system performance. The indicator system for local community member is assumed to consist of four indicators: one for the social dimension and three for the environmental dimension of performance (see Table 6A). There are no indicators for the operational dimension or the economic dimension.

Social Indicators for the Local Community Member Indicator System

Social welfare is the only defined indicator of the social dimension of performance for the local community member group. This indicator relates to the opportunity of local community members to get a job either directly or indirectly as a result of the local air transport system (DETR, 1999). A convenient measure can be the ratio between the number of community members employed by the air transport system and total number of

employed community members. This measure is preferred to be as high as possible and to increase with an increase of employment in the local community.

Environmental Indicators of the Local Community Member Indicator System

Noise disturbance, air pollution and safety are defined as indicators of the environmental dimension of performance.

Noise disturbance reflects the annoyance of local people by noise from ATM. This annoyance depends on both subjective and objective factors. Subjective factors reflect individual sensitivity to noise. In such case, any noise being equal or exceeding a given individuals threshold is considered annoying. The most important objective factors include the amount of noise energy generated by aircraft flying over the affected area, the distance between residential location and aircraft flight path, and the quality of houses with respect to noise isolation. Bearing in mind both types of factors, two measures can be measured. First is the total number of complaints about aircraft noise by local community members during a given period of time. Second is the ratio of complaints per ATM during a given period of time. Both measures are preferred to be as low as possible and to decrease with an increase in the number of ATM.

Air pollution relates to the exposure of local community members to the harmful impacts of air pollution generated by the local air transport system. This indicator can be measured as the ratio between the quantities of air pollution generated by the local air transport system and total air pollution generated by all local air polluting sources. This indicator is preferred to be as low as possible and to decrease with an increase of total air pollution.

Safety relates to perceived risk of death or injury, or damage or loss of local property due to aircraft accidents. It can be measured by the number of aircraft accidents per ATM carried out during a given period of time. This measure is preferred to be as low as possible and to decrease with an increase in the number of ATM.

The Indicator System for Local and Central Government

Usually, local and central government are not directly interested in the operational dimension of air transport system performance except in cases of significant disruptions. Particular disruptions appear as aircraft incidents or accidents, and significant reduction of punctuality and reliability of air services. These disruptions may deteriorate the overall air transport system

performance, other dependent socio-economic activities, and consequently the quality of life. Otherwise, the local and central government are primarily focused on the economic, social and environmental dimensions of the system performance. The indicator system consists of seven indicators: three for economic, one for social and three for the environmental dimension of performance (see Table 7A). There are no operational indicators.

Economic Indicators for the Local and Central Government Indicator System

Economic welfare, globalization and internalisation, and externalities are defined to express the economic dimension of the system performance.

Economic welfare relates to contributions of the air transport system to the local and regional welfare. A measure can be a proportion of the GDP carried out by air transport system compared to the total GDP of the region. This measure is preferred to be as great as possible and to increase with an increase in total GDP.

Internalisation and globalization relates to contribution of the air transport system to the internationalisation of local and regional business—trade, investments, and tourism. Three measures can be used to quantify this indicator. First is the proportion of trade carried out by air transport in relation to total regional trade. Trade can be expressed by the volume and/or value of export and import. Second is the ratio between the number of long-distant business trips carried out by air transport mode related to the total number of long-distant trips carried out by all transport modes from or to the region during a given period of time. Third is the ratio between the number of long-distant tourist trips by air transport mode compared to the total number of long-distant tourist trips by all transport modes in the region during a given period of time. All three measures are preferred to be as great as possible and to increase with an increase in the total amount of trade or number of business or tourist trips, respectively.

Externalities relate to the costs of air transport noise, air pollution, and air incidents or accidents. Sometimes congestion cost is also included (Janic, 1999; Levison et. al, 1996). Local and central governments are both interested in these costs because of their responsibility for creating a healthy and environmentally friendly society and their responsibility for implementing policies that really change particular impacts (DETR, 2001; EC, 1997). Once such appropriate policies are introduced, the operators (airlines and airports) and end-users (air travellers as the actual payers of

the externalities) will become more interested in these aspects of the air transport system operation. The externalities can be measured by the average expenses per unit of the system output measured by RPK/RPM used for either preventing or remedying air transport noise, air pollution and air incidents and accidents (Ying-Lu, 2000). This measure is preferred to be as low as possible and to decrease with an increase in the system output.

Social Indicators of the Local and Central Government Indicator System

Overall social welfare is the only defined indicator of the social dimension of performance for the local and central government. This indicator represents benefits gained by total direct and indirect employment by the air transport system at the local and regional level. Total annual number of people employed by the air transport system can be used as a measure of this indicator, which is preferred to be as high as possible and to increase over time.

Environmental Indicators of the Local and Central Government Indicator System

Four indicators are defined for the environmental dimension of performance: global energy efficiency, global noise disturbance, global air pollution, and global land use.

Global energy efficiency relates to the total energy consumed by the air transport industry of the country or region in question during a given period of time. This indicator emerges as particularly important for the central government while planning the energy budget of the country. Nevertheless, for the purpose of assessing sustainability, a convenient measure of this indicator can be expressed in relative terms by the average amount of fuel consumed per unit of the system output measured by RTK/RTM carried out during a given period of time. This measure is preferred to be as low as possible and to decrease with an increase in the volume of system output.

Global noise disturbance relates to global exposure of local and regional people to noise generated by the air transport system. This indicator can be measured by the total number of people exposed to the air transport noise during a given period of time. The measure is preferred to be as low as possible and to decrease over time.

Global air pollution relates to global emissions of air pollutants by the air transport system. This indicator can be measured by total emissions of air pollutants per unit of output measured by RTK/RTM. In this case, total

air pollution consists of air pollution during the LTO cycle, and climb, cruise, and descent phases of flight (EC, 1998). This measure is preferred to be as low as possible and to decrease with an increase in total system output.

Global land use relates to the total area of land used for the local and regional air transport infrastructure. An appropriate measure for this indicator seems to be the ratio between the total area of land and total volume of output. In such case, the measure reflects the intensity of land use. This measure is preferred to be as low as possible and to decrease with an increase in air transport system output.

The Indicator System for Others

Other actors such as international aviation organisations, the environmental lobbies and pressure groups and public can use the same indicator systems and individual measures as the other actors. However, because of diversity of the objectives and preferences, interpretation of the particular indicators and measures will likely be different.

DISCUSSIONS AND CONCLUSIONS

This paper has provided a methodology for assessing sustainability of an air transport system. The methodology has been based on the indicator systems of sustainability defined to represent the objectives and preferences of different groups of actors with respect to the air transport system's operational, economic, social and environmental dimensions of performance.

The indicator systems have been developed with respect to the basic principles and rules regarding their generality, transparency and applicability of the individual indicators. Consequently, they are able to measure the system performance in both absolute and relative terms, and independent of its output, which is assumed to generally increase over time. In addition, they are able to assess sustainability of the system as a whole or of its particular components at the global, regional and local level. Fifty-eight individual indicators and sixty-eight measures have been defined in the scope of the indicator systems corresponded to seven groups of actors. Table 1 summarises the relevant statistics. An explanation of particular indicators and their measures is provided in the appendix.

As can be seen, the indicators reflecting the operational dimension of the system performance are the most numerous followed by the number of those reflecting the economic and environmental dimensions. Evidently,

Table 1. Statistics on the Indicator Systems and Measures of Sustainability of Air Transport System

Group of actors	Dimensions of performance				
	Operational	*Economic*	*Social*	*Environmental*	
	Number of the individual indicators/measures				*Total*
1. Users air travellers	5/6	1/1	1/1	1/3	8/11
2. Airports	4/6	2/2	-	5/5	11/13
3. ATM/ATC	4/5	2/2	-	2/2	8/9
4. Airlines	5/8	2/2	-	4/4	11/14
5. Airspace manufacturers	3/3	2/2	-	3/3	8/8
6. Local community members	-	-	1/1	3/4	4/5
7. Local/central government	-	3/3	1/1	4/4	8/8
Total	**21/28**	**12/12**	**3/3**	**21/24**	**58/68**

the environmental indicators are relevant for all actors. They relate to the fuel consumption and associated air pollution, noise, waste, and land use. Operational indicators are relevant for users, air transport operators, and aerospace manufacturers. Air travellers, airports, ATM/ATC service providers and airlines indictors reflect demand, capacity, quality of service, safety and security. Local and central government, the system users and operators, and aerospace manufacturers are interested in the economic indicators. Users consider the costs of their trip. The local and central governments are mostly interested in contributions of the air transport system to the GDP, internalisation and globalisation of local and regional economy in terms of trade, investments and tourism, and local and global externalities. Airlines, airport operators and aerospace manufacturers primarily look after profitability and productivity of their business. Indicators of social dimension of performance reflecting overall social welfare in terms of local and regional direct and indirect employment are relevant only for local community members and local and central governments.

Quantification of indicators in the scope of the particular indicator systems and evaluation of sustainability of an air transport system and its components with respect to their values should be the matter of further research.

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APPENDIX

Table 1A. The Indicator System for Users

Dimension of performance	Indicator	Explanation	Measure—dependent variable	Independent variable
Operational	*Experienced punctuality of service*	- Flights carried out on time - Delay of air trip	- Percent of flights on time - Average delay per flight	-Total number of flights per period of time -Total number of flights per period of time
	Experienced unreliability of service	- Cancellation and/or diversion of flights	- Percent of cancelled (or diverted) flights	-Total number of flights per period of time
	Lost and damaged baggage	- Lost and/or damage of baggage	- Average number of lost (or damaged) baggage per passenger	- Total number of passenger served per period of time
	Safety	- Perceived risk of death (or injury) during air trip	- Average number of deaths (injuries) per RPK/RPM	- Total RPK/RPM per period of time
	Security	- Perceived risk of treat by illegal dangerous devices	- Average umber of detected dangerous devices per passenger	- Total number of screened passengers per period of time
Economic	*Economic convenience*	- Generalised travel cost	- Average airfare per passenger	- Period of time
Social	*Spatial convenience*	- Number of destinations served by an airline from given airport	- Number of destinations per airport and airline	- Period of time
Environmental	*Comfort and health*	- Comfort at airport terminal crowding (passenger density)	- Average number of passengers per unit of terminal area - Average queuing time per passenger	- Total number of passengers served per period of time - Total number of passengers served per period of time - Period of time
		- Quality of air in aircraft - Seat configuration in aircraft	- Quantity of fresh air delivered to aircraft cabin per unit of time - Average number and size of seats in economy class	- Period of time

RPK/RPM — Revenue Passenger Kilometre or Revenue Passenger Mile

Table 2A. The Indicator System for Airports

Dimension of performance	Indicator	Explanation	Measure —dependent variable	Independent variable
Operational	*Demand*	- Number of WLU - Number of ATM	- Number of WLU accommodated per period of time - Number of ATM accommodated per period of time	- Period of time - Period of time
	Capacity	- Maximum number of WLU - Maximum number of ATM - Delay of ATM or WLU	- Maximum number of WLU per unit of time - Maximum number of ATM per unit of time	- Period of time - Period of time
	Quality of service	- Substitution of air services by adequate surface services	- Average delay per ATM (WLU) - Percent of substituted flights	- Total number of ATM or WLU per period of time - Total number of shot haul flights per period of time
	Integrated service			
Economic	*Profitability*	- Operating profits	- Average earnings per WLU	- Total WLU per period of time
Social	*Labour productivity*	- Output per employee	- Average number of WLU or ATM per employee	- Total number of employees per period of time
Environmental	*Energy inefficiency*	- Energy consumption for airport operation	- Average quantity of energy per WLU	- Total WLU per period of time
	Noise inefficiency	- Generation of long-term noise level	- Total area determined by given long-term noise level - L_{eq}	- Total number of ATM per period of time
	Air pollution inefficiency	- Emission of air pollutants by polluting events	Average quantity of air pollution per LTO cycle	- Total number of LTO cycles per period of time
	Waste inefficiency	- Generation of waste	- Average quantity of waste per WLU	- Total WLU per period of time
	Land use inefficiency	- Land taken for airport infrastructure and its utilisation	- Number of WLU carried out per unit of land	- Total surface of land taken

WLU Workload Unit; ATM Air Traffic Movement (arrival or departure); LTO Landing/Take-Off

Table 3A. The Indicator System for Air Traffic Management/Air Traffic Control (ATM/ATC)

Dimension of performance	Indicator	Explanation	Measure dependent variable	Independent variable
Operational	*Demand*	- Number of flights	- Number of controlled flights per period of time	- Period of time
	Capacity	- The maximum number of flights	- Maximum number of controlled flights per unit of time	- Period of time
	Safety	- Perceived risk of air traffic accident	- Average number of aircraft accidents or near midair collisions per flight	- Total number of flights per period of time
	Punctuality of serviceEconomic	- Traffic (flights) not delayed due to ATM/ATC restrictions - ATM/ATC delays	- Percent of non-delayed flights - Average delay per delayed flight	- Total number of flights per period of time - Total number of flights per period of time
Environmental	*Cost efficiency*	- Operating cost of ATM services	- Average cost per controlled flight	- Total number of flights per period of time
	Labour productivity	- Output per employee	- Average number of controlled flights per employee	- Total number of employees per period of time
	Energy efficiency	- Extra energy (fuel) consumption	- Average extra fuel consumed per flight	- Total number of flights per period of time
	Air pollution efficiency	- Extra air pollution	- Average extra emission of pollutants per flight	- Total number of flights per period of time

Table 4A. The Indicator System for Airlines

Dimension of performance	Indicator	Explanation	Measure—dependent variable	Independent variable
Operational	*Airline size*	- Total transport work carried out	- Volume of output—RTK/RTM—per period of time	- Period of time
		- Number of passengers served	- Number of passengers per period of time	- Period of time
		- Volume of freight transported	- Volume of freight per period of time	- Period of time
	Load factor	- Utilisation of available capacity	- RTK/RTM or ATK/ATM	- Total ATK/ATM per period of time
	Operational punctuality	- On-time flights	- Percent of on-time flights	- Total number of flights per period of time
		- Length of delays	- Average delay per flight	- Total number of flights per period of time
	Unreliability of service	- Cancelled (or diverted) flights	- Percent of cancelled (or diverted) flights	- Total number of flights per period of time
	Safety	- Risk of aircraft accident/incident	- Average number of aircraft accidents or incidents per RTK/RTM or FH	- Total RTK/RTM or FH per period of time
Economic	*Profitability*	- Operating profits	- Average earnings per RTK/RTM	- Total RTK/RTM per period of time
	Labour productivity	- Output per employee	- Average number of RTK/RTM per employee	- Total number of employees per period of time
Environmental	*Energy efficiency*	- Energy (fuel) consumption	- Average fuel consumption per RTK/RTM, D, or FH	- Total RTK/RTM, D, or FH per period of time
	Air pollution efficiency	- Emission of air pollutants	- Average air pollution per RTK/RTM, D or FH	- Total RTK/RTM, D, or FH per period of time
	Noise efficiency	- Use of aircraft of Stage 3 and 4 in the fleet	- Percent of aircraft of Stage 3 and 4 type in the fleet	- Total number of aircraft in the fleet per period of time
	Waste efficiency	- Generation of in-flight waste	- Average quantity of in-flight waste per RTK/RTM	- Total RTK/RTM per period of time

RTK/RTM Revenue Ton-Kilometre or Revenue Ton-Mile;; ATK/ATM Available Ton-Kilometre or Available Ton-Mile; D Distance flown; FH Flying Hours

Table 5A. The Indicator System for Aerospace Manufacturers

Dimension of performance	Indicator	Explanation	Measure—dependent variable	Independent variable
Operational	*Innovations of aircraft*	- New aircraft in terms of technical productivity and cost efficiency	- Average technical productivity per aircraft - Average cost per unit of capacity–ASK/ASM	- Period of time - Aircraft capacity seats
	Innovations of ATM/ATC and airport facilities and equipment	- New ATM/ATC and airport facilities and aircraft	- Cumulative aircraft position error - Capacity of airport facilities and equipment	- Period of time - Period of time
	Reliability of structures	- Failures of the system components	- Average number of failures per unit of time	- Total operating time
Economic	*Profitability*	- Operating profits	- Average earnings per unit sold	- Total number of units sold per period of time
	Labour productivity	- Output per employee	- Average number of units produced per employee	- Total number of employees per period
Environmental	*Energy efficiency*	- Reduction of fuel consumption of new engines and aircraft	- Percent of reduction of fuel consumption per unit of engine power or aircraft operation weight	- Total engine power or aircraft operating weight
	Air pollution efficiency	- Reduction of air pollution of newengines and aircraft	- Percent of reduction of air pollution per unit of engine power or aircraft operating weight	- Total engine power or aircraft operating weight
	Noise efficiency	- Reduction of noise of new engines and aircraft	- Percent of reduction of noise per unit of engine power or aircraft operating weight	- Total engine power or aircraft operating weight

ASK/ASM Aircraft Seat Kilometre or Aircraft Seat Mile

Table 6A. The Indicator System for Local Community Members

Dimension of performance	Indicator	Explanation	Measure—dependent variable	Independent variable
Social	*Social welfare*	- Relationship between employment by ATS and total local employment	- Proportion of ATS employees in total local employment	- Total number of local employees per period of time
Environmental	*Noise disturbance*	- Annoyance of local people by noise	- Total number of complaints to noise by community people per period of time	- Total number of ATM per period of time
			- Average number of complaints per ATM	
	Air pollution	- Exposure of local people to air pollution generated by ATS	- Proportion of ATS air pollution in total air pollution in the community	- Total number of ATM per period of time - Total air pollution in the region per period of time
	Safety	- Perceived risk of death or injury and/or damage or loss of community property due to aircraft accident	- Average number of air accidents per ATM	- Total number of ATM per period of time

ATM Air Transport Movement (arrival or departure); ATS Air Transport System

Table 7A. The Indicator System for Local and Central Government

Dimension of performance	Indicator	Explanation	Measure—dependent variable	Independent variable
Economic	*Economic welfare*	- Contribution of ATS to GDP	- Proportion of GDP by ATS in total GDP	- Total GDP per period of time
	Internalisation and globalisation	- Use of ATS for long-distance business (trade and trips) and tourism	- Proportion of business trips (or trade) by ATS by total number of long-distance business trips (or total trade)	- Total number of long-distance business trips (total trade) per period of time
			- Proportion of tourist trips by ATS in total number of long-distance tourist trips	- Total number of long-distance tourist trips per period of time
	Externalities	- Total cost of the environmental damage (noise, air pollution, congestion, accidents and incidents)	- Average expenses per period of time	- Period of time
Social	*Overall social welfare*	- Total direct and indirect employment	- Total number of the ATS employees per period of time	- Period of time
Environmental	*Global energy efficiency*	- Total energy consumption by ATS	- Average energy consumption per RTK/RTM	- Total RTK/RTM per period of time
	Global noise disturbance	- Peoples exposure to ATS noise in the region or country	- Total number of exposed people to ATS noise per period of time	- Period of time
	Global air pollution	- Global air pollution in the region or country	- Total ATS air pollution per period of time	- Period of time
	Global land use	- Land used for regional and/or national ATS infrastructure	- Area of land for ATS infrastructure per RTK/RTM	- Total RTK/RTM per period of time

RTK/RTM Revenue Passenger Kilometre or Revenue Passenger Mile; ATS Air Transport System

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