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AIRLINE SYSTEMS SIMULATION ——A COMPUTER SYSTEM

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Summary

ALSS (Airline Systems Simulation) is a computer program which simulates an operation of an airline company. Taking into account of passenger growth, airline networks, utilization of mixed fleet and competition with surface transport means, we can calculate an overall profit of an airline company, the number of carried passengers, the optimum number of flight service on each route and the optimum selection of the type of aircraft.

Introduction

Selection of an adequate aircraft on each route is one of the most important desision-making business for top managements of an airline company. It depends upon the characteristics of route (passenger density, airport facilities, weather on the route, etc.)

Therefore, for the purpose of investigating specifications of the suitable aircraft, for an airline comany, it will be necessary to simulate the overall management of airline business. Lockhead [1] and Douglas [2] have developed a system, simulating an airline operation.

Monte Carlo method is extensively adopted for this kind of simulation, however it may require a large capability of computer. Consequently, it may take a lot of money and of time to accomplish a complete simulation of airline business, even now when the electronic computers have achieved a great progress.

In the present study, we have assumed:

(1) Cost being calculated by ATA formula [3]: Direct operating cost and indirect operating cost are calculated by the new ATA formula of 1965-1966.

(2) Simultaneous operation of mixed fleet on a net work: Usually air line company operates a various types of airplanes on her net work service routes. We can determine the optimum type of airplane adequate for the operation on each route.

(3) A mathematical model of passenger's behavior is introduced, representing passenger's selection of suitable transport means.

(4) Utilization of aircraft in a year is assumed by the ATA formula.

(5) An introduction of evaluation function to an objective function of airline operation, reflecting the policy of top management.

ALSS Main Program

The ALSS main program is indicated in Fig. 1. As imputs, we introduce:

(1) The net work characteristics: potential number of air passengers, field length of airport, stage length.

(2) Direct operating cost and indirect operating cost are calculated by the way of ATA formula revised in 1965-1966.

(3) Assuming the passenger's behavier, number of passengers carried on each route is obtained.

(4) Profit = retail sales − cost on each route, is worked out.

(5) Taking into account of the potential uncarried passengers who have transfers to the surface transportation means from air, a new objective function is introduced.

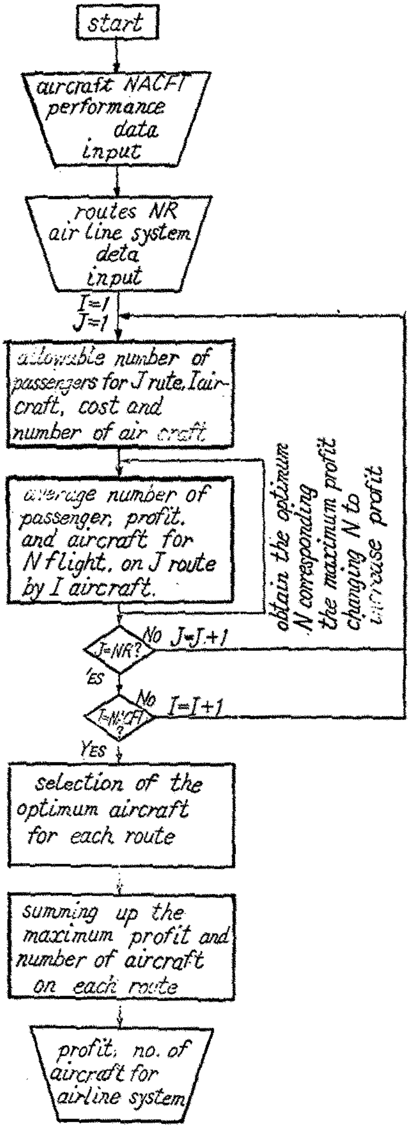
start
aircraft NACFT performance data input
routes NR air line system deta input
I=1
J=1
allowable number of passengers for J rute, I aircraft, cost and number of air craft
average number of passenger, profit, and aircraft for N flight, on J route by I aircraft.
obtain the optimum N corresponding the maximum profit changing N to increase profit
J=NR?
No J=J+1
YES
I=NACFT?
No I=I+1
YES
selection of the optimum aircraft for each route
summing up the maximum profit and number of aircraft on each route
profit, no. of aircraft for airline system

Fig. 1.

(6) Optimum frequency of service corresponding the maximum value of the objective function is determined. From the ATA utilization formula of aircraft, we can calculate the necessary number of aircraft to be able servicing the optimum frequency of flight on each route.

(7) Summing up the profit and number of aircraft, we can obtain the gross profit and total number of aircraft and also most suitable type of airplane can be determined.

A Mathematicl Model of Passenger's Behavior

Passenger's increasing characteristics according to the frequency of flight service may be considered in the following way. In Fig. 2, D

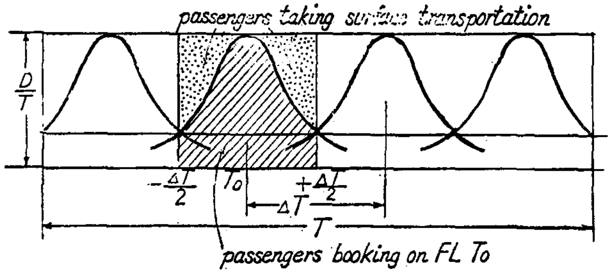

Fig. 2.

stands for the daily potential air passenger on a particular route and the shaded area corresponds the number of passengers who are willing to embark on the flight departing at the time T_0. Here we have assumed that the need of travel for a particular person occurs uniformly in working hours of a day. We can easily modify the program to include the time variation of potential demand for air travel, if reliable statistics are available. As is indicated in the figure, we assumed that the probability of taking a flight which is scheduled to depart at time T_0,

$$P(T_0/t)=\frac{1}{\sqrt{2\pi}\,\sigma}\exp\frac{(t-T_0)^2}{2\sigma^2} \tag{1}$$

where t stands the most appropriate schedule for him. Therefore, the number of passengers who would like to book on the flight departing at T_0, yields

$$(2) \qquad P_b=\int_{T_0-\frac{\Delta T}{2}}^{T_0+\frac{\Delta T}{2}} \frac{D}{T}P(T_0/t)dt$$

$D\Delta T/T-P_b$ corresponds to the passengers who are forced to take other transportation means, like automobile or railway. Because there is the limit S of payload of an aircraft, P_b does not always coincide with the passengers carried on the flight T_0. Therefore, P_b-S means the passengers who can not embark on the flght T_0 because of full booking. Fig. 3 indicates the ratio $P_b/D\ \Delta T/T$ in terms of frequency of daily service, we notice that the actualized ratio of potential air passengers

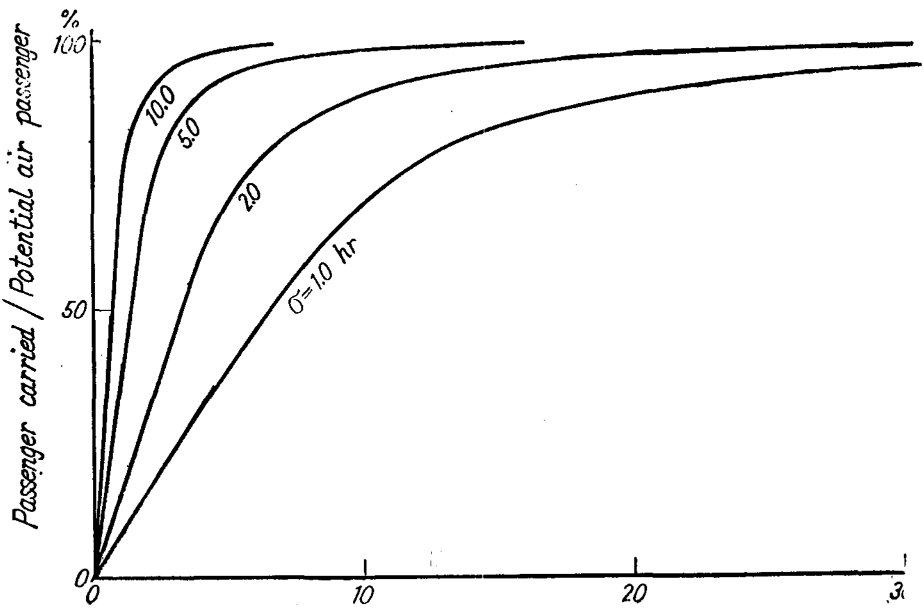

Fig. 3.

depends on σ representing the passenger's characteristics.

Objective Function of Air Line Business

The profit of airline company is defined as

$$P=ax-c, \tag{3}$$

where a is transportation fare and c is operating cost while x is, a random variable representing the number of carried passengers. Consequently ax stands for revenue, and the profit is represented as (1).

Using the statistics of carried passengers we find that the load factor, corresponding the maximum profit, is about 80—90%.

This does not represent the actual situation of airline companies. Their aim of operation is likely to achieve 50—60% in terms of load factor. However, it is rather difficult to evaluate the value of airline operation and almost impossible to ask the objectives or policy of managements. Considering the publicity of transportation business and rapid growth of passengers, the air line company should try to carry potential air passengers as much as possible.

Hence, we introduce a generalized profit which is defined as

$$P_G=ax-c-\alpha(D-x), \text{ if } D>x, \tag{4}$$

in place of (1), where α means a potential loss caused by missing one customer, and D is a potential air passenger. Therefore $D-x$ is expressing the number of passengers who transferred to the other air line or the other means of transportation.

We assumed

$$\alpha=1/2\,a, \tag{5}$$

in the following analysis, and find the way of operation that maximizes the generalized profit.

Model Airline Operation

Table 1 is an example of ALSS output, when it is applied to a model airline net work, as indicated in Fig. 4.

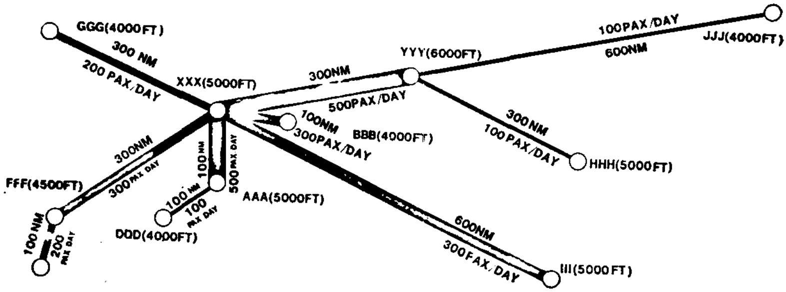

Fig. 4.

Number of passengers carried on each route, revenue income, number of flight, types of aircraft, optimum for each route, etc., obtained as outputs of ALSS.

We also investigated the appropiateness of the output of ALSS when it is applied to the all Japan domestic operation in the past. Table 2 indicates the outputs which are similar to Table 1.

Each of these figures indicate reasonable values when compared with the statistics of 1966.

European Continental Operation

ALSS is applied to simulate the all European airline operation. The leading 80 air routes (80 major sectors) are selected and prediction of air traffic in the summer of 1978 on each route is introduced as input of ALSS.

The necessary number of each aircraft composing the optimum fleet coresponding to the maximum generalized profit has been obtained.

They are as follows.

Table 1.

AIRLINE SYSTEM SIMULATION (ALSS)

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                ***ALSS1*** TR=5

            AIR LINE       HYPOTHETICAL AIRLINE    A
     (1)DAILY PROFIT          9766   (2)DAILY COST          31193   (3)GENERALIZED PROFIT        30246
        DAILY PAX.       1445      DAILY PAX.N.M.          498041    (4)AVERAGE LOAD FACTOR      0.6567
            (5)FLEET
                YX043       6.57

 (6)AAA-XXX   (7)DIST.=  100   (8)FARE=  13.17   (9)TSIGMA=  0.65   (10)DEMAND=   500   (11)SDDMND=  250   (12)ALTERNATE=  200
            (13)SHARE=1.000  (14)REVENUE RATE=1.000
                AIRPORT=AAA    FIELD LENGTH=  5000     ELEVATION=     0     TEMPERATURE DIFFERENCE FROM ISA= 15.0
                AIRPORT=XXX    FIELD LENGTH=  5500     ELEVATION=     0     TEMPERATURE DIFFERENCE FROM ISA= 15.0

                A/C      (15)TB      (16)COST(17)ALLOW.PAX(18)FREQ. (19)PROFIT  (20)SDPRFT  (21)PAX  (22)POB (23)AV.L/F (24)A/C REQ.(25)GEN.PRFT
            *   YX043     0.50         3786     50           4       -1136        475        202      201   0.503      0.863        190

   BBB-XXX    DIST.=  100      FARE=  13.17      TSIGMA=  0.65      DEMAND=   300      SDDMND=  150      ALTERNATE=  200
              SHARE=1.000      REVENUE RATE=1.000
                    -HBB       FIEL...        4000     ELEVATION=           TEMPERATURE ...
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1. PROFIT(i.e.REVENUE-COST) OF TOTAL SYSTEM(U.S.$) FOR OPTIMUM OPERATION.
2. DIRECT AND INDIRECT COST OF TOTAL SYSTEM, ACCORDING TO THE ATA STANDARD METHOD(U.S.$).
3. IMAGINARY PROFIT ASSUMING THE FARE TO BE 1.5 TIMES THE ACTUAL. OPERATION IS DEFINED TO BE OPTIMUM WHEN GENERALIZED PORFIT OF EACH ROUTE IS MAXIMUM, TO ACCOUNT FOR THE EFFECTS OF COMPETITION, PUBLIC SERVICES, POLICIES TO STIMULATE FURTHER GROWTH OF PASSENGER, etc. (U.S.$).
4. TOTAL NUMBER OF PASSENGERS DEVIDED BY TOTAL NUMBER OF AVAILABLE SEATS.
5. OPTIMUM FLEET COMPOSITION(NAME AND REQUIRED NUMBER OF AIRCRAFT).
6. ROUTE CONNECTING A PAIR OF AIRPORTS.
7. DISTANCE BETWEEN AIRPORTS ALONG THE AIR ROUTE(N.M.)
8. FARE CORRESPONDING TO AVERAGE U.S. DOMESTIC SERVICES. (U.S.$)
9. AVERAGE TIME DURATION FOR MOST OF PASSENGERS TO WAIT FOR FLIGHT INSTEAD OF CHANGING TO SURFACE TRANSPORTATIONS(HOUR)
10. DAILY POTENTIAL AIR PASSENGER DEMAND(TOTAL OF BOTH WAYS) DEFINED AS TOTAL NUMBER OF PASSENGER WILLING TO USE AIR TRANSPORTATION IF AVAILABLE AT HIS CONVENIENCE.
11. STANDARD DEVIATION OF POTENTIAL PASSENGER DEMAND INCLUDING EFFECTS OF DAILY AND SEASONAL VARIATIONS.
12. DISTANCE TO ALTERNATE AIRPORT(NM)
13. PASSENGER SHARE OF THE AIRLINE AS COMPARED WITH COMPETING AIRLINES ON THE SAME ROUTE.
14. ACTUAL REVENUE DEVIDED BY(FARE×NO. OF PASSENGER CARRIED)
15. BLOCK TIME(HOUR)
16. TOTAL DAILY COST FOR EACH ROUTE(U.S. $.)
17. ALLOWABLE NO. OF PASSENGER TO BE CARRIED FOR EACH FLIGHT.
18. OPTIMUM FREQUENCY OF SERVICE(ONE WAY) FOR GIVEN AIRCRAFT AND DEMAND.
19. NET DAILY PROFIT FOR EACH ROUTE(REVENUE-COST). MINUS SIGN MEANS THAT OPERATIONS ARE CONTINUED FOR PUBLIC SERVICES OR IN VIEW OF FUTURE GROWTH OF PASSENGERS.
20. STANDARD DEVIATION OF PROFIT.
21. DAILY NUMBER OF PASSENGER APPEARING AT SALES COUNTERS(BOTH WAYS).
22. DAILY NUMBER OF PASSENGERS CARRIED BY AIR(BOTH WAYS).
23. AVERAGE LOAD FACTOR FOR OPTIMUM OPERATION.
24. NUMBER OF AIRCRAFT REQUIRED FOR OPERATION OF EACH ROUTE.
25. GENERALIZED PROFIT FOR EACH ROUTE. OPERATION IS PLANNED TO MAXIMIZE THIS, AND IF MAXIMIZED GENERALIZED PROFIT IS NEGATIVE, OPERATION IS GIVEN UP.

Table 2.

ALSS1 TR=5

AIR LINE: JAPAN65C

DAILY PROFIT 45501169 DAILY COST 137083467 GENERALIZED PROFIT 136793488

DAILY PAX. 21582 DAILY PAX.N.M. 5743835

FLEET

B727	12.83
YS-11	22.41
F.27	64.47

SPK-HKD* DIST.= 97 FARE= 4677 TSIGMA= 1.07 DEMAND= 308 SDDMND= 154 ALTERNATE= 200

RUNWAY LENGTH= 3940

	A/C	TB	COST	ALLOW.PAX	FREQ.	PROFIT	SDPRFT	PAX	POB	AV.L/F	A/C REQ.	GEN.PRFT
	B727	0.61	0	51	0	0	0	0	0	0.000	0.000	0
	YS-11	0.66	974922	60	3	-261088	150247	153	153	0.424	0.714	95829
*	F.27	0.71	1008160	40	4	-125245	151282	194	189	0.590	0.986	316213

SPK-OBH* DIST.= 89 FARE= 4511 TSIGMA= 0.87 DEMAND= 375 SDDMND= 188 ALTERNATE= 200

RUNWAY LENGTH= 3940

	A/C	TB	COST	ALLOW.PAX	FREQ.	PROFIT	SDPRFT	PAX	POB	AV.L/F	A/C REQ.	GEN.PRFT
	B727	0.60	0	51	0	0	0	0	0	0.000	0.000	0
	YS-11	0.62	953051	60	3	-266857	144449	152	152	0.423	0.699	76240
*	F.27	0.68	1230831	40	5	-181744	161713	238	233	0.581	1.205	342799

SPK-KUH* DIST.= 145 FARE= 5819 TSIGMA= 2.10 DEMAND= 0 SDDMND= 0 ALTERNATE= 200

RUNWAY LENGTH= 3940

	A/C	TB	COST	ALLOW.PAX	FREQ.	PROFIT	SDPRFT	PAX	POB	AV.L/F	A/C REQ.	GEN.PRFT
*	B727	0.71	0	51	0	0	0	0	0	0.000	0.000	0
	YS-11	0.87	0	60	0	0	0	0	0	0.000	0.000	0
	F.27	0.93	0	40	0	0	0	0	0	0.000	0.000	0

OBH-KUH* DIST.= 43 FARE= 3226 TSIGMA= 0.16 DEMAND= 1116 SDDMND= 558 ALTERNATE= 200

RUNWAY LENGTH= 3940

	A/C	TB	COST	ALLOW.PAX	FREQ.	PROFIT	SDPRFT	PAX	POB	AV.L/F	A/C REQ.	GEN.PRFT
*	B727	0.50	0	51	0	0	0	0	0	0.000	0.000	[illegible]
	YS-11	0.41	0	60	0	0	0	0	0	0.000	0.000	0
	[illegible] 27	0.47	0	40	0	0	0	0	0	0.000	0.000	0

117 FARE= 5[illegible] DEMAND= 112 ALTERNATE= 2[illegible]

[illegible]TH= 3940

SDPRFT [illegible]

prospective aircraft	no. of passenger	no. of aircraft
Y X 097	30	11
098	50	0
099	75	2
100	100	8
101	150	17
102	200	50
103	250	74
104	300	17

The result shows a considerable coincidence with the conclusion obtained previously by a separate analysis [4].

Conclusion and Remarks

A computer program is developed to simulate the overall operation of airline network. In the course of development, a mathematical model representing passenger's behavior and a new objective function reflecting the airline policy are introduced. For the cost estimation the new ATA formula are extensively applied.

We can determine the most profitable selection of aircraft on each route and the optimum number of flight as well as the necessary number of airplanes. The program will be utilized for the purpose of operations research for an aircraft manufacturer and at the same time it will become a useful tool of decision making for an airline company who is looking forward to introduce a new type of aeroplane. It can also furnish the optimum schedule of flight service when the potential passengers on a route is known.

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