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AIRLINE FLIGHT SCHEDULING

USING LINEAR PROGRAMMING

by

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SUMMARY

Fleet assignment and scheduling are two major, and strongly related, steps in an Airline's decision-making process of determining the supply of air transportation services. Due to a rapidly and unpredictably changing environment, airline schedules can currently no longer be prepared a long time ahead of implementation. These changes increase the importance of flexible computer- based planning systems. Fast algorithms need to be developed which can provide quick and accurate answers to identified sub-problems in the overall scheduling process.

This report briefly summarizes a research effort to develop a program for one such sub-problem, namely the determination of the best departure times for the aircraft, given set of flights and the distribution of passenger demand throughout the day. The main focus of this report is on the linear programming formulation. However, some preliminary scheduling results for a prototype network are included as well.

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List of Contents

NOMENCLATURE

fr[i] : flight frequency of flight route **i**,
i : flight route number,
j : aircraft number per type,
$\mathbf{j}_i$: aircraft number **j** of type **i**,
k : airport number,
l : slot number,
plac[i][j] : placement of aircraft type **i**, with number **j**, at initial scheduling period on initial airport of flight route **i**,
score[i][l] : score of slot **l** of flight route **i**,
apn[i] : number of airports served on flight route **i**,
$\mathbf{AC}_i$: set of aircraft of the type used on flight route **i**,
AVAI[i] : availability of aircraft type **i**, in network.
CAP[i] : capacity of the aircraft type that is used on flight route **i**,
DEM[i][k][l] : market demand for flight route **i**, on flight leg number **k**, at slot time **l**,
FL : flight leg link variables,
MU[i] : maximum utilization per scheduling period of aircraft types used on flight route **i**,
NET : set of flight routes in network.
RC[$\mathbf{k}_i$] : airport (runway) capacity of airport number k on flight route **i**,
RT[i] : route flight time of flight route **i**,
SL : stay leg link variable,
SLOT[i] : number of slots at initial airport of flight route **i**,
S : set of slots in network.

DEFINITION

Flight : specified by its itinerary (example : AAA-BBB-CCC), its departure and arrival time at every stopping airport, and the aircraft type used.
Flight Leg : non stop component of a flight.

I. INTRODUCTION

Commonly, scheduling is needed to solve problems with a limited number of resources in order to achieve a maximum output or profit (minimum cost and maximum revenue), or minimize total production time.

In flight operations, some areas that require good scheduling are airline operation (e.g. crew scheduling, and maintenance scheduling) and air traffic control (aircraft flow control).

In aircraft operations, the scheduling problem is aimed at obtaining the best departure time that gives maximum profit (but also considers passenger objectives) or to maximize revenue and minimize passenger dissatisfaction (minimum spill and maximum transported demand, minimum travel time). The scheduling of service production (flights) becomes very important because the product (flight service) cannot be stored. Due to rapid changes in aircraft competition and operation conditions, computer-based scheduling can be a very significant tool.

Some recent papers in air transportation have described airline scheduling problems, such as in Rubbrecht [Ref. 1], Soumis et al. [Ref. 2 and Ref. 3]. Various methods have been proposed to solve scheduling problems. Among those methods, dynamic programming is widely used. In this paper, briefly, the implementation of a linear programming method will be described, with passenger satisfaction as the objective function. The scheduling here is a step following the fleet assignment stage that has been performed previously.

Terminology

By using a graphical method, the problem will be transformed into a linear program, and subsequently the problem is solved by CPLEX (a Linear Programming Solver that is available on the CONVEX, TU Delft Mainframe).

In terms of a graphical approach, a network is defined as an interaction of some nodes, and the activity between nodes, which is called an arc. A node can be an origin, intermediate or destination airport. All arcs are directed links, so that the graphical model is a directed network.

Here, a ***flight*** is specified by its itinerary (example : AAA-BBB-CCC), its departure and arrival time at every stopping airport, and the aircraft type used. In this context, a node physically represents an airport, and an arc represents a production process or flight between two nodes (non stop component) of a flight. A route is composed of flight-legs that are not exclusively belonging to only one flight.

Some scheduling parameters that are related to nodes and arcs are described in the following table, Table 1.

Table 1. Parameter Related to Node and Arc

Related to	Leg (arc or link)	Node
Parameter	Aircraft Type, Travel Time, Travel Fuel Consumption, Travel Cost, Demand (Potential), Ticket Price, Revenue, Capacity, etc.	Origin Airport, Destination Airport, Departure Time, Arrival Time, Turn Around Time, Landing Fees, etc.

Problem:

Scheduling problems become highly complex if all aspects, including competition should be considered in the analysis. Therefore in this work, the airline scheduling is restricted to finding the best departure time of every flight from a set of "candidate" departure-times (slots), to which a priori a certain "score" has been assigned. This work is an extended step to fleet assignment. The competition problem is assumed to be included in the determination of the score value for each slot.

An airline has to determine its aircraft operation schedule (fleet assignment has been done) to satisfy the passenger time conveniences (minimum adjusting time and minimum travel time). Because the flight time is assumed to be fixed, the passenger objective is assumed to be included in the scoring consideration (also *competitiveness with others airline and other transportation modes*).

Briefly the problem can be summarized as follows :

0. Find the best departure time of every flight, that gives the higher total score,
1. given the objective score of all possible departing times of every flight (at the origin airport),
2. given the available number of aircraft of each type,
3. given the frequency per flight, and
4. given the capacity of each airport to be served.

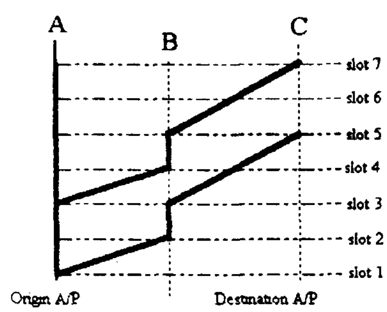
The number of aircraft and the number of flights are results from the fleet assignment phase [Ref. 5 and Appendix D].

II. APPROACHES TO THE PROBLEM

2.1 Candidate Flight

One of the most important aspects in scheduling is allocating a departure time. A flight can be performed any time during a scheduling period, however in this model an aircraft does not return to the airport (initial airport), at the end of scheduling period. The number of candidate slots is decided by entering the time difference between two candidate slots. Candidate means that the slot could be used by aircraft to perform a take-off (or landing in a destination airport), or to remain at the ground. Based on this approach, the departing and arrival time of a flight is determined from the slot number actually used. For example, if the time period of a candidate slot is 10 minutes and the scheduling period is started at 4.00 am, slot number 24 is at 7.50 am (take off slot is started from number one at 4.00 am).

It is recommended to make the period of candidate flights not fixed, and times of candidate flight can be entered as an input (this consideration has the background that the time difference depends on airport capacity and aircraft type).



Turn Around Time 1time slot

flight time A-B = 1time slot

flight time B-C = 2 time slot

Fig. 1 Multistop Flight

2.2 Graphical Representation of An Airline Network

Generally, a flight can be divided into two types, non-stop flights and multistop flights. The non-stop flights have different characteristics from multistop flights, but in a graphical method all characteristics of non-stop flights are present in a multistop flight. In a multistop flight, the take off and landing activity is not just in the origin and destination airport of a flight route, but also in an intermediate airport. The flow of aircraft in a multistop flight can be represented as in Figure 1.

2.3 Passenger Problem

Soumis [Ref. 2] has mentioned that the two main factors that rule the passenger choice are attractiveness and availability. The attractiveness factor is related to passenger dissatisfaction, and the availability factor is related to passenger over-capacity (spill).

Components of attractiveness factor are time difference between passenger desired departure time and scheduled departure time, time duration of route (number of stops and/or connections), convenience offered on the route (meals, wide body aircraft, service, etc.). However, the availability of a route is dependent on the aircraft capacity and the demand.

In this paper, the availability factor is considered. Therefore, it is assumed that the passenger problem (attractiveness and availability) is represented into a score for each slot of each route.

III. MATHEMATICAL FORMULATION

The method that will be used to solve the problem is linear programming. The generic format of linear programming is constructed from variables, constraints, and an objective function.

3.1 Variables

In this mathematical model of a network, the variables are flight leg links and stay links. A flight leg links is an arc that represents a flight between two connected airports (Origin-Destination, Origin-Intermediate, Intermediate-Intermediate, or Intermediate-Destination). On the other hand, a stay link is a link that represents turn around activity at an intermediate airport or keeping an aircraft at an origin airport.

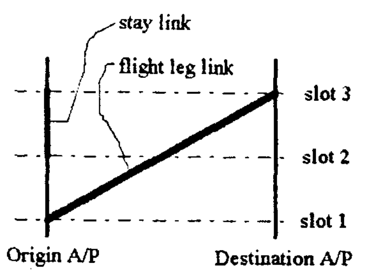


Fig. 2 Flight Leg and Stay Link

3.1.1 Flight Link Variables

A flight leg link can be identified from the flight route number, aircraft number (per type), initial airport, and number of slot. So that, if i is flight route number, j_i is aircraft number j of type i (type of aircraft is related to the number of flight route, it could be that a type of aircraft is used on more than one flight), the flight leg link is given by

$$FL[i][j_i][k][l]$$
$$1 \leq k < apn[i], \text{ initial airport of flight leg}$$
$$i \in NET,\ j_i \in AC_i, \text{ and } l \in S.$$
$$apn[i] \text{ is number of airport that served by flight i}$$

Related to a flight leg link variable is a Flight Slot Difference. Flight slot difference is the number of slots corresponding to the flight time of that flight leg. The flight slot difference is denoted by

$$FS[i][j_i][k], \text{ and is constant.}$$

3.1.2 Stay Link Variables

An aircraft, actually is placed on one of the airports in the airline network. If an aircraft is not used to produce service (doesn't fly), that aircraft will stay at the airport. Because a network represents the aircraft flow, the aircraft flow activities at airport are modeled into stay links. A stay link can be identified from the airport number (i), aircraft type (j), aircraft number at j type (j_i), and the initial slot number. In this graphical model, the stay link only occurs at origin and destination airports. A Stay link is denoted by

$$SL[i][j][j_i][l]$$
$$i \in NET,\ j \in ACT,\ j_i \in AC_i, \text{ and } l \in S.$$

Note that l = 0, means that an aircraft is placed in airport i at the initial scheduling period. The value of that slot (l=0) is one or zero. The one means that the aircraft type[i] number j_i is placed on airport route i. The value of this variable is an input.

3.2 Objective Function

The scheduling process is divides into two parts. The first part is to determine the value of score for each slot (departing slot) of all origin airport, related to flight routes. Because the value of score is determine-d separately, it could be that the result is very subjective. To increase the objectivity, some considerations have to be taken into acount in the determination of the score values.

Considerations that can be included are passenger spill and over capacity (the value of score is related to the difference between aircraft capacity and market demand), or total flight time. Because the total flight time is fixed, in this model, the scoring only depends on passenger spill and over capacity. The score is maximum difference of demand and aircraft capacity of every flight leg at flight route. In this prototype model, the time-of-day demand is generated by the random procedure and consists of two peaks during a day [Appendix A].

Mathematically the score can be written as

score[i][l] = 1/max{abs[DEM[i][k][l] - CAP[i]]}

$1 \leq k <$ apn[i], initial airport of flight leg
abs : absolute value
max : maximum

The value of score for the case study is presented in appendix B.
The scoring approach can not be avoided since LP can not accept a formulation MAX of MAX (maximax).

The objective function of this model is to maximize the total score of all realized flights The objective function can be formulated as

$$Max \sum_{i \in NET} \sum_{l \in S} \sum_{j_i \in AC_i} score[i][l] \times FL[i][j_i][1][l] \qquad (1)$$

3.3 Constraints

In the airline operations airlines have some operational limitations. Those involve the number of aircraft belonging to the airline (fixed number per type of aircraft), the flight frequencies that must be served (bounded per flight route), maximum utilization (per aircraft), maximum capacity of runway, etc. In this model the connectivity of a flight leg to one or more other flight legs (belonging to the other flight route) has not been implemented yet. For example in the case study, the airport BBB is not connected to airport DDD with a flight route. So if the passengers want to go to DDD from BBB, they must stop over at CCC to change the flight (from flight route AAA-BBB-CCC, use BBB-CCC leg, and continue to flight route AAA-CCC-DDD, use CCC-DDD leg). If the arrival time of flight AAA-BBB-CCC at airport CCC is earlier than the departure time of leg CCC-DDD (of flight route AAA-CCC-DDD), with not too long a time difference, the two legs (BBB-CCC and CCC-DDD) are connected.

3.3.1 Placement of an Aircraft

At the starting of a scheduling period, the aircraft is placed into some airport. If an aircraft type i, with number j (type i), is placed at the initial airport of flight route i, the value of placement parameter is

$$plac[i][j] = 1, \qquad (2.a)$$

Otherwise, if the aircraft is not placed at the airport

$$plac[i][j] = 0. \qquad (2.b)$$

Placement of an aircraft is not a constraint, but is a right hand side of an aircraft flow conservation constraint.

3.3.2 Aircraft Flow Conservation in Origin Airport

In this approach, the aircraft activities in an airport are take-off (departing) and landing (arrival). An aircraft will be ready to make a departure (with carrying passengers) at T (slot time) if that aircraft has arrived before T-TS, (TS is turn around slot time). The following figure is a graphical presentation of the conservation flow at airport B at slot time number 5.

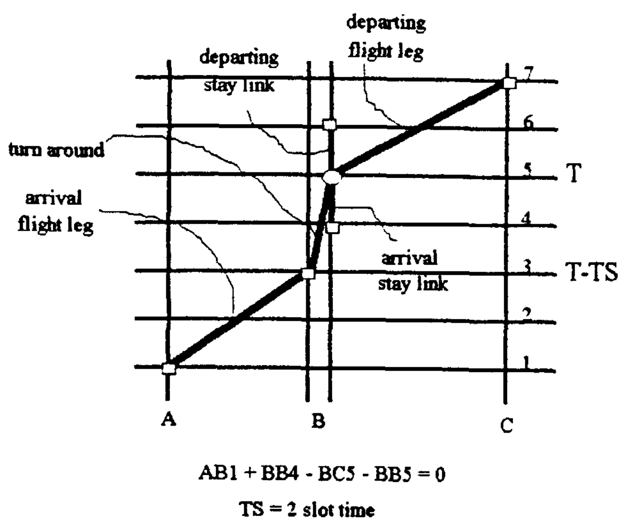


Fig. 3 Aircraft Flow Conservation At Airport B

Explanation of Figure 3:

B is an origin or a destination airport. AB1 is a flight leg from airport A to airport B, that involves a take-off at airport A at slot time number 1 and arrival at B at slot time number 3. BB4 is a stay leg at airport B that is initiated at slot time number 4 and is finished at slot time number 5. BC5 is a flight leg from airport B to airport C, that involves s take-off at airport B at slot time number 5 and arrival at C at slot time number 7. BB5 is a stay leg at airport B that is initiated at slot time number 5 and is finished at slot time number 6. AB1 and BC5 must use the same aircraft type.

For a slot number more than one and less or equal than l_s+TS (l_s is largest possible slot number at an airport for which no aircraft can arrive (landing) at that airport) (TS[i][1] is turn around slot time, a number slot time that equivalent to the turn around time, of aircraft type i at airport at origin airport on route i, *a route related to an aircraft type*), the conservation model becomes

$$-FL[i][j_i][1][l+1] + SL[i][j_i][l+1] - SL[i][j_i][l] = 0 \qquad (3.a)$$

$$2 \leq l \leq l_s + TS[i][1]$$

In particular, for l=1,

$$-FL[i][j_i][1][l+1] - SL[i][j][j_i][l+1] = plac[i][j] \qquad (3.b)$$

If the slot number is more than l_s, and less than l_f (l_f is largest possible slot number to perform a take-off, such that the landing at destination airport is still during the scheduling period), the conservation of aircraft flow becomes

$$FL[\neg i][j_{\neg i}][1][l_t - TS[\neg i][1]] - FL[i][j_i][1][l_t] + SL[i][j][j_i][l_t - 1] - SL[i][j][j_i][l_t] = 0 \qquad (3.c)$$

$$l_s < l_t \leq l_f,$$

aircraft type i = aircraft type ¬i, and $j_{\neg i} = j_i$,

aircraft j_i take off at slot l_t, aircraft $j_{\neg i}$ landing at slot l_t-TS[¬i][1]

For the slot larger than l_f, the conservation of aircraft flow becomes

$$FL[[\neg i][j_{\neg i}][1][l - TS[\neg i][1]] + SL[i][j][j_i][l-1] - SL[i][j][j_i][l] = 0 \qquad (3.d)$$

$$l_f < l \leq l_n,$$

aircraft type i = aircraft type ¬i, and $j_{\neg i} = j_i$

aircraft $j_{\neg i}$ landing at slot l_t-TS[¬i][1]

l_n is largest permitted slot number in scheduling period

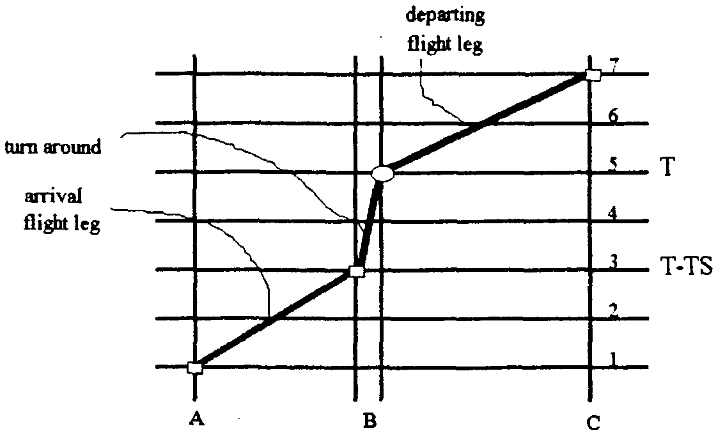
3.3.3 Aircraft flow conservation in Intermediate Airport

An aircraft is not allowed to stay at an intermediate airport, so that the conservation flow equation becomes

$$FL[i][j_i][k][l_k] - FL[i][j_i][k+1][l_{k+1}] = 0 \qquad (4)$$

$$l_{k+1} = l_k + \Delta FS[i][j_i][k] + \Delta TS[i][j_i][k+1]$$

The following figure is a graphical presentation of aircraft flow conservation at an intermediate airport of a flight route with itinirery A-B-C.



AB1 - BC5 = 0
TS = 2 slot time, B is an intermediate airport

Fig. 4 Aircraft Flow Conservation At An Intermediate Airport

3.3.4 Flight Route Frequency Constraints

The number of frequencies is a route parameter. In airline operations (short range planning) the number of flights in a route must be more than or equal the minimum flight frequency. But, if we work with a problem based on the fleet assignment, the frequency is fixed. The frequency, in this context, is an inequality constraint

$$\sum_{l=1}^{SLOT[i]} FL[i][j][1][l] \leq fr[i] \tag{5}$$

for i ∈ NET, j ∈ AVAI[i], and $fr[i]$: frequency of flight route i.

3.3.3 Utilization Constraints

The number of flight hours per aircraft is usually limited. The operational time limitation depends on the aircraft type. The utilization limitation is formulated as:

$$\sum_{l=1}^{SLOT[i]} FL[i][j][1][l]*RT[i] \leq MU[i] \tag{6}$$

for i ∈ NET, j ∈ AVAI[i], and
$RT[i]$: flight time in route i,
$MU[i]$: maximum utilization of aircraft type i in scheduling period.

3.3.4 Airport Capacity Constraints

The number of runways available in an airport defines the capacity to takeoff and land on the same time. For airports that have two runways, both take off and landing can be done at the same time. In this paper, the number of takeoffs and landings depends on airport capacity. The value of airport capacity is thus indicative of the number of runways. If runway capacity equals two, this means that the airport has two runways (not

necessary for landing or takeoff).
The airport capacity constraint [number of departing runways] can be formulated into

$$\sum_{i \in NET} \sum_{j \in AC_i} \{FL[i][j][k][l] - FL[\neg i][j_{\neg i}][k_i][l]\} \leq RC\,[k_i] \quad (7)$$

The first part of equation (7) indicates the take-off aircraft and the other indicates the landing aircraft. This equation means, maximum number of aircraft that takeoff and land in airport AP[i][k_i] is not more than the capacity of airport *RC*[k_i].

IV. CASE STUDY

4.1 Airline Network

Seven cases have been studied. All of these cases have the same network form, and operate the same number of aircraft (of each type). The airlines network is illustrated in the following figure.

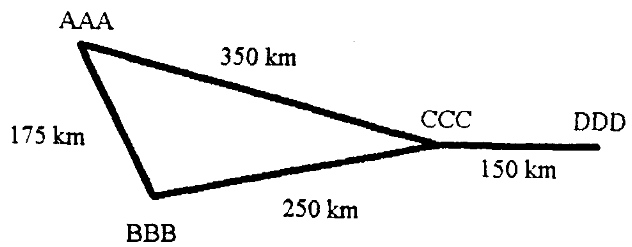


Fig. 5 Airline Network

The airline serves four airports with eight flight legs. Those airport are connected by four round-trip routes (or eight one-way routes). The following table describes the operation types of all routes,

Table 2 Flight Routes

	ITINERARY	AIRCRAFT	FLIGHT FREQ.	ROUND-TRIP
ROUTE 1 (& 2)	AAA-BBB	F-100	2	YES
ROUTE 3 (& 4)	AAA-CCC-DDD	F-100	5	YES
ROUTE 5 (& 6)	AAA-CCC	F-50	4	YES
ROUTE 7 (& 8)	AAA-BBB-CCC	F-50	3	YES

In the next table, Table 3, the summary of all problems will be described. The first column of the table contains the name of the problem setting. The second column consists of the value of maximum utilization per day of all aircraft that are used in the network; the first value is maximum utilization of Fokker F-100, and the second value is the maximum utilization of Fokker F-50. The third and fourth column consist of the value of the aircraft allocation at the initial scheduling time. For example, at column number 3 and row number 3, the value is [2;0;0;0], it means that for a problem setting case2, at the initial scheduling time, two F-100's are allocated at airport AAA. The last column describes the value of the separation time. The separation time is the time difference of two slots or the time difference between two take-offs or two landings or a take-off and a landing, if only one runway is available at the airport.

Table 3 Summary of The Case Studies

	Max. utilization / day (minutes) [F100 ; F50]	F100 Allocation [A;B;C;D]	F50 Allocation [A;B;C;D]	Separation Time (minutes)
case1	540 ; 540	2;0;0;0	2;0;0;0	10
case2	800 ; 800	2;0;0;0	2;0;0;0	10
case3	540 ; 540	1;1;00	2;0;0;0	10
case4	540 ; 540	0;2;0;0	2;0;0;0	10
case5	540 ; 540	2;0;0;0	0;0;2;0	10
case6	540 ; 540	2;0;0;0	1;0;1;0	10
case7	800 ; 800	2;0;0;0	2;0;0;0	5

The effect of maximum utilization limits during a day is studied in case1 and case2. In case1 maximum utilization is 540 minutes/day (for all aircraft), in case 2 maximum utilization is 800 minutes/day (all aircraft). The other parameters are similar.

Case1, case3, and case4 have a difference in F-100 aircraft allocation at the initial scheduling time. In case1, all F-100's are allocated to airport AAA. In case3, one aircraft starts at airport AAA and the other one at airport BBB. In case4, all of the aircraft are allocated to airport BBB. The other parameters are similar.

Case1, case5, and case6 have a difference in F-50 aircraft allocation at the initial scheduling time. In case1 all of the aircraft are allocated to airport AAA. In case5, all aircraft are allocated to airport CCC. In case6, one aircraft is allocated to airport AAA, and the other one to airport CCC. The other parameters are similar.

The study of the effect of separation time in scheduling has been done for case2 versus case7. In case2, the separation time is 10 minutes, and in case7 the separation time is 5 minutes.

4.2 Summary of Results

The results are summarized in Table 4.

Table 4 Summary of Results

Parameter	case1	case2	case3	case4	case5	case6	case7
Nr. of Flight Freq							
Route 01	2	2	2	2	2	2	2
Route 02	2	2	2	2	2	2	2
Route 03	5	5	4	4	5	4	5
Route 04	4	5	4	4	4	4	5
Route 05	4	4	4	4	4	4	4
Route 06	4	4	4	4	4	4	4
Route 07	3	3	3	3	3	3	3
Route 08	3	3	3	3	3	3	3
Aircraft Utilization per day (minutes)							
F-100 #1	458	549	366	446	458	525	525
F-100 #2	525	525	525	446	525	366	549
F-50 #1	537	618	517	517	463	527	618
F-50 #2	517	436	537	537	500	527	436
Nr. of Slots	109	109	109	109	109	109	217
Nr. of Constraints	2286	2286	2286	2286	2286	2286	4570
Nr. of Variables	3424	3424	3424	3424	3424	3424	6872
CPU Time (seconds)							
Matrix Generator	1.75	1.76	1.76	1.74	1.89	1.73	4.04
Optimization	309.50	38.34	307.72	307.70	540.37	312.78	52.73
Objective Value	5.457	8.700	6.913	7.083	7.377	8.529	10.073

Refer to appendix E, for detailed results.

V. CONCLUSIONS and RECOMMENDATIONS

5.1 Conclusions

A linear programming method has been tried to solve the scheduling problem in aircraft operations. The applications of linear programming (Integer Programming) seems to be enough powerfull, but it would be useful if the results could be compared to a dynamic programming methods or any other method.

If these programs are combined with the fleet assignment program, some managerial decisions can be studied. Those decisions relate to aircraft selections, aircraft allocations, and route generations (assuming that the demand is fixed). By varying the type of aircraft, the best aircraft type can be selected. The best aircraft is the aircraft that gives the highest score, assuming that all other parameters are similar. Aircraft allocation is important because, the allocation of aircraft determines the greatest score that can be reached. With the defined flight leg demand, the route can be selected from all route possibilities.

From the case study, it can be concluded that aircraft allocation considerations is important. In that condition, it is a good decision to put all F-100 aircrafts at airport BBB, one F-50 aircraft at airport AAA, and the other F-50 in airport CCC.

If the maximum utilization is 540 minutes, not all proposed flights (output from fleet assignment process) can be realized. All proposed flights can be realized if the utilization limitation is increased to 800 minute/day (or 650 minutes/day). This result indicates that the utilization limitation in the fleet assignment process is not sufficient to warrant the satisfaction of the utilization limitation of individual aircraft, but only for a group aircraft. If the maximum utilization is increased (case2 and case7) the CPU time is greatly decreased and all flights are executed.

In the computer program, the separation time (vortex separation) for all aircraft is assumed to be fixed. In real operation conditions, the separation time depends on the type of the first aircraft and the predecessor aircraft (first aircraft vortex). The shortest separation time is if the first aircraft is a small aircraft (below 57000 N MTOW), followed by a heavy aircraft (up to 1.360.000 N MTOW). And the longest separation time is if the first aircraft is a heavy aircraft, followed by a small aircraft (11 km separation). With the assumption the approach or touch down velocity of a heavy aircraft is 110 knots, the longest separation time is about 3.3 minutes, so that 5 minutes separation is a realistic from an operational perspective.

Sometimes, the value of aicraft utilization is less than the maximum utulization, and the flight frequency is also less than the proposed flight frequency. This can occur, because the value of score on a route sometimes is decreased to less than half of the maximum score, and the greatest values is too close. In this conditions, the program tends to chose one flight that gives the highest score, rather than two flights that have a smaller total score. To solve this problem, in the first program, the objective function is changed to

$$MAX \sum_{i \in NET} \sum_{l \in S} \sum_{j_i \in AC_i} (1000 + score[i][l]) \times FL[i][j_i][1][l]$$

This approach has implemented in the first program.

5.2 Recommendations

This scheduling program is an prototype program, some imperfection still exist. It is recommended to improve this program. Some improvements are

- Combine this program with the fleet assignment program (could be the program from D. C. T. Van Egmond) by developing an interface program. In the interface program, an input subroutine still must be developed, because the scheduling programs do not just use output from the fleet assigment program, but also need some scheduling parameters.
  Those program can be combined if, the model of passenger demand is improved. (Fleet assignment program doesn't use time-of-day demand, so the demand must be obtained from a statistical procedure, by probability analysis of demand).
- It is better to convert the score with money-value. So the meaning of the objective value is easy to understand.
- Dr. Visser recommends that the utilization constraints are relaxed, while penalyzing any excess utilization time. Also it is better to make an aircraft source model, so it is no longer needed to make the initial allocation, or the allocation can be included in the network programming formulation

References

1. Francois Soumis., Jacques-A Ferland, and Jean-Marc Rousseau, ***A Model For Large Scale Aircraft Routing and Scheduling Problem***, Transportation Research, Vol. 14B, pp. 191-201, 1980.
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4. M. Terrab and A. R. Odoni, ***Ground-Holding Strategies for ATC Flow Control***, Working Paper, MIT Operations Research Center, September 1990.
5. D. C. T. Van Egmond, ***Airline System Simulation Using Linear Programming***, Master Thesis, Faculty of Aerospace Engineering, Technical Univesity Delft, Delft-Holland, June 1991.
6. Octavio Richetta, and Amedeo R. Odoni, ***Solving Optimality The Static Ground-Holding Policy Problem in Air Traffic Control***, Transportation Science, Vol. 27, No. 3, Augustus 1993.
7. Renfrey B. Potts, and Robert M. Oliver, ***Flow in transportation Network***, Academic Press, New York, 1972.

APPENDIX A
TIME-OF-DAY DEMAND FOR EACH FLIGHT LEG

These time-of-day demand (seats) values are generated by a random procedure that seed at 281165 and consist two peaks during a day. The random value then be processed so that the demand values variate from a minimum value to a maximum value

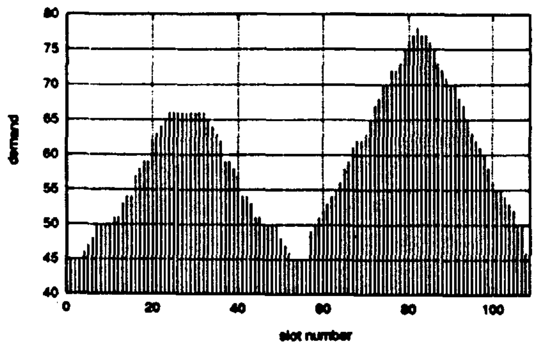


Figure A-1 <u>Time-of-Day Demand of Flight Leg AAA-BBB</u>

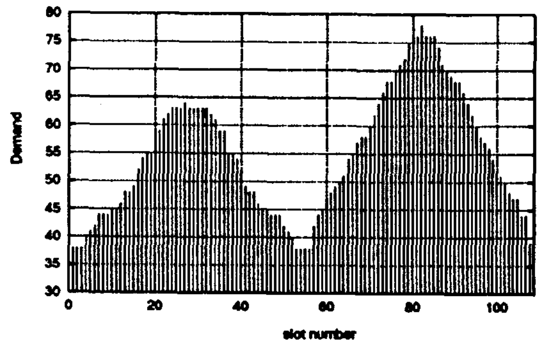


Figure A-2 <u>Time-of-Day Demand of Flight Leg BBB-AAA</u>

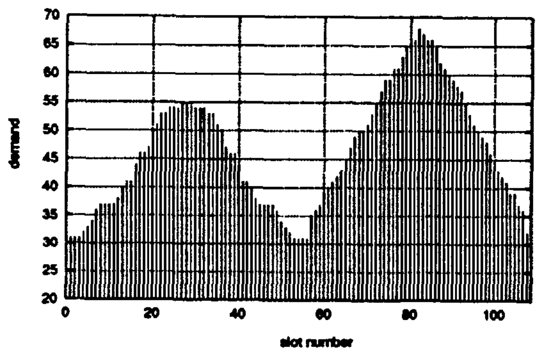


Figure A-3 <u>Time-of-Day Demand of Flight Leg AAA-CCC</u>

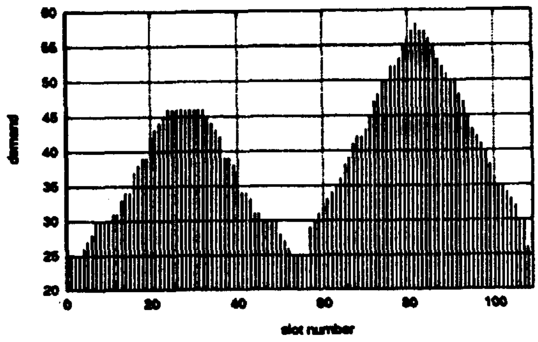


Figure A-4 Time-of-Day Demand of Flight Leg CCC-AAA

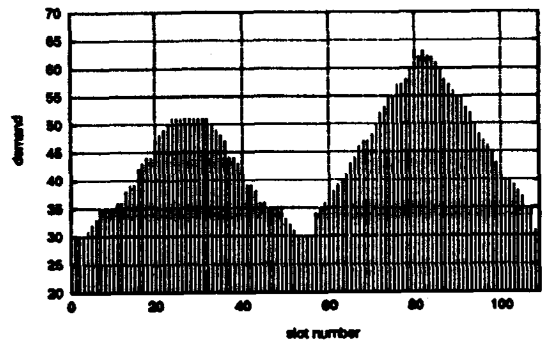


Figure A-5 Time-of-Day Demand of Flight Leg AAA-DDD

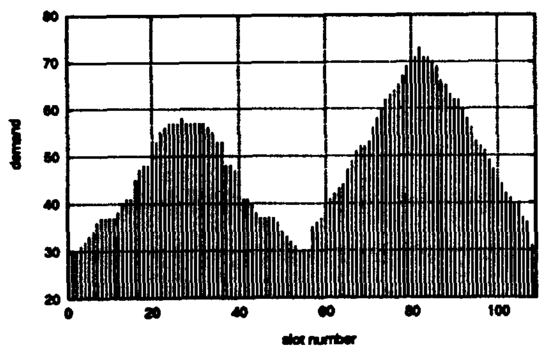


Figure A-6 Time-of-Day Demand of Flight Leg DDD-AAA

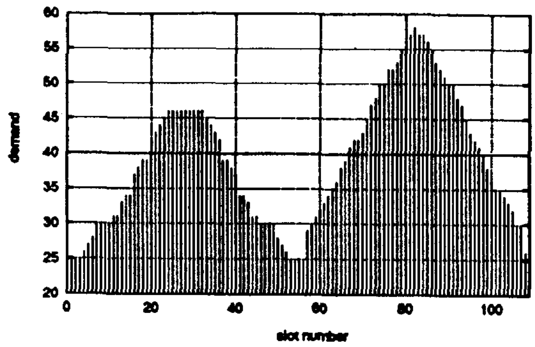


Figure A-7 Time-of-Day Demand of Flight Leg BBB-CCC

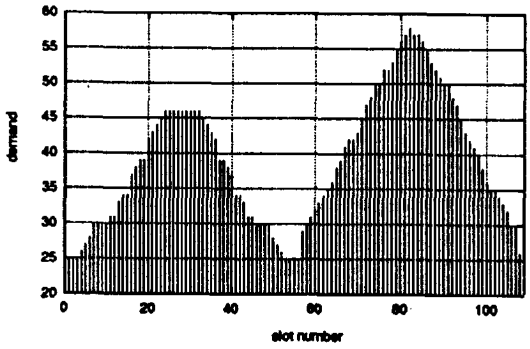


Figure A-8 Time-of-Day Demand of Flight Leg CCC-BBB

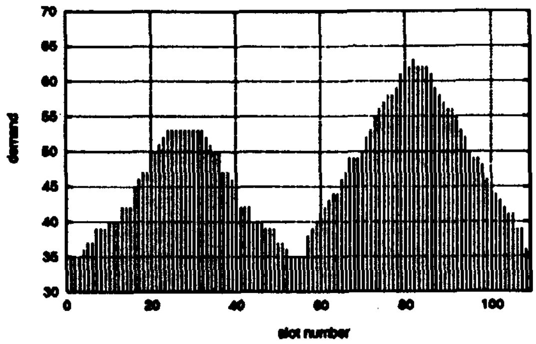


Figure A-9 Time-of-Day Demand of Flight Leg CCC-DDD

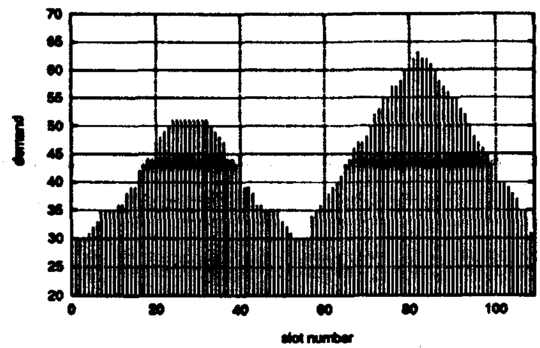


Figure A-10 Time-of-Day Demand of Flight Leg DDD-CCC

APPENDIX B
SLOT SCORING FOR EACH ROUTE

Score of a slot time in a route means
the maximum difference between
the demand (passenger) and the aircraft capacity (supply)
on all flight leg on the route
that can be formulated into

$$SCORE = 1/UM$$

$$UM = Max(abs[PAX_{i,j,s} - CAPA_i])$$

for $j \in i$
j : flight leg, i : route,
s : slot number
PAX : Passenger, CAPA : Aircraft Capacity

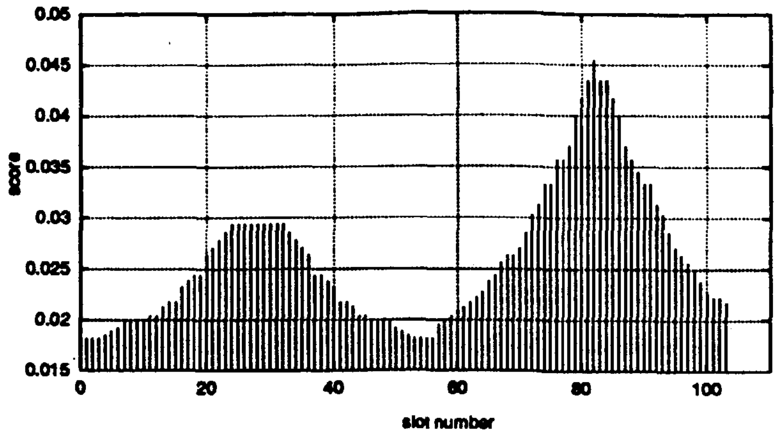


Figure B-1 **SLOT SCORES of ROUTE 01**

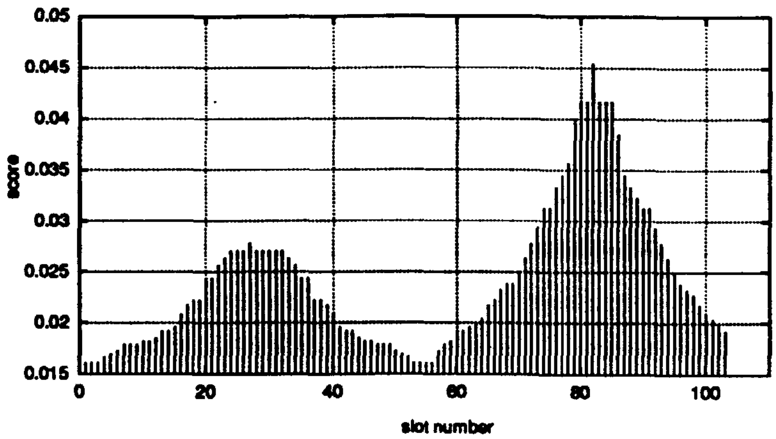


Figure B-2 **SLOT SCORES of ROUTE 02**

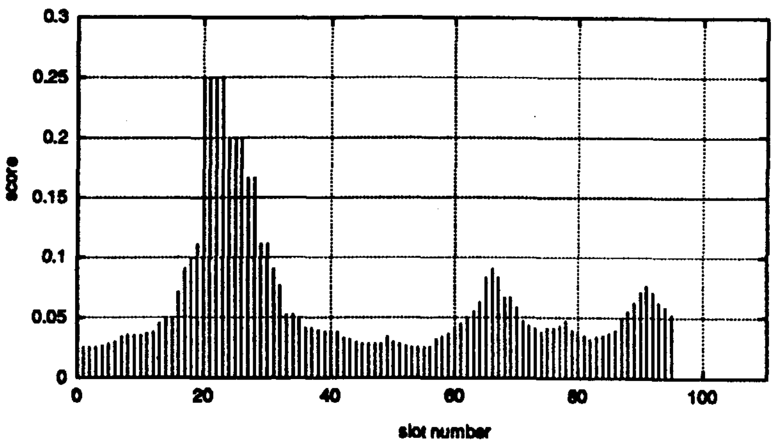


Figure B-3 **SLOT SCORES of ROUTE 03**

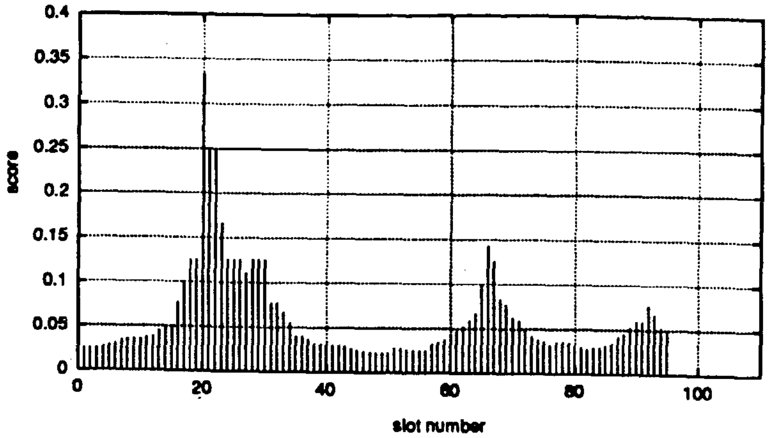


Figure B-4 <u>SLOT SCORES of ROUTE 04</u>

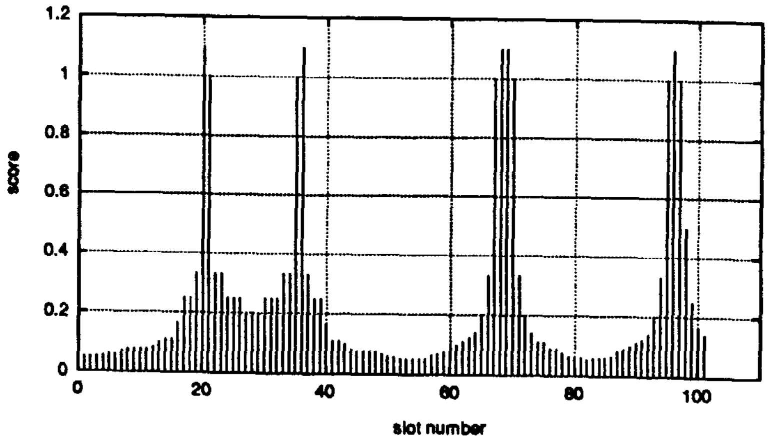


Figure B-5 <u>SLOT SCORES of ROUTE 05</u>

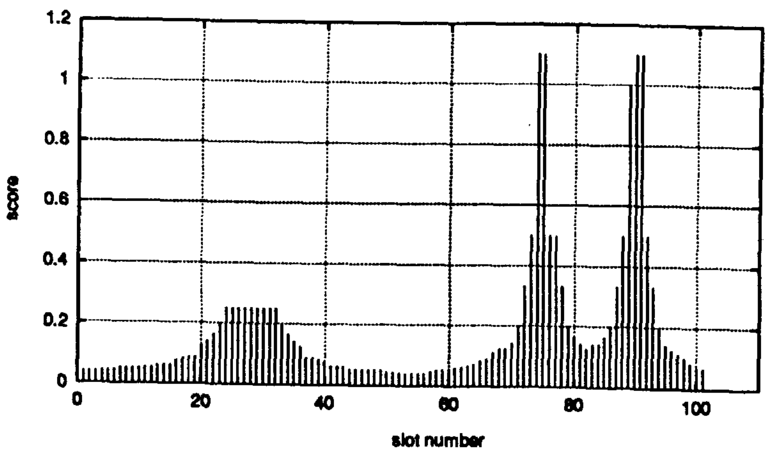


Figure B-6 <u>SLOT SCORES of ROUTE 06</u>

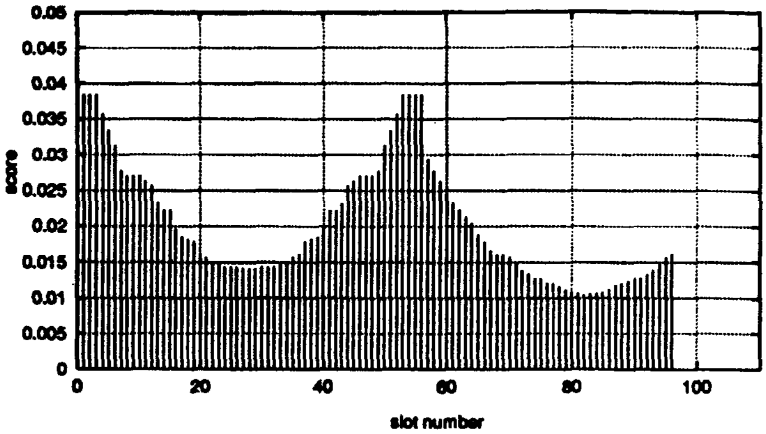


Figure B-7 <u>SLOT SCORES of ROUTE 07</u>

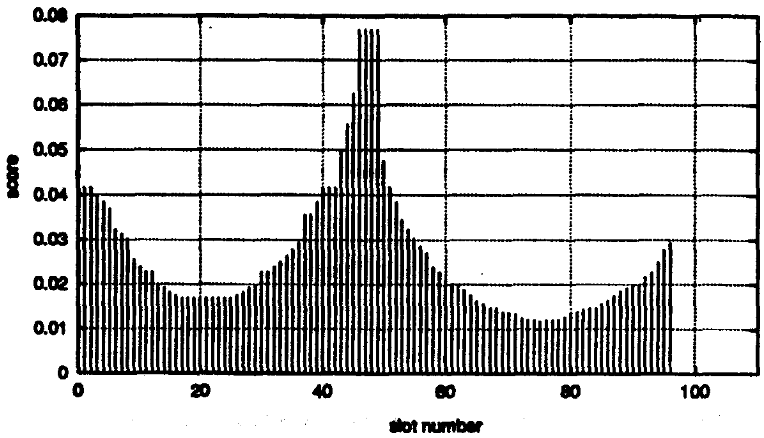


Figure B-8 <u>SLOT SCORES of ROUTE 08</u>

Appendix C
PROGRAM USERS MANUAL

Two computer programs have been developed with the objective to validate a problem formulation in scheduling by linear programming. The first program is a matrix generator program (named *neti.c*, placed in directory **dono/shop/sche**). The main objective of this program is to produce a LP format[1] file of the scheduling problems. And then, the LP format file is fed to the second program.

The second program is an optimizer program (named *ana.c*, placed in directory **dono/shop/sche**). The LP format file is read by the second program, optimized using CPLEX, and interpreted into an easy-to-understand form (write to file report #2).

C.1 Program Components

C.1.1 Program Inputs

Two kinds of input are necessary for running this program. The first input is *running-time input* and the second input is *file input* that have to be prepared before the program is run.

The running-time inputs of the first program (compiled and executable program of neti.c) are (first) *name of problem setting* (maximum 8 characters), the second is *starting time of schedulling* (in 24 hour in a day system, and integer value), the third is *ending time of scheduling* (in 24 hour in a day system, integer value), the last one is *separation time* (in minutes, integer value) between two slots in an airport. All of this input can be easily entered, because the program will prompt you in running time.

For the second program (ana.c), the running-time input is the name of problem setting, similar to the first input in the first program.

File input name must be created as the name of problem setting. For example, if the name of problem setting is CASE1, the name of file input must be CASE1.d. The maximum width of the problem setting is eight characters, and the minimum width of problem setting is one.

The file input consists of six data groups. Those data groups represent aircraft data, airport data, market data, and network data. Every data group is begun by a data group title. In the following data structure expalanation, the line number is the line number in the data group, not the line number in the file input.

The first data group is the ***aircraft data group***. Aircraft datas that be entered are

1'st line : number of aircraft type and one comment word,

the number of aircraft type is the same as the number of the line in the aircraft data group.

2'nd line until (nac[2]+1)'th line : aircraft data,

aircraft data consist (sequentially) aircraft name, block time constant (hour), block time gradient (hour/km), aircraft seat capacity, and maximum utility per day (minutes). The maximum number of characters in the aircraft name is five. The line number of the aircraft data is important, because this number will be used as aircraft number in the next data group. If an aircraft data is placed in line 4 (line 3, 2, and 1 are not blank lines) the aircraft number is 3 (that aircraft is aircraft number 3, 4-1).

---

1 LP format is one of format (other is MPS) of problem formulation in Linear Programming that can be read by CPLEX.

2 nac is number of aircarft type

The second data group is the ***airport data group***. Airport data that need to be entered are

1'st line : number of airport in network and one comment word.

The number of the airport is same as the number of columns in the airport data group.

2'nd line : name of airport.

The column number of this data is important because the column number is the number of airport that will be used in other data group. All airport names in the airline network must be specified. The maximum number of characters in the airport name is three.

3'rd line : runway capacity data,

the runway capacity data represents the ability to take off or land at an airport at a given slot time. This data is the same as the number of runways in an airport, if all runways can be used as takeoff or landing runway.

4'th and (nac+3)'th line : aircraft allocation data.

The row of data (started by line 4 of data group) represents aircraft types used in network and the column of data relates to the airport. So that, if two aircraft of type number 2 are allocated at the first scheduling time in airport number 4, the value of line number 5 (nac+3, nac = 2) and column number 4 of data airport data group is 2.

Note : All aircraft must be allocated in an airport origin (or destination). If an aircraft is allocated in an intermediate airport, the input has no effect.

The third data group is the ***distance data group***. If two airports are connected, the value of distance (in kilometer) must be specified. If two airports are not connected, it is not necessary to write the zero distance value in the distance data group. The distance data group is begun by the data group title with number of distance data and one comment word (distance), in the first line of distance data group. The other lines is distance data. The number of distances is equal to the number of lines after the data group title in the distance data group. First column of data is a origin-destination pair (X-Y) that describes the airport number, and the second column describes the distance of the origin-destination pair in kilometers that have been mentioned in the previous column.

For example :

if in the airport data, names of airport have been declared like

AAA BBB CCC DDD

and the distance between airport AAA and CCC is 350 km, we just must write :

1-3 350.0

The fourth data group is the ***market data group***. The market data group contains the information about the maximum and minimum demand in time of day at every market (flight leg market). The first line of this data is the data group title that describes the number of legs in a network and one comment word. For the others line of the market data, the first column is origin-destination pair, the second column is maximum passenger demand, and the last column is minimum passenger demand.

For example :

if in airport data, names of airport have been declared like

AAA BBB CCC DDD

and the maximum and minimum passenger demand in flight leg (AAA-CCC) is 80 and 37 passengers, we just must write :

1-3 80 37

(see appendix B, for maximum and minimum demand explanation)

The fifth data group is the ***route data group***. As like other data groups, this data group is begun by the data group title. The data group title contains the number of data lines, that also means the number of routes, and one word comment. Two symmetrical routes just must be declared as one route data. For example if first route is AAA-BBB-CCC and second route is CCC-BBB-AAA, we just must write route AAA-BBB-CCC with explanation that this route is symmetric (round-trip).

The first column in the route data group is type of route. Type of route can be a symmetrical and asymmetrical (one-way) route (write as s for symmetry and u for unsymmetry). The second column is the chain (or path) of airports on a route (i.e. AAA-BBB-CCC), the third column is the aircraft type number, and the last column is the number of the flight frequency in that route. The number of aircraft types is equal to the line number in the aircraft data group (first data group), excluding the data group title.

For example :

if in airport data, names of airport have been declared like

AAA BBB CCC DDD

and the route AAA-CCC-DDD is a symmetrical route that uses aircraft type number 1, and the flight frequencies proposed (output of the fleet assignment stage) is five flights. In the line of data we just write

s 1-3-4 1 5

this represents two routes, AAA-CCC-DDD and DDD-CCC-AAA, with the same aircraft type and the same flight frequencies.

The other data group is the ***turn around time data group***. The first line of this **data group is the data group title (turn_around_time) and the others contains the matrix of** turn around time. The row number of the matrix represents the aircraft number, and the column number represents the airport number. The value of turn arround time is in minutes.

Example of data set for an airline network in file input is

```
2       number_of_aircraft_type                     |                      line1 : title
F100    0.42327   0.00137   100     540             | aircraft data group    2 : aicraft #1 data
F50     0.27976   0.00218   50      540             |                        3 : aircraft #2 data
4       number_of_airport                           ||                       1 : title
AAA     BBB       CCC       DDD                     ||                       2 : airport name
2       2         2         2                       || airport data group    3 : runway capacity
2       0         0         0                       ||                       4 : 2 aircraft #1 in A/P AAA
1       0         1         0                       ||                       5 : aircraft #2, AAA=1, CCC=1
4       distance                            |||                              1 : title
1-2     250.0                               |||                              2 : distance AAA-BBB 250 km
1-3     350.0                               ||| distance data group          3 : distance AAA-CCC 350 km
2-3     175.0                               |||                              4 : distance BBB-CCC 175 km
3-4     150.0                               |||                              5 : distance CCC-DDD 150 km
10      market_maximum_minimum                      ||||                     1 : title
1-2     70        30                                ||||                     2 : market AAA-BBB
1-3     80        40                                ||||                     3 : market AAA-CCC
1-4     50        20                                ||||                     4 : market AAA-DDD
2-3     75        15                                ||||                     5 : etc. .....
3-4     65        30                                |||| market data group   6
2-1     65        20                                ||||                     7
3-1     80        10                                ||||                     8
4-1     75        20                                ||||                     9
3-2     60        15                                ||||                     10
4-3     55        25                                ||||                     11
4       number_of_route                             |||||                    1 : title
s       1-3-4     1         3                       |||||                    2 : route 1 and 2
s       1-3       1         4                       ||||| route data group   3 : route 3 and 4
s       1-2-3     2         3                       |||||                    4 : route 5 and 6
s       1-3       2         2                       |||||                    5 : route 7 and8
turn_around_time                            ||||||                           1 : title
15      15        15        15              |||||| turn around time data group  2 : turn round time of aircraft #1
10      10        10        10              ||||||                           3 : turn around time of
aircraft#2
```

C.1.2 Matrix Generator Program : ***neti.c***

The matrix generator program involves a data-reading segment, a route processing segment (create a new route from symmetric route input, generate a transfer flight if necessary, and calculation of flight time), random generator for market demand, score generator, write LP format file (xxxxxxxx.lp), and produce some file outputs (network file : xxxxxxxx.NET, time file : xxxxxxxx.TIM, variable file : xxxxxxxx.VAR, and first report file : xxxxxxxx.R1) that is to be used as input to the second program.

This program needs is file input and running time input. The file input must be prepared before running the program.

C.1.3 Optimizer and Analizer Program : ana.c

Optimization and analysis are performed by one program. The optimization segment uses CPLEX callable library that is available on the CONVEX (Computer Mainframe in TU Delft). The input files that are needed by this program are xxxxxxxx.lp, xxxxxxxx.TIM, xxxxxxxx.VAR, and xxxxxxxx.NET. xxxxxxxx is name of the problem setting. The running-time input is the name of problem setting. The output of this program is xxxxxxxx.R2.

C.1.4 Output of The Program

Output of the first program :

1. xxxxxxxx.lp
   is LP format file of the scheduling problem.
2. xxxxxxxx.VAR
   is list of the number of variables (flight link and stay link variables), related to route number, aircraft type number (for stay link variables), aircraft number per aircraft type, initial airport number, and initial slot number.
3. xxxxxxxx.TIM
   involves starting scheduling time, ending scheduling time, and separation time.
4. xxxxxxxx.NET
   involves the information of the network, quite similar to the file input, except the market data group, the turn around data group, the distance data group, the block time parameters of aircraft, the seat capacity of aircraft, the runway capacity, the aircraft allocation data, and symmetricity of route, but plus the flight time of every flight leg per aircraft type.
5. xxxxxxxx.R1
   report format of network data. This report includes aircraft related data (aircraft name, aircraft block time parameter, aircraft seat capacity, and maximum utilization for every aircraft), airport related data (aircraft allocation, runway capacity, turn arround time), and score of every route at every slot time.

Output of the second program is xxxxxxxx.R2, that consists of the information about the schedule. That information involves flight schedule, aircraft utility, realized route flight frequency, and proposed route flight frequency for every route, statistics of take off and landing activity in an airport during a day.

C.2 Compiling Procedure

Compiling procedure of neti.c and make an executable file neti :

make neti

or

cc -o neti neti.c

Compiling procedure of ana.c and make an executable file ana :

```
cc -o ana ana.c -lcplexmip -DSYSCONVEX -lveclib -link -A_use_libc_sema=___ap\$use_libc_sema -g
```

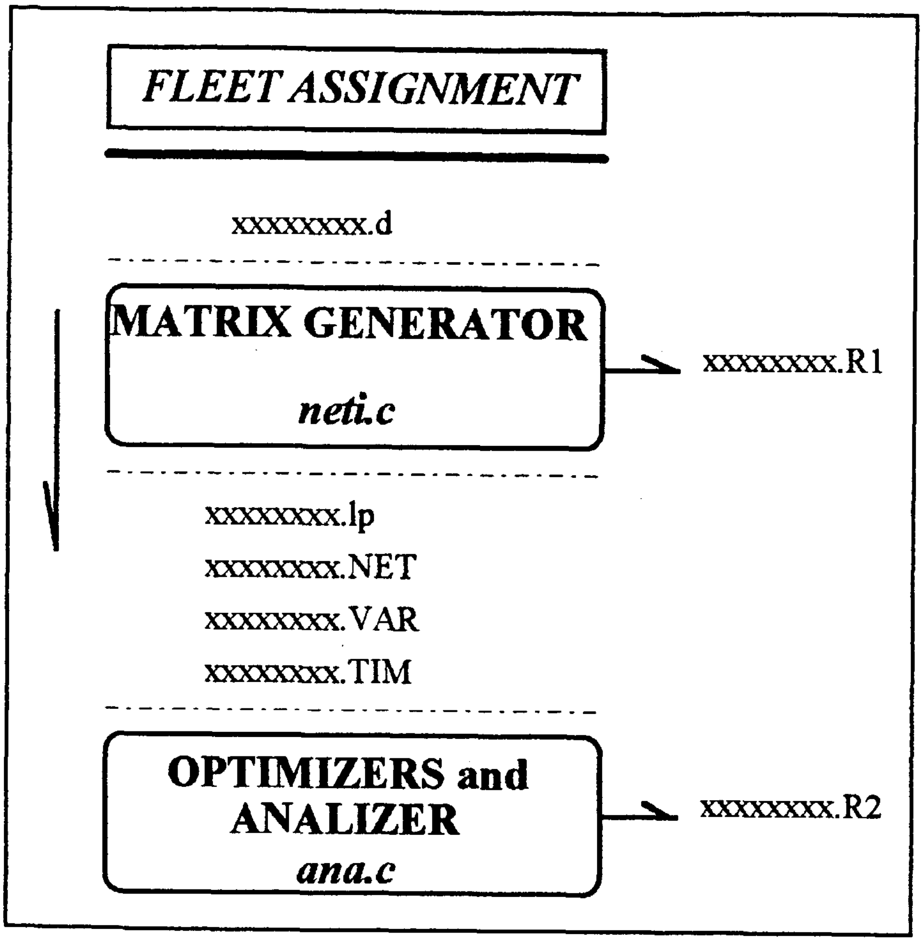
or if you have file cplex.com that containts that compiling command, you just use

cplex.com

C.3 Flow Chart of Scheduling Process

The schedulling procedure can be represented by the following diagram (next page)

Flow of Scheduling, started by fleet assignment process :



APPENDIX D
FLEET ASSIGNMENT RESULT

```
Problem 'case.mps' read.
Read Time =   0.06 sec.

Maximize
 PROFIT: - 12000 ac1001 - 6500 ac1002 - 1500 fl1001 - 3000 fl1002
         - 800 fl1003  - 1400 fl1004 + 60 px1001 + 60 px1002
         + 70 px1003 + 70 px1004 + 70 px1005 + 100 px1006
         + 75 px1007 + 80 px1008
Subject To
 cscp1001: - 70 fl1001 + px1001 <= 0
 cscp1002: - 70 fl1002 + px1003 + px1006 <= 0
 cscp1003: - 70 fl1002 + px1006 + px1008 <= 0
 cscp1004: - 35 fl1003 + px1004 <= 0
 cscp1005: - 35 fl1004 + px1002 + px1005 <= 0
 cscp1006: - 35 fl1004 + px1005 + px1007 <= 0
 csod1001: px1001 + px1002 <= 300
 csod1002: px1003 + px1004 + px1005 <= 400
 csod1003: px1006 <= 150
 csod1004: px1007 <= 125
 csod1005: px1008 <= 250
 csut1001: - 540 ac1001 + 79.398 fl1001 + 183.312 fl1002 <= 0
 csut1002: - 540 ac1002 + 127.698 fl1003 + 181.444 fl1004 <= 0
Bounds
 0 <= ac1001 <= 10000
 0 <= ac1002 <= 10000
 0 <= fl1001 <= 99
 0 <= fl1002 <= 99
 0 <= fl1003 <= 99
 0 <= fl1004 <= 99
 All other variables are >= 0.
Integers
 ac1001  ac1002  fl1001  fl1002  fl1003  fl1004

Integer optimal solution:  Objective =    1.7475000000e+04
Solution Time =    0.14 sec.    Iterations = 64   Nodes = 48

Variable Name                      Solution Value
ac1001                 =                2.000000
ac1002                 =                2.000000
fl1001                 =                2.000000
fl1002                 =                5.000000
fl1003                 =                4.000000
fl1004                 =                3.000000
px1001                 =              140.000000
px1002                 =              105.000000
px1003                 =              250.000000
px1004                 =              140.000000
px1006                 =              100.000000
px1007                 =              105.000000
px1008                 =              250.000000
All other variables in the range 1-14 are zero.
```

APPENDIX E
PROGRAM OUTPUT

Aircraft Related Data : case1

A/C Name	BTa hr.	BTb hr/km	CAPACITY SEAT	AVAI. A/C	MAX. Util. minutes
F100	0.4233	0.0014	100	2	540
F50	0.2798	0.0022	50	2	540

Airport Related Data : case1

About :	Airport Name AAA	BBB	CCC	DDD
Runway Cap.	2	2	2	2
A/C Alocation				
F100	2	0	0	0
F50	2	0	0	0
Turn Arround Time (minutes)				
F100	15	15	15	15
F50	10	10	10	10

Flight Schedule Per Aircraft of case1

Flight NO.	O-D	Dep. Time	A/C
MS0301	AAA-CCC	05:00	F100#01
MS0301	CCC-DDD	06:20	F100#01
MS0401	DDD-CCC	07:20	F100#01
MS0401	CCC-AAA	08:20	F100#01
MS0302	AAA-CCC	09:40	F100#01
MS0302	CCC-DDD	11:00	F100#01
MS0402	DDD-CCC	14:50	F100#01
MS0402	CCC-AAA	15:50	F100#01
MS0303	AAA-CCC	17:10	F100#01
MS0303	CCC-DDD	18:30	F100#01
MS0304	AAA-CCC	04:50	F100#02
MS0304	CCC-DDD	06:10	F100#02
MS0403	DDD-CCC	07:10	F100#02
MS0403	CCC-AAA	08:10	F100#02
MS0305	AAA-CCC	09:30	F100#02
MS0305	CCC-DDD	10:50	F100#02
MS0404	DDD-CCC	14:50	F100#02
MS0404	CCC-AAA	15:50	F100#02
MS0101	AAA-BBB	17:10	F100#02
MS0201	BBB-AAA	18:10	F100#02
MS0102	AAA-BBB	19:10	F100#02
MS0202	BBB-AAA	20:10	F100#02
MS0501	AAA-CCC	04:10	F50#01
MS0601	CCC-AAA	05:40	F50#01
MS0502	AAA-CCC	07:00	F50#01
MS0602	CCC-AAA	08:30	F50#01
MS0701	AAA-BBB	09:50	F50#01
MS0701	BBB-CCC	10:50	F50#01
MS0603	CCC-AAA	13:50	F50#01
MS0503	AAA-CCC	15:10	F50#01
MS0604	CCC-AAA	18:50	F50#01
MS0702	AAA-BBB	04:00	F50#02
MS0702	BBB-CCC	05:00	F50#02
MS0801	CCC-BBB	06:10	F50#02
MS0801	BBB-AAA	07:20	F50#02
MS0504	AAA-CCC	09:50	F50#02
MS0802	CCC-BBB	11:30	F50#02
MS0802	BBB-AAA	12:40	F50#02
MS0703	AAA-BBB	13:40	F50#02
MS0703	BBB-CCC	14:40	F50#02
MS0803	CCC-BBB	19:50	F50#02
MS0803	BBB-AAA	21:00	F50#02

Aircarft Utilization Per Day : case1

Aircraft	Utility/day (minutes)
F100#01	458.280
F100#02	525.420
F50#01	537.665
F50#02	517.457

Flight Frequency Per Day : case1

ROUTE NO.	FREQ/DAY REALIZED	FREQ/DAY PROPOSED	ITINERARY
001	2	2	AAA-BBB
002	2	2	BBB-AAA
003	5	5	AAA-CCC-DDD
004	4	5	DDD-CCC-AAA
005	4	4	AAA-CCC
006	4	4	CCC-AAA
007	3	3	AAA-BBB-CCC
008	3	3	CCC-BBB-AAA

Airport Statistics : case1

SLOT NO.	Time	Activities in A/P AAA	BBB	CCC	DDD
001	04:00	T1L_	T_L_	T_L_	T_L_
002	04:10	T1L_	T_L_	T_L_	T_L_
006	04:50	T1L_	T_L1	T_L_	T_L_
007	05:00	T1L_	T1L_	T_L_	T_L_
009	05:20	T_L_	T_L_	T_L1	T_L_
011	05:40	T_L_	T_L_	T1L_	T_L_
012	05:50	T_L_	T_L_	T_L1	T_L_
013	06:00	T_L_	T_L_	T_L2	T_L_
014	06:10	T_L_	T_L_	T2L_	T_L_
015	06:20	T_L_	T_L_	T1L_	T_L_
018	06:50	T_L1	T_L_	T_L_	T_L1
019	07:00	T1L_	T_L_	T_L_	T_L1
020	07:10	T_L_	T_L1	T_L_	T1L_
021	07:20	T_L_	T1L_	T_L_	T1L_
024	07:50	T_L_	T_L_	T_L1	T_L_
025	08:00	T_L_	T_L_	T_L1	T_L_
026	08:10	T_L1	T_L_	T1L1	T_L_
027	08:20	T_L_	T_L_	T1L_	T_L_
028	08:30	T_L_	T_L_	T1L_	T_L_
032	09:10	T_L1	T_L_	T_L_	T_L_
033	09:20	T_L1	T_L_	T_L_	T_L_
034	09:30	T1L_	T_L_	T_L_	T_L_
035	09:40	T1L1	T_L_	T_L_	T_L_
036	09:50	T2L_	T_L_	T_L_	T_L_
040	10:30	T_L_	T_L_	T_L1	T_L_
041	10:40	T_L_	T_L1	T_L1	T_L_
042	10:50	T_L_	T1L_	T1L_	T_L_
043	11:00	T_L_	T_L_	T1L1	T_L_
046	11:30	T_L_	T_L_	T1L_	T_L1
047	11:40	T_L_	T_L_	T_L_	T_L1
048	11:50	T_L_	T_L_	T_L1	T_L_
052	12:30	T_L_	T_L1	T_L_	T_L_
053	12:40	T_L_	T1L_	T_L_	T_L_
058	13:30	T_L1	T_L_	T_L_	T_L_
059	13:40	T1L_	T_L_	T_L_	T_L_
060	13:50	T_L_	T_L_	T1L_	T_L_
064	14:30	T_L_	T_L1	T_L_	T_L_
065	14:40	T_L_	T1L_	T_L_	T_L_
066	14:50	T_L_	T_L_	T_L_	T2L_
067	15:00	T_L1	T_L_	T_L_	T_L_
068	15:10	T1L_	T_L_	T_L_	T_L_
070	15:30	T_L_	T_L_	T_L2	T_L_
071	15:40	T_L_	T_L_	T_L1	T_L_
072	15:50	T_L_	T_L_	T2L_	T_L_
075	16:20	T_L_	T_L_	T_L1	T_L_
078	16:50	T_L2	T_L_	T_L_	T_L_
080	17:10	T2L_	T_L_	T_L_	T_L_
084	17:50	T_L_	T_L1	T_L_	T_L_
086	18:10	T_L_	T1L_	T_L1	T_L_
088	18:30	T_L_	T_L_	T1L_	T_L_
090	18:50	T_L1	T_L_	T1L_	T_L_
092	19:10	T1L_	T_L_	T_L_	T_L1
096	19:50	T_L_	T_L1	T1L_	T_L_
097	20:00	T_L1	T_L_	T_L_	T_L_
098	20:10	T_L_	T1L_	T_L_	T_L_
102	20:50	T_L1	T_L1	T_L_	T_L_
103	21:00	T_L_	T1L_	T_L_	T_L_
108	21:50	T_L1	T_L_	T_L_	T_L_

Aircraft Related Data : case2

A/C Name	BTa hr.	BTb hr/km	CAPACITY SEAT	AVAI. A/C	MAX. Util. minutes
F100	0.4233	0.0014	100	2	800
F50	0.2798	0.0022	50	2	800

Airport Related Data : case2

About :	Airport Name AAA	BBB	CCC	DDD
Runway Cap.	2	2	2	2
A/C Alocation				
F100	2	0	0	0
F50	2	0	0	0
Turn Arround Time (minutes)				
F100	15	15	15	15
F50	10	10	10	10

Flight Schedule Per Aircraft of case2

Flight NO.	O-D	Dep. Time	A/C
MS0301	AAA-CCC	04:50	F100#01
MS0301	CCC-DDD	06:10	F100#01
MS0401	DDD-CCC	07:10	F100#01
MS0401	CCC-AAA	08:10	F100#01
MS0302	AAA-CCC	09:30	F100#01
MS0302	CCC-DDD	10:50	F100#01
MS0402	DDD-CCC	14:50	F100#01
MS0402	CCC-AAA	15:50	F100#01
MS0303	AAA-CCC	17:10	F100#01
MS0303	CCC-DDD	18:30	F100#01
MS0403	DDD-CCC	19:30	F100#01
MS0403	CCC-AAA	20:30	F100#01
MS0304	AAA-CCC	04:50	F100#02
MS0304	CCC-DDD	06:10	F100#02
MS0404	DDD-CCC	07:10	F100#02
MS0404	CCC-AAA	08:10	F100#02
MS0305	AAA-CCC	09:30	F100#02
MS0305	CCC-DDD	10:50	F100#02
MS0405	DDD-CCC	14:50	F100#02
MS0405	CCC-AAA	15:50	F100#02
MS0101	AAA-BBB	17:10	F100#02
MS0201	BBB-AAA	18:10	F100#02
MS0102	AAA-BBB	19:10	F100#02
MS0202	BBB-AAA	20:10	F100#02
MS0501	AAA-CCC	07:10	F50#01
MS0601	CCC-AAA	08:30	F50#01
MS0502	AAA-CCC	09:50	F50#01
MS0801	CCC-BBB	11:30	F50#01
MS0801	BBB-AAA	12:40	F50#01
MS0701	AAA-BBB	13:40	F50#01
MS0701	BBB-CCC	14:40	F50#01
MS0602	CCC-AAA	16:10	F50#01
MS0702	AAA-BBB	17:40	F50#01
MS0702	BBB-CCC	18:40	F50#01
MS0802	CCC-BBB	19:50	F50#01
MS0802	BBB-AAA	21:00	F50#01
MS0703	AAA-BBB	04:00	F50#02
MS0703	BBB-CCC	05:00	F50#02
MS0603	CCC-AAA	08:30	F50#02
MS0503	AAA-CCC	09:50	F50#02
MS0803	CCC-BBB	11:50	F50#02
MS0803	BBB-AAA	13:00	F50#02
MS0504	AAA-CCC	15:10	F50#02
MS0604	CCC-AAA	18:50	F50#02

Aircarft Utility Per Day : case2

Aircraft	Utility/day (minutes)
F100#01	549.936
F100#02	525.420
F50#01	618.282
F50#02	436.839

Flight Frequency Per Day : case2

ROUTE NO.	FREQ/DAY REALIZED	PROPOSED	ITINERARY
001	2	2	AAA-BBB
002	2	2	BBB-AAA
003	5	5	AAA-CCC-DDD
004	5	5	DDD-CCC-AAA
005	4	4	AAA-CCC
006	4	4	CCC-AAA
007	3	3	AAA-BBB-CCC
008	3	3	CCC-BBB-AAA

Airport Statistics : case2

SLOT NO.	Time	Activities in A/P AAA	BBB	CCC	DDD
001	04:00	T1L_	T_L	T_L_	T_L_
006	04:50	T2L_	T_L1	T_L_	T_L_
007	05:00	T_L_	T1L_	T_L_	T_L_
012	05:50	T_L_	T_L_	T_L2	T_L_
013	06:00	T_L_	T_L_	T_L1	T_L_
014	06:10	T_L_	T_L_	T2L_	T_L_
018	06:50	T_L_	T_L_	T_L_	T_L2
020	07:10	T1L_	T_L_	T_L_	T2L_
024	07:50	T_L_	T_L_	T_L2	T_L_
026	08:10	T_L_	T_L_	T2L_	T_L_
027	08:20	T_L_	T_L_	T_L1	T_L_
028	08:30	T_L_	T_L_	T2L_	T_L_
032	09:10	T_L2	T_L_	T_L_	T_L_
034	09:30	T2L_	T_L_	T_L_	T_L_
035	09:40	T_L2	T_L_	T_L_	T_L_
036	09:50	T2L_	T_L_	T_L_	T_L_
040	10:30	T_L_	T_L_	T_L2	T_L_
042	10:50	T_L_	T_L_	T2L_	T_L_
043	11:00	T_L_	T_L_	T_L2	T_L_
046	11:30	T_L_	T_L_	T1L_	T_L2
048	11:50	T_L_	T_L_	T1L_	T_L_
052	12:30	T_L_	T_L1	T_L_	T_L_
053	12:40	T_L_	T1L_	T_L_	T_L_
054	12:50	T_L_	T_L1	T_L_	T_L_
055	13:00	T_L_	T1L_	T_L_	T_L_
058	13:30	T_L1	T_L_	T_L_	T_L_
059	13:40	T1L_	T_L_	T_L_	T_L_
060	13:50	T_L1	T_L_	T_L_	T_L_
064	14:30	T_L_	T_L1	T_L_	T_L_
065	14:40	T_L_	T1L_	T_L_	T_L_
066	14:50	T_L_	T_L_	T_L_	T2L_
068	15:10	T1L_	T_L_	T_L_	T_L_
070	15:30	T_L_	T_L_	T_L2	T_L_
071	15:40	T_L_	T_L_	T_L1	T_L_
072	15:50	T_L_	T_L_	T2L_	T_L_
074	16:10	T_L_	T_L_	T1L_	T_L_
075	16:20	T_L_	T_L_	T_L1	T_L_
078	16:50	T_L2	T_L_	T_L_	T_L_
080	17:10	T2L_	T_L_	T_L_	T_L_
081	17:20	T_L1	T_L_	T_L_	T_L_
083	17:40	T1L_	T_L_	T_L_	T_L_
084	17:50	T_L_	T_L1	T_L_	T_L_
086	18:10	T_L_	T1L_	T_L1	T_L_
088	18:30	T_L_	T_L1	T1L_	T_L_
089	18:40	T_L_	T1L_	T_L_	T_L_
090	18:50	T_L1	T_L_	T1L_	T_L_
092	19:10	T1L_	T_L_	T_L_	T_L1
094	19:30	T_L_	T_L_	T_L_	T1L_
095	19:40	T_L_	T_L_	T_L1	T_L_
096	19:50	T_L_	T_L1	T1L_	T_L_
097	20:00	T_L1	T_L_	T_L_	T_L_
098	20:10	T_L_	T1L_	T_L1	T_L_
100	20:30	T_L_	T_L_	T1L_	T_L_
102	20:50	T_L1	T_L1	T_L_	T_L_
103	21:00	T_L_	T1L_	T_L_	T_L_
106	21:30	T_L1	T_L_	T_L_	T_L_
108	21:50	T_L1	T_L_	T_L_	T_L_

Aircraft Related Data : case3

A/C Name	BTa hr.	BTb hr/km	CAPACITY SEAT	AVAI. A/C	MAX. Util. minutes
F100	0.4233	0.0014	100	2	540
F50	0.2798	0.0022	50	2	540

Airport Related Data : case3

About :	Airport Name AAA	BBB	CCC	DDD
Runway Cap.	2	2	2	2
A/C Alocation				
F100	1	1	0	0
F50	2	0	0	0
Turn Arround Time (minutes)				
F100	15	15	15	15
F50	10	10	10	10

Flight Schedule Per Aircraft of case3

Flight NO.	O-D	Dep. Time	A/C
MS0301	AAA-CCC	09:30	F100#01
MS0301	CCC-DDD	10:50	F100#01
MS0401	DDD-CCC	14:50	F100#01
MS0401	CCC-AAA	15:50	F100#01
MS0302	AAA-CCC	17:10	F100#01
MS0302	CCC-DDD	18:30	F100#01
MS0402	DDD-CCC	19:30	F100#01
MS0402	CCC-AAA	20:30	F100#01
MS0201	BBB-AAA	05:50	F100#02
MS0303	AAA-CCC	07:10	F100#02
MS0303	CCC-DDD	08:30	F100#02
MS0403	DDD-CCC	09:30	F100#02
MS0403	CCC-AAA	10:30	F100#02
MS0304	AAA-CCC	12:00	F100#02
MS0304	CCC-DDD	13:20	F100#02
MS0404	DDD-CCC	14:50	F100#02
MS0404	CCC-AAA	15:50	F100#02
MS0101	AAA-BBB	17:30	F100#02
MS0202	BBB-AAA	18:30	F100#02
MS0102	AAA-BBB	19:30	F100#02
MS0701	AAA-BBB	04:00	F50#01
MS0701	BBB-CCC	05:00	F50#01
MS0801	CCC-BBB	06:10	F50#01
MS0801	BBB-AAA	07:20	F50#01
MS0702	AAA-BBB	09:50	F50#01
MS0702	BBB-CCC	10:50	F50#01
MS0802	CCC-BBB	12:00	F50#01
MS0802	BBB-AAA	13:10	F50#01
MS0501	AAA-CCC	15:10	F50#01
MS0803	CCC-BBB	19:50	F50#01
MS0803	BBB-AAA	21:00	F50#01
MS0502	AAA-CCC	07:10	F50#02
MS0601	CCC-AAA	08:30	F50#02
MS0503	AAA-CCC	09:50	F50#02
MS0602	CCC-AAA	11:10	F50#02
MS0504	AAA-CCC	15:00	F50#02
MS0603	CCC-AAA	16:20	F50#02
MS0703	AAA-BBB	17:40	F50#02
MS0703	BBB-CCC	18:40	F50#02
MS0604	CCC-AAA	19:50	F50#02

Aircarft Utilization Per Day : case3

Aircraft	Utility/day (minutes)
F100#01	366.624
F100#02	525.420
F50#01	517.457
F50#02	537.665

Flight Frequency Per Day : case3

ROUTE NO.	FREQ/DAY REALIZED	PROPOSED	ITINERARY
001	2	2	AAA-BBB
002	2	2	BBB-AAA
003	4	5	AAA-CCC-DDD
004	4	5	DDD-CCC-AAA
005	4	4	AAA-CCC
006	4	4	CCC-AAA
007	3	3	AAA-BBB-CCC
008	3	3	CCC-BBB-AAA

Airport Statistics : case3

SLOT NO.	Time	Activities in A/P AAA	BBB	CCC	DDD
001	04:00	T1L_	T_L_	T_L_	T_L_
006	04:50	T_L_	T_L1	T_L_	T_L_
007	05:00	T_L_	T1L_	T_L_	T_L_
012	05:50	T_L_	T1L_	T_L_	T_L_
013	06:00	T_L_	T_L_	T_L1	T_L_
014	06:10	T_L_	T_L_	T1L_	T_L_
016	06:30	T_L1	T_L_	T_L_	T_L_
020	07:10	T2L_	T_L1	T_L_	T_L_
021	07:20	T_L_	T1L_	T_L_	T_L_
026	08:10	T_L1	T_L_	T_L1	T_L_
027	08:20	T_L_	T_L_	T_L1	T_L_
028	08:30	T_L_	T_L_	T2L_	T_L_
032	09:10	T_L_	T_L_	T_L_	T_L1
034	09:30	T1L_	T_L_	T_L_	T1L_
035	09:40	T_L1	T_L_	T_L_	T_L_
036	09:50	T2L_	T_L_	T_L_	T_L_
038	10:10	T_L_	T_L_	T_L1	T_L_
040	10:30	T_L_	T_L_	T1L1	T_L_
041	10:40	T_L_	T_L1	T_L_	T_L_
042	10:50	T_L_	T1L_	T1L_	T_L_
043	11:00	T_L_	T_L_	T_L1	T_L_
044	11:10	T_L_	T_L_	T1L_	T_L_
046	11:30	T_L1	T_L_	T_L_	T_L1
048	11:50	T_L_	T_L_	T_L1	T_L_
049	12:00	T1L_	T_L_	T1L_	T_L_
051	12:20	T_L1	T_L_	T_L_	T_L_
055	13:00	T_L_	T_L1	T_L1	T_L_
056	13:10	T_L_	T1L_	T_L_	T_L_
057	13:20	T_L_	T_L_	T1L_	T_L_
061	14:00	T_L1	T_L_	T_L_	T_L1
066	14:50	T_L_	T_L_	T_L_	T2L_
067	15:00	T1L_	T_L_	T_L_	T_L_
068	15:10	T1L_	T_L_	T_L_	T_L_
070	15:30	T_L_	T_L_	T_L2	T_L_
072	15:50	T_L_	T_L_	T2L_	T_L_
074	16:10	T_L_	T_L_	T_L1	T_L_
075	16:20	T_L_	T_L_	T1L1	T_L_
078	16:50	T_L2	T_L_	T_L_	T_L_
080	17:10	T1L_	T_L_	T_L_	T_L_
082	17:30	T1L1	T_L_	T_L_	T_L_
083	17:40	T1L_	T_L_	T_L_	T_L_
086	18:10	T_L_	T_L1	T_L1	T_L_
088	18:30	T_L_	T1L1	T1L_	T_L_
089	18:40	T_L_	T1L_	T_L_	T_L_
092	19:10	T_L1	T_L_	T_L_	T_L1
094	19:30	T1L_	T_L_	T_L_	T1L_
095	19:40	T_L_	T_L_	T_L1	T_L_
096	19:50	T_L_	T_L_	T2L_	T_L_
098	20:10	T_L_	T_L1	T_L1	T_L_
100	20:30	T_L_	T_L_	T1L_	T_L_
102	20:50	T_L_	T_L1	T_L_	T_L_
103	21:00	T_L1	T1L_	T_L_	T_L_
106	21:30	T_L1	T_L_	T_L_	T_L_
108	21:50	T_L1	T_L_	T_L_	T_L_

Aircraft Related Data : case4

A/C Name	BTa hr.	BTb hr/km	CAPACITY SEAT	AVAI. A/C	MAX. Util. minutes
F100	0.4233	0.0014	100	2	540
F50	0.2798	0.0022	50	2	540

Airport Related Data : case4

About :	Airport Name AAA	BBB	CCC	DDD
Runway Cap.	2	2	2	2
A/C Alocation				
F100	0	2	0	0
F50	2	0	0	0
Turn Arround Time (minutes)				
F100	15	15	15	15
F50	10	10	10	10

Flight Schedule Per Aircraft of case4

Flight NO.	O-D	Dep. Time	A/C
MS0201	BBB-AAA	04:00	F100#01
MS0301	AAA-CCC	05:00	F100#01
MS0301	CCC-DDD	06:20	F100#01
MS0401	DDD-CCC	07:20	F100#01
MS0401	CCC-AAA	08:20	F100#01
MS0302	AAA-CCC	14:50	F100#01
MS0302	CCC-DDD	16:10	F100#01
MS0402	DDD-CCC	18:40	F100#01
MS0402	CCC-AAA	19:40	F100#01
MS0101	AAA-BBB	21:00	F100#01
MS0202	BBB-AAA	05:50	F100#02
MS0303	AAA-CCC	07:10	F100#02
MS0303	CCC-DDD	08:30	F100#02
MS0403	DDD-CCC	09:30	F100#02
MS0403	CCC-AAA	10:30	F100#02
MS0304	AAA-CCC	12:00	F100#02
MS0304	CCC-DDD	13:20	F100#02
MS0404	DDD-CCC	14:50	F100#02
MS0404	CCC-AAA	15:50	F100#02
MS0102	AAA-BBB	17:30	F100#02
MS0701	AAA-BBB	04:00	F50#01
MS0701	BBB-CCC	05:00	F50#01
MS0801	CCC-BBB	06:10	F50#01
MS0801	BBB-AAA	07:20	F50#01
MS0702	AAA-BBB	09:50	F50#01
MS0702	BBB-CCC	10:50	F50#01
MS0802	CCC-BBB	12:00	F50#01
MS0802	BBB-AAA	13:10	F50#01
MS0501	AAA-CCC	15:10	F50#01
MS0803	CCC-BBB	19:50	F50#01
MS0803	BBB-AAA	21:00	F50#01
MS0502	AAA-CCC	07:10	F50#02
MS0601	CCC-AAA	08:30	F50#02
MS0503	AAA-CCC	09:50	F50#02
MS0602	CCC-AAA	11:10	F50#02
MS0703	AAA-BBB	13:20	F50#02
MS0703	BBB-CCC	14:20	F50#02
MS0603	CCC-AAA	16:20	F50#02
MS0504	AAA-CCC	17:40	F50#02
MS0604	CCC-AAA	19:00	F50#02

Aircarft Utilization Per Day : case4

Aircraft	Utility/day (minutes)
F100#01	446.022
F100#02	446.022
F50#01	517.457
F50#02	537.665

Flight Frequency Per Day : case4

ROUTE NO.	FREQ/DAY REALIZED	PROPOSED	ITINERARY
001	2	2	AAA-BBB
002	2	2	BBB-AAA
003	4	5	AAA-CCC-DDD
004	4	5	DDD-CCC-AAA
005	4	4	AAA-CCC
006	4	4	CCC-AAA
007	3	3	AAA-BBB-CCC
008	3	3	CCC-BBB-AAA

Airport Statistics : case4

SLOT NO.	Time	Activities in A/P AAA	BBB	CCC	DDD
001	04:00	T1L_	T1L_	T_L_	T_L_
005	04:40	T_L1	T_L_	T_L_	T_L_
006	04:50	T_L_	T_L1	T_L_	T_L_
007	05:00	T1L_	T1L_	T_L_	T_L_
012	05:50	T_L_	T1L_	T_L_	T_L_
013	06:00	T_L_	T_L_	T_L2	T_L_
014	06:10	T_L_	T_L_	T1L_	T_L_
015	06:20	T_L_	T_L_	T1L_	T_L_
016	06:30	T_L1	T_L_	T_L_	T_L_
019	07:00	T_L_	T_L_	T_L_	T_L1
020	07:10	T2L_	T_L1	T_L_	T_L_
021	07:20	T_L_	T1L_	T_L_	T1L_
025	08:00	T_L_	T_L_	T_L1	T_L_
026	08:10	T_L1	T_L_	T_L1	T_L_
027	08:20	T_L_	T_L_	T1L1	T_L_
028	08:30	T_L_	T_L_	T2L_	T_L_
032	09:10	T_L_	T_L_	T_L_	T_L1
033	09:20	T_L1	T_L_	T_L_	T_L_
034	09:30	T_L_	T_L_	T_L_	T1L_
035	09:40	T_L1	T_L_	T_L_	T_L_
036	09:50	T2L_	T_L_	T_L_	T_L_
038	10:10	T_L_	T_L_	T_L1	T_L_
040	10:30	T_L_	T_L_	T1L_	T_L_
041	10:40	T_L_	T_L1	T_L_	T_L_
042	10:50	T_L_	T1L_	T_L_	T_L_
043	11:00	T_L_	T_L_	T_L1	T_L_
044	11:10	T_L_	T_L_	T1L_	T_L_
046	11:30	T_L1	T_L_	T_L_	T_L_
048	11:50	T_L_	T_L_	T_L1	T_L_
049	12:00	T1L_	T_L_	T1L_	T_L_
051	12:20	T_L1	T_L_	T_L_	T_L_
055	13:00	T_L_	T_L1	T_L1	T_L_
056	13:10	T_L_	T1L_	T_L_	T_L_
057	13:20	T1L_	T_L_	T1L_	T_L_
061	14:00	T_L1	T_L_	T_L_	T_L1
062	14:10	T_L_	T_L1	T_L_	T_L_
063	14:20	T_L_	T1L_	T_L_	T_L_
066	14:50	T1L_	T_L_	T_L_	T1L_
068	15:10	T1L_	T_L_	T_L_	T_L_
069	15:20	T_L_	T_L_	T_L1	T_L_
070	15:30	T_L_	T_L_	T_L1	T_L_
072	15:50	T_L_	T_L_	T1L1	T_L_
074	16:10	T_L_	T_L_	T1L_	T_L_
075	16:20	T_L_	T_L_	T1L1	T_L_
078	16:50	T_L1	T_L_	T_L_	T_L1
082	17:30	T1L1	T_L_	T_L_	T_L_
083	17:40	T1L_	T_L_	T_L_	T_L_
086	18:10	T_L_	T_L1	T_L_	T_L_
089	18:40	T_L_	T_L_	T_L_	T1L_
090	18:50	T_L_	T_L_	T_L1	T_L_
091	19:00	T_L_	T_L_	T1L_	T_L_
093	19:20	T_L_	T_L_	T_L1	T_L_
095	19:40	T_L_	T_L_	T1L_	T_L_
096	19:50	T_L_	T_L_	T1L_	T_L_
098	20:10	T_L1	T_L_	T_L_	T_L_
101	20:40	T_L1	T_L_	T_L_	T_L_
102	20:50	T_L_	T_L1	T_L_	T_L_
103	21:00	T1L_	T1L_	T_L_	T_L_
107	21:40	T_L_	T_L1	T_L_	T_L_
108	21:50	T_L1	T_L_	T_L_	T_L_

Aircraft Related Data : case5

A/C Name	BTa hr.	BTb hr/km	CAPACITY SEAT	AVAI. A/C	MAX. Util. minutes
F100	0.4233	0.0014	100	2	540
F50	0.2798	0.0022	50	2	540

Airport Related Data : case5

About :	Airport Name AAA	BBB	CCC	DDD
Runway Cap.	2	2	2	2
A/C Alocation				
F100	2	0	0	0
F50	0	0	2	0
Turn Arround Time (minutes)				
F100	15	15	15	15
F50	10	10	10	10

Flight Schedule Per Aircraft of case5

Flight NO.	O-D	Dep. Time	A/C
MS0301	AAA-CCC	07:10	F100#01
MS0301	CCC-DDD	08:30	F100#01
MS0401	DDD-CCC	09:30	F100#01
MS0401	CCC-AAA	10:30	F100#01
MS0302	AAA-CCC	12:00	F100#01
MS0302	CCC-DDD	13:20	F100#01
MS0402	DDD-CCC	14:30	F100#01
MS0402	CCC-AAA	15:30	F100#01
MS0303	AAA-CCC	17:10	F100#01
MS0303	CCC-DDD	18:30	F100#01
MS0304	AAA-CCC	04:50	F100#02
MS0304	CCC-DDD	06:10	F100#02
MS0403	DDD-CCC	07:10	F100#02
MS0403	CCC-AAA	08:10	F100#02
MS0305	AAA-CCC	09:30	F100#02
MS0305	CCC-DDD	10:50	F100#02
MS0404	DDD-CCC	14:50	F100#02
MS0404	CCC-AAA	15:50	F100#02
MS0101	AAA-BBB	17:10	F100#02
MS0201	BBB-AAA	18:10	F100#02
MS0102	AAA-BBB	19:10	F100#02
MS0202	BBB-AAA	20:10	F100#02
MS0801	CCC-BBB	04:00	F50#01
MS0801	BBB-AAA	05:10	F50#01
MS0701	AAA-BBB	09:20	F50#01
MS0701	BBB-CCC	10:20	F50#01
MS0802	CCC-BBB	11:50	F50#01
MS0802	BBB-AAA	13:00	F50#01
MS0501	AAA-CCC	14:40	F50#01
MS0601	CCC-AAA	16:20	F50#01
MS0502	AAA-CCC	19:50	F50#01
MS0602	CCC-AAA	05:40	F50#02
MS0503	AAA-CCC	07:10	F50#02
MS0603	CCC-AAA	08:30	F50#02
MS0504	AAA-CCC	09:50	F50#02
MS0803	CCC-BBB	11:30	F50#02
MS0803	BBB-AAA	12:40	F50#02
MS0702	AAA-BBB	13:40	F50#02
MS0702	BBB-CCC	14:40	F50#02
MS0604	CCC-AAA	16:10	F50#02

Aircarft Utilization Per Day : case5

Aircraft	Utility/day (minutes)
F100#01	458.280
F100#02	525.420
F50#01	463.712
F50#02	500.688

Flight Frequency Per Day : case5

ROUTE NO.	FREQ/DAY REALIZED	FREQ/DAY PROPOSED	ITINERARY
001	2	2	AAA-BBB
002	2	2	BBB-AAA
003	5	5	AAA-CCC-DDD
004	4	5	DDD-CCC-AAA
005	4	4	AAA-CCC
006	4	4	CCC-AAA
007	2	3	AAA-BBB-CCC
008	3	3	CCC-BBB-AAA

Airport Statistics : case5

SLOT NO.	Time	Activities in A/P AAA	BBB	CCC	DDD
001	04:00	T L	T L	T1L	T L
006	04:50	T1L	T L	T L	T L
007	05:00	T L	T L1	T L	T L
008	05:10	T L	T1L	T L	T L
011	05:40	T L	T L	T1L	T L
012	05:50	T L	T L	T L1	T L
013	06:00	T L1	T L	T L	T L
014	06:10	T L	T L	T1L	T L
018	06:50	T L1	T L	T L	T L1
020	07:10	T2L	T L	T L	T1L
024	07:50	T L	T L	T L1	T L
026	08:10	T L	T L	T1L1	T L
027	08:20	T L	T L	T L1	T L
028	08:30	T L	T L	T2L	T L
032	09:10	T L1	T L	T L	T L1
033	09:20	T1L	T L	T L	T L
034	09:30	T1L	T L	T L	T1L
035	09:40	T L1	T L	T L	T L
036	09:50	T1L	T L	T L	T L
038	10:10	T L	T L1	T L1	T L
039	10:20	T L	T1L	T L	T L
040	10:30	T L	T L	T1L1	T L
042	10:50	T L	T L	T1L	T L
043	11:00	T L	T L	T L1	T L
045	11:20	T L	T L	T L1	T L
046	11:30	T L1	T L	T1L	T L1
048	11:50	T L	T L	T1L	T L
049	12:00	T1L	T L	T L	T L
052	12:30	T L	T L1	T L	T L
053	12:40	T L	T1L	T L	T L
054	12:50	T L	T L1	T L	T L
055	13:00	T L	T1L	T L1	T L
057	13:20	T L	T L	T1L	T L
058	13:30	T L1	T L	T L	T L
059	13:40	T1L	T L	T L	T L
060	13:50	T L1	T L	T L	T L
061	14:00	T L	T L	T L	T L1
064	14:30	T L	T L1	T L	T1L
065	14:40	T1L	T1L	T L	T L
066	14:50	T L	T L	T L	T1L
068	15:10	T L	T L	T L1	T L
070	15:30	T L	T L	T1L1	T L
071	15:40	T L	T L	T L1	T L
072	15:50	T L	T L	T1L1	T L
074	16:10	T L	T L	T1L	T L
075	16:20	T L	T L	T1L	T L
076	16:30	T L1	T L	T L	T L
078	16:50	T L1	T L	T L	T L
080	17:10	T2L	T L	T L	T L
081	17:20	T L1	T L	T L	T L
082	17:30	T L1	T L	T L	T L
084	17:50	T L	T L1	T L	T L
086	18:10	T L	T1L	T L1	T L
088	18:30	T L	T L	T1L	T L
090	18:50	T L1	T L	T L	T L
092	19:10	T1L	T L	T L	T L1
096	19:50	T1L	T L1	T L	T L
098	20:10	T L	T1L	T L	T L
102	20:50	T L1	T L	T L	T L
103	21:00	T L	T L	T L1	T L

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Aircraft Related Data : case6
==============================================================
A/C Name     BTa     BTb      CAPACITY   AVAI.   MAX. Util.
             hr.     hr/km      SEAT      A/C     minutes
--------------------------------------------------------------
   F100    0.4233  0.0014       100        2        540
    F50    0.2798  0.0022        50        2        540
--------------------------------------------------------------


Airport Related Data : case6
==========================================================
                    Airport Name
  About :              AAA       BBB       CCC       DDD
----------------------------------------------------------

  Runway Cap.           2         2         2         2

  A/C Alocation
        F100            2         0         0         0

         F50            1         0         1         0

  Turn Arround Time (minutes)
        F100           15        15        15        15

         F50           10        10        10        10

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Flight Schedule Per Aircraft of case6

Flight NO.	O-D	Dep. Time	A/C
MS0301	AAA-CCC	04:50	F100#01
MS0301	CCC-DDD	06:10	F100#01
MS0401	DDD-CCC	07:10	F100#01
MS0401	CCC-AAA	08:10	F100#01
MS0302	AAA-CCC	09:30	F100#01
MS0302	CCC-DDD	10:50	F100#01
MS0402	DDD-CCC	14:50	F100#01
MS0402	CCC-AAA	15:50	F100#01
MS0101	AAA-BBB	17:10	F100#01
MS0201	BBB-AAA	18:10	F100#01
MS0102	AAA-BBB	19:10	F100#01
MS0202	BBB-AAA	20:10	F100#01
MS0303	AAA-CCC	04:50	F100#02
MS0303	CCC-DDD	06:10	F100#02
MS0403	DDD-CCC	07:10	F100#02
MS0403	CCC-AAA	08:10	F100#02
MS0304	AAA-CCC	17:10	F100#02
MS0304	CCC-DDD	18:30	F100#02
MS0404	DDD-CCC	19:30	F100#02
MS0404	CCC-AAA	20:30	F100#02
MS0701	AAA-BBB	04:00	F50#01
MS0701	BBB-CCC	05:00	F50#01
MS0601	CCC-AAA	08:30	F50#01
MS0501	AAA-CCC	09:50	F50#01
MS0801	CCC-BBB	11:30	F50#01
MS0801	BBB-AAA	12:40	F50#01
MS0702	AAA-BBB	14:00	F50#01
MS0702	BBB-CCC	15:00	F50#01
MS0602	CCC-AAA	16:10	F50#01
MS0502	AAA-CCC	19:50	F50#01
MS0802	CCC-BBB	04:00	F50#02
MS0802	BBB-AAA	05:10	F50#02
MS0503	AAA-CCC	07:10	F50#02
MS0603	CCC-AAA	08:30	F50#02
MS0504	AAA-CCC	09:50	F50#02
MS0803	CCC-BBB	11:30	F50#02
MS0803	BBB-AAA	12:40	F50#02
MS0703	AAA-BBB	13:40	F50#02
MS0703	BBB-CCC	14:40	F50#02
MS0604	CCC-AAA	16:10	F50#02

Aircarft Utilization Per Day : case6

Aircraft	Utility/day (minutes)
F100#01	525.420
F100#02	366.624
F50#01	527.561
F50#02	527.561

Flight Frequency Per Day : case6

ROUTE NO.	FREQ/DAY REALIZED	FREQ/DAY PROPOSED	ITINERARY
001	2	2	AAA-BBB
002	2	2	BBB-AAA
003	4	5	AAA-CCC-DDD
004	4	5	DDD-CCC-AAA
005	4	4	AAA-CCC
006	4	4	CCC-AAA
007	3	3	AAA-BBB-CCC
008	3	3	CCC-BBB-AAA

Airport Statistics : case6

SLOT NO.	Time	Activities in A/P AAA	BBB	CCC	DDD
001	04:00	T1L_	T_L_	T1L_	T_L_
006	04:50	T2L_	T_L1	T_L_	T_L_
007	05:00	T_L_	T1L1	T_L_	T_L_
008	05:10	T_L_	T1L_	T_L_	T_L_
012	05:50	T_L_	T_L_	T_L2	T_L_
013	06:00	T_L1	T_L_	T_L1	T_L_
014	06:10	T_L_	T_L_	T2L_	T_L_
018	06:50	T_L_	T_L_	T_L_	T_L2
020	07:10	T1L_	T_L_	T_L_	T2L_
024	07:50	T_L_	T_L_	T_L2	T_L_
026	08:10	T_L_	T_L_	T2L_	T_L_
027	08:20	T_L_	T_L_	T_L1	T_L_
028	08:30	T_L_	T_L_	T2L_	T_L_
032	09:10	T_L2	T_L_	T_L_	T_L_
034	09:30	T1L_	T_L_	T_L_	T_L_
035	09:40	T_L2	T_L_	T_L_	T_L_
036	09:50	T2L_	T_L_	T_L_	T_L_
040	10:30	T_L_	T_L_	T_L1	T_L_
042	10:50	T_L_	T_L_	T1L_	T_L_
043	11:00	T_L_	T_L_	T_L2	T_L_
046	11:30	T_L_	T_L_	T2L_	T_L1
052	12:30	T_L_	T_L2	T_L_	T_L_
053	12:40	T_L_	T2L_	T_L_	T_L_
058	13:30	T_L2	T_L_	T_L_	T_L_
059	13:40	T1L_	T_L_	T_L_	T_L_
061	14:00	T1L_	T_L_	T_L_	T_L_
064	14:30	T_L_	T_L1	T_L_	T_L_
065	14:40	T_L_	T1L_	T_L_	T_L_
066	14:50	T_L_	T_L1	T_L_	T1L_
067	15:00	T_L_	T1L_	T_L_	T_L_
070	15:30	T_L_	T_L_	T_L1	T_L_
071	15:40	T_L_	T_L_	T_L1	T_L_
072	15:50	T_L_	T_L_	T1L_	T_L_
073	16:00	T_L_	T_L_	T_L1	T_L_
074	16:10	T_L_	T_L_	T2L_	T_L_
078	16:50	T_L1	T_L_	T_L_	T_L_
080	17:10	T2L_	T_L_	T_L_	T_L_
081	17:20	T_L2	T_L_	T_L_	T_L_
084	17:50	T_L_	T_L1	T_L_	T_L_
086	18:10	T_L_	T1L_	T_L1	T_L_
088	18:30	T_L_	T_L_	T1L_	T_L_
090	18:50	T_L1	T_L_	T_L_	T_L_
092	19:10	T1L_	T_L_	T_L_	T_L1
094	19:30	T_L_	T_L_	T_L_	T1L_
096	19:50	T1L_	T_L1	T_L_	T_L_
098	20:10	T_L_	T1L_	T_L1	T_L_
100	20:30	T_L_	T_L_	T1L_	T_L_
102	20:50	T_L1	T_L_	T_L_	T_L_
103	21:00	T_L_	T_L_	T_L1	T_L_
106	21:30	T_L1	T_L_	T_L_	T_L_

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 Aircraft Related Data : case7
==============================================================
 A/C Name     BTa    BTb      CAPACITY   AVAI.  MAX. Util.
              hr.   hr/km       SEAT      A/C    minutes
--------------------------------------------------------------
    F100    0.4233  0.0014      100        2       800
     F50    0.2798  0.0022       50        2       800
--------------------------------------------------------------
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```
 Airport Related Data : case7
=========================================================
                  Airport Name
  About :            AAA       BBB       CCC       DDD
---------------------------------------------------------

  Runway Cap.         2         2         2         2

  A/C Alocation
        F100          2         0         0         0

         F50          2         0         0         0

  Turn Arround Time (minutes)
        F100          15        15        15        15

         F50          10        10        10        10

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Flight Schedule Per Aircraft of case7

Flight NO.	O-D	Dep. Time	A/C
MS0301	AAA-CCC	05:45	F100#01
MS0301	CCC-DDD	06:55	F100#01
MS0401	DDD-CCC	07:50	F100#01
MS0401	CCC-AAA	08:45	F100#01
MS0302	AAA-CCC	09:55	F100#01
MS0302	CCC-DDD	11:05	F100#01
MS0402	DDD-CCC	14:50	F100#01
MS0402	CCC-AAA	15:45	F100#01
MS0101	AAA-BBB	16:55	F100#01
MS0201	BBB-AAA	17:50	F100#01
MS0102	AAA-BBB	18:45	F100#01
MS0202	BBB-AAA	19:40	F100#01
MS0303	AAA-CCC	05:45	F100#02
MS0303	CCC-DDD	06:55	F100#02
MS0403	DDD-CCC	07:50	F100#02
MS0403	CCC-AAA	08:45	F100#02
MS0304	AAA-CCC	09:55	F100#02
MS0304	CCC-DDD	11:05	F100#02
MS0404	DDD-CCC	14:50	F100#02
MS0404	CCC-AAA	15:45	F100#02
MS0305	AAA-CCC	16:55	F100#02
MS0305	CCC-DDD	18:05	F100#02
MS0405	DDD-CCC	19:10	F100#02
MS0405	CCC-AAA	20:05	F100#02
MS0701	AAA-BBB	04:00	F50#01
MS0701	BBB-CCC	04:55	F50#01
MS0601	CCC-AAA	08:05	F50#01
MS0501	AAA-CCC	09:20	F50#01
MS0801	CCC-BBB	11:35	F50#01
MS0801	BBB-AAA	12:40	F50#01
MS0502	AAA-CCC	15:05	F50#01
MS0602	CCC-AAA	16:20	F50#01
MS0702	AAA-BBB	17:45	F50#01
MS0702	BBB-CCC	18:40	F50#01
MS0802	CCC-BBB	19:50	F50#01
MS0802	BBB-AAA	20:55	F50#01
MS0703	AAA-BBB	04:00	F50#02
MS0703	BBB-CCC	04:55	F50#02
MS0603	CCC-AAA	08:05	F50#02
MS0503	AAA-CCC	09:20	F50#02
MS0803	CCC-BBB	11:30	F50#02
MS0803	BBB-AAA	12:35	F50#02
MS0504	AAA-CCC	15:05	F50#02
MS0604	CCC-AAA	16:20	F50#02

Aircarft Utilization Per Day : case7

Aircraft	Utility/day (minutes)
F100#01	525.420
F100#02	549.936
F50#01	618.282
F50#02	436.839

Flight Frequency Per Day : case7

ROUTE NO.	FREQ/DAY REALIZED	PROPOSED	ITINERARY
001	2	2	AAA-BBB
002	2	2	BBB-AAA
003	5	5	AAA-CCC-DDD
004	5	5	DDD-CCC-AAA
005	4	4	AAA-CCC
006	4	4	CCC-AAA
007	3	3	AAA-BBB-CCC
008	3	3	CCC-BBB-AAA

Airport Statistics : case7

SLOT NO.	Time	Activities in A/P AAA	BBB	CCC	DDD
001	04:00	T2L	T_L	T_L	T_L
010	04:45	T_L	T_L2	T_L	T_L
012	04:55	T_L	T2L	T_L	T_L
022	05:45	T2L	T_L	T_L	T_L
023	05:50	T_L	T_L	T_L2	T_L
033	06:40	T_L	T_L	T_L2	T_L
036	06:55	T_L	T_L	T2L	T_L
044	07:35	T_L	T_L	T_L	T_L2
047	07:50	T_L	T_L	T_L	T2L
050	08:05	T_L	T_L	T2L	T_L
055	08:30	T_L	T_L	T_L2	T_L
058	08:45	T_L	T_L	T2L	T_L
063	09:10	T_L2	T_L	T_L	T_L
065	09:20	T2L	T_L	T_L	T_L
069	09:40	T_L2	T_L	T_L	T_L
072	09:55	T2L	T_L	T_L	T_L
078	10:25	T_L	T_L	T_L2	T_L
083	10:50	T_L	T_L	T_L2	T_L
086	11:05	T_L	T_L	T2L	T_L
091	11:30	T_L	T_L	T1L	T_L
092	11:35	T_L	T_L	T1L	T_L
094	11:45	T_L	T_L	T_L	T_L2
102	12:25	T_L	T_L1	T_L	T_L
103	12:30	T_L	T_L1	T_L	T_L
104	12:35	T_L	T1L	T_L	T_L
105	12:40	T_L	T1L	T_L	T_L
113	13:20	T_L1	T_L	T_L	T_L
114	13:25	T_L1	T_L	T_L	T_L
131	14:50	T_L	T_L	T_L	T2L
134	15:05	T2L	T_L	T_L	T_L
139	15:30	T_L	T_L	T_L2	T_L
142	15:45	T_L	T_L	T2L	T_L
147	16:10	T_L	T_L	T_L2	T_L
149	16:20	T_L	T_L	T2L	T_L
153	16:40	T_L2	T_L	T_L	T_L
156	16:55	T2L	T_L	T_L	T_L
162	17:25	T_L2	T_L	T_L	T_L
164	17:35	T_L	T_L1	T_L	T_L
166	17:45	T1L	T_L	T_L	T_L
167	17:50	T_L	T1L	T_L1	T_L
170	18:05	T_L	T_L	T1L	T_L
175	18:30	T_L1	T_L1	T_L	T_L
177	18:40	T_L	T1L	T_L	T_L
178	18:45	T1L	T_L	T_L	T_L1
183	19:10	T_L	T_L	T_L	T1L
186	19:25	T_L	T_L1	T_L	T_L
188	19:35	T_L	T_L	T_L1	T_L
189	19:40	T_L	T1L	T_L	T_L
191	19:50	T_L	T_L	T1L1	T_L
194	20:05	T_L	T_L	T1L	T_L
197	20:20	T_L1	T_L	T_L	T_L
202	20:45	T_L	T_L1	T_L	T_L
204	20:55	T_L	T1L	T_L	T_L
205	21:00	T_L1	T_L	T_L	T_L
213	21:40	T_L1	T_L	T_L	T_L

Memorandum 678

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