PERIODICA POLYTECHNICA SER. TRANSP. ENG. VOL. 31, NO. 1–2, PP. 3–16 (2003)

MODERN CREW MANAGEMENT METHODS IN AIR TRANSPORT

Botond KŐVÁRI

Department of Transport Economics
Budapest University of Technology and Economics
H–1111 Budapest, Bertalan Lajos u. 2., Hungary
e-mail: bkovari@kgazd.bme.hu

Received: September 10, 2002

Abstract

Crew cost is the second highest in the total operating cost of an airline, after fuel. That is because, the effective management of the crew is very important. Crew management means the allocation mechanism of the existing cockpit and cabin crew to the flights. In this paper I introduce the steps of the crew planning, the determining factors, methods for optimisation, and one of the most popular planning software.

Keywords: air transport, crew management, crew planning, crew optimisation, Carmen software.

1. Crew Categories

A definite amount of crew persons is requested, for flights of each category. Crew can be grouped into two types:

- Cockpit crew. Captain, assistant pilot and on older airplane types the board engineer, too. Most pilots have licence for more airplane types, this way the airline can save money.
- Cabin crew. Stewardesses and the leading stewardess, in most cases they are allowed to operate on all airplane types of the airline.

The problem of the crew management means to select the requested number of persons in each category, because they cannot substitute each other.

2. Phases of Planning

Fig. 1 shows the main operating plan of an airline, from the view of crew management.

Of course these phases are always changing, they are interdependent. Until the final publication of the schedule many changes may happen. The steps are as follows:

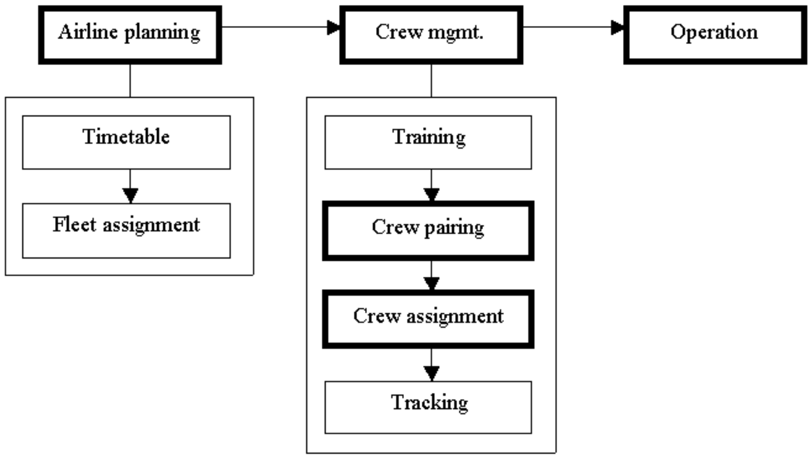

Fig. 1. Phases of the fleet and crew planning of an airline

- *Timetable*: elaboration of the schedule considering the market demands, the possibilities of the airline and the slots (allowed landing times).
- *Fleet assignment*: assigning a plane to the flight. Factors for consideration: market demand (passenger number), constraints (e.g. which type of plane cannot land at an airport). If the schedule cannot be completed with the given fleet, re-planning is needed. The aim is to select a plane for each flight to get the highest profit, which means, in optimal case, that the occupancy is 100%.
- *Training*: education, continuous teaching and simulation practices for the crew.
- *Crew pairing*: determination of the number of crew members for a given flight, in each category. It does not mean the assignment of any person, the object is to establish the number of crew members flying from and to a given airport. The selected persons for a flight are not always working, they are sometimes only transferred to the destination airport.
- *Crew assignment*: assign a person to the flight. Factors to take into consideration: labour time limitation, minimal required flight hours, holiday, licence for an airplane type and special conditions. Crew gets a fix salary in Europe, so it is promoted to let them work as much as possible to save number of crew and money.
- *Tracking*: monitoring of the daily operation, handling irregularities.

3. Factors to Be Taken into Consideration during the Planning Procedure

Regulations to be taken into account during the planning procedure can be classified into two groups:

- international and governmental regulations,
- internal regulations of the airline.

In Europe, the internal rules are generally stricter than the governmental ones, they are properly elaborated, up to date, and so they are less documented.

The rules, which are to be taken into account, are determined in the Labour- and Rest Time Regulation of the airline. They primarily deal with the maximum allowed and the minimal required flight hours. Considering this the most important *daily limits* are as follows:

- the net flying time for one day is maximum 9 hours, for long distance flights 10 hours,
- the minimal required rest time is 12 hours, and not less than the working time the day before. It can be minimally 8 hours, if the crew was informed 24 hours before, and they did not work during the previous 24 hours.

Here two important definitions must be made:

- Flying time: the blocktime, time from push back until stop.
- Labour time: flying time + time of reporting for work + reserve service time + training + ... Report for work is 70 minutes before departure time. After determining the labour time the free time can be calculated.

Arrangement of the crew is *affected* by many factors:

- crew requests (night working time, early finish, late begin, . . .),
- location of crew basis, and airports where hotels are needed,
- how many persons can be accommodated in each basis,
- predetermined matching (typically captain – assistant pilot),
- equal distribution of labour between crew members,
- preferences for flights (seniority),
- various flights,
- limitations (special approach, appropriate experience, . . .),
- co-ordination of management and crew aims.

Network structure also influences the crew pairing and the nowadays spreading hub & spoke system makes not only the fleet, but also the crew planning difficult.

The time periods, when crew is *not available* are the following:

- deadhead, the person is flying but not working, e.g. he or she must be transferred to the destination airport, where he will begin to work,
- holiday,
- illness,
- take part in conference,
- recreation holiday,
- training,
- holiday remained from the previous period.

Table 1. Activities planned in advance

Name	Day														
	MO	TU	WE	TH	FR	SA	SU	MO	TU	WE	TH	FR	SA	SU	...
John Smith	CO										RF				
Steve Tylor					SA							HP	HP	HP	
Andrew Szabo	HP	HP	HP	HP	HP	HP	CO								
Jan Ford	RF	RF											SA		

CO: Conference, RF: Requested Freeday, SA: Simulation Abroad, HP: Holiday Packet.

The activities planned in advance must be taken into account, it can be published in a form of a table (*Table1*), but in case of unexpected fall out *spare crew* must be at service.

The following activities belong neither to work, nor to rest time:

- travel between home and the airport,
- transfer between two flights at the airport.

In *Table 2* I summarise the factors to be taken into account in North America and in Europe.

Table 2. Factors in North America and in Europe

	North America	Europe
Crew category	Crew pairing is by categories	
Relationship between fleet and crew	Assigning cockpit crew is by airplane type and with cabin crew simultaneously	
Network structure	Hub & spoke	Less structured
Regulations	Most important are the FAA regulations	Often changing airline rules
Schedule	From Monday to Friday the same	Less periodical
Crew payment	After flying hours	Fixed

4. Levels of Crew Planning

The schedule changes two times a year. The number of crew members is determined for a year, but many changes happen during the season. The requested number of crew members will be determined taking into account the following:

- the requested number of crew members for performing the schedule (pairing),
- spare, standby crew,
- crew needed because of other reasons (e.g. unexpected illness).

Deterministic factors *for a year* are holidays and the minimal required flying hours.

The planning period is a *month*. The steps of setting up the monthly plan for a person, are following:

- other activities, days when the person is unavailable,
- flights to performance,
- spare and standby days,
- free days.

The monthly plan must be published 168 hours before its starting day.

96 hours before reporting for work the *daily plan* must be at hand.

5. Optimisation Methods

5.1. The Daily Problem

The objective is of the *day* is to assign the appropriate crew for all flights. This method can be perfectly applied, when the schedule is the same every day. In any other case this method also gives the basis for planning.

In *Table 3* a simple daily problem is presented.

Table 3. Daily problem with six flights

Flight nr.	From	To	Departure time	Arrival time	Flying time
1	A	B	7:30	9:00	1.5
2	B	A	9:45	11:15	1.5
3	A	B	12:00	13:30	1.5
4	B	A	14:15	15:45	1.5
5	C	A	5:00	11:00	6
6	A	C	12:30	18:30	6

The airport ‘A’ is viewed as the *basis*, on the other two hotels are needed.

Fig. 2 shows the three airports and the flying time between them.

It is clear, that for the long distance flight (A-C) two crews are required, because flying there and back takes much more than 12 hours.

Fig. 3 shows the flights on a Gant-diagram. The mark of a flight is a rectangle, the number in it is the flight number. Above the mark there is the number of the

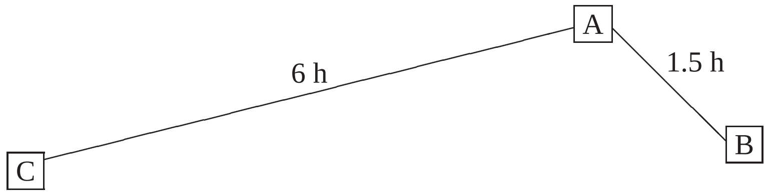

Fig. 2. The airports according to the example

crews, before and after the mark there are the departure and arrival airports. In total we use three crews.

The first solution (**a**) works with two crews on the long distance flight, and the 1-2-3-4 flights are covered by the third crew. By the other idea (**b**) the crew assigned to the long distance also covers one of the short distance flights, so the third crew must only be used on every second day. This is the optimal solution.

In case **a)** the crew allocation is the same every day, with the remark that the 2. and 3. crew are handled together. Of course one crew covers one day the morning, the other day the afternoon long distance flight. Crew 1 operates between the airports 'A' and 'B', the basis is airport 'A'. Crews 2 and 3 work between 'C' and 'A', so on airport 'C' housing is needed.

In the optimal case (**b**) the assignment repeats every second day. Crews 1 and 2 work between airports 'A', 'B' and 'C', hotel is needed at airport 'C'. Crew 3 works between 'A' and 'B', no hotel required.

To make the comparison easy, I illustrate both cases for two days.

In the first case all the three crews are needed every day, but in the optimal case the third crew is required only every second day, so the number of crews required for one day is 2.5!

The *assignment of the crews* can be graphically shown like that of the airplanes. In *Fig. 4* the optimal solution (**b**) is presented. The flight number is still in the rectangle.

5.2. Solving the Daily Problem with Linear Programming

The problem can be solved in two steps:

- determine all possible pairings,
- choose the optimal solution so that all flights are covered.

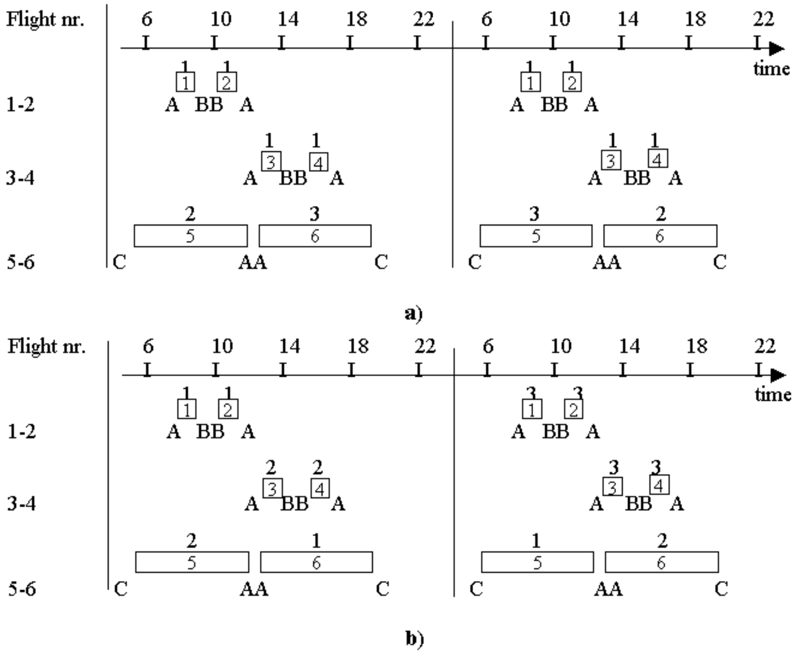

Fig. 3. Solution possibilities

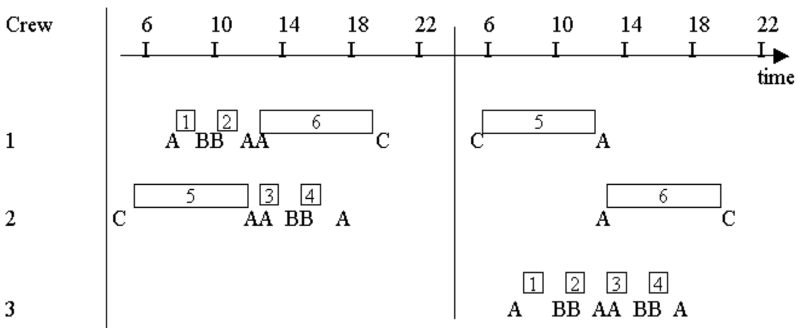

Fig. 4. The optimal allocation of the crews showed in Gant-diagram

5.2.1. Determining All Possible Pairings

For the schedule shown in *Table* 3 I first determine how many possibilities are available to allocate a crew for the flights. There are 17 solutions, so a crew can work in 17 combinations on the flights. There are also such assignments which repeat every second day, so the crews work changing each other. This means 2 crews, but I handle them as one. All possibilities are shown in *Table* 4. Reading the table: number: pairing number, flight: the flight to which the crew is assigned, c: change (layover), piece: how many crews are required (by change it is two), airports: on which airport the crew begins and ends the work. If housing is needed, I mark the location bold and underlined.

Table 4. All possible pairings

Number	Flight	Piece	Airports	Number	Flight	Piece	Airports
p1	5-c-6	2	**C**, A	p10	6-c-5-3-4	2	A, **C**
p2	5-c-1-2-6	2	**C**, A	p11	1-c-2	2	A, **B**
p3	5-3-c-2-6	2	C, **B**	p12	1-c-4	2	A, **B**
p4	5-3-4-c-6	2	**C**, A	p13	1-c-2-3-4	2	A, **B**
p5	1-2	1	A	p14	1-2-3-c-2	2	A, **B**
p6	1-4	1	A	p15	1-2-3-c-2-3-4	2	A, **B**
p7	3-4	1	A	p16	3-c-2	2	A, **B**
p8	1-2-3-4	1	A	p17	3-c-2-3-4	2	A, **B**
p9	6-c-5	2	A, **C**				

5.2.2. Choose the Optimal Solution

We have to choose the pairings, which are able to cover all flights with minimal cost. One pairing always means one unit cost, if two crews are needed (with change), the cost is also double.

The *objective function* is:

$$\sum_P c_p x_p \to \min .$$

subject to:

$$\sum a_{ip} x_p = n_i , \tag{1}$$

$$\sum b_{jp} x_p \leq m_j , \tag{2}$$

$$x_p \geq 0, \tag{3}$$

where
- c_p cost of the crew,
- x_p decision factor, whether the pair is used or not,
- P all possible pairings (in this case 1..17),
- a_{ip} how many times flight i. is covered by crew p.,
- n_i all crews required for flight i.,

i	flight number (in this case 1..6),
j	set of labour time constraints,
b_{jp}	working time of crew p,
m_j	labour time limitations.

The first constraint means that all flights must be covered, the second means that labour time limitation cannot be exceeded.

The value of x_p is 1 if the crew is used every day, 0 if it is not used. If it is used every second day, $x_p = 0.5$.

There are $x_{1..17}$ in the example for the usage factors for all pairings (according to *Table 4*).

The objective function is:

$$2x_1 + 2x_2 + 2x_3 + 2x_4 + x_5 + x_6 + x_7 + x_8 + 2x_9 + 2x_{10} + \\ + 2x_{11} + 2x_{12} + 2x_{13} + 2x_{14} + 2x_{15} + 2x_{16} + 2x_{17} \to \min .$$

The constraint that every flight must be covered exactly one time, results the following: an assigned crew must be determined for all flights (according to *Table 4*). If the crew is used two times I notice it here two times, too.

$$\begin{aligned}
&\text{Flight 1.}: && x_2 + x_5 + x_6 + x_8 + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} && = 1 \\
&\text{Flight 2.}: && x_2 + x_3 + x_5 + x_8 + x_{11} + x_{13} + 2x_{14} + 2x_{15} + x_{16} + x_{17} && = 1 \\
&\text{Flight 3.}: && x_3 + x_4 + x_7 + x_8 + x_{10} + x_{13} + x_{14} + 2x_{15} + x_{16} + 2x_{17} && = 1 \\
&\text{Flight 4.}: && x_4 + x_6 + x_7 + x_8 + x_{10} + x_{12} + x_{13} + x_{15} + x_{17} && = 1 \\
&\text{Flight 5.}: && x_1 + x_2 + x_3 + x_4 + x_9 + x_{10} && = 1 \\
&\text{Flight 6.}: && x_1 + x_2 + x_3 + x_4 + x_9 + x_{10} && = 1
\end{aligned}$$

Solution

1. If the value of x_i is limited by 0 or 1, that means the allocation is the same every day, because the crew which is required is used every day.
   The problem can be solved with the Excel software, with solver. In the initial step I determine all x_i value in 1, this is shown in *Fig. 5*.
   The available pairings are in the second row, and the total cost, which is to be minimised is in the cell R7. The constraints, that for all flights one and only one crew must be assigned are in the areas C10..15 and G10..15.
   In this case a solution can be:

$$x_1 = x_8 = 1, \text{ for the other } i \text{ values } x_i = 0.$$

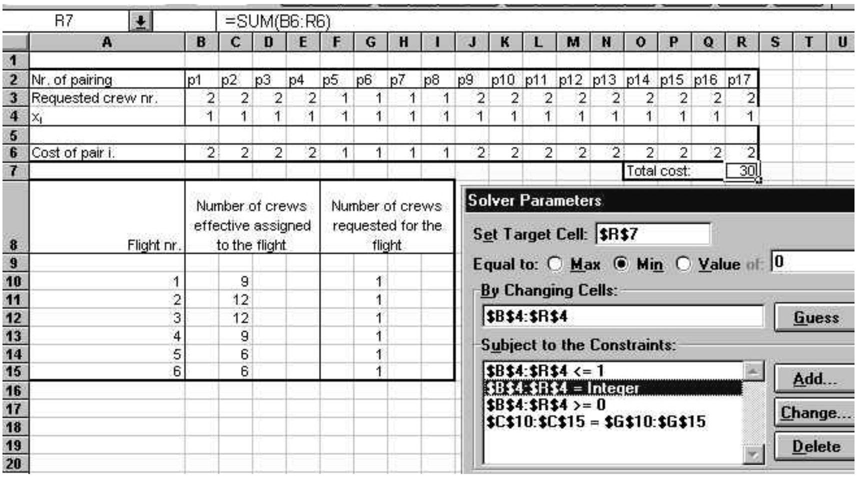

Fig. 5. Initial values of the problem

The daily required crews (total cost):

$$\Sigma c_p x_p = 2^*1 + 1^*1 = 3.$$

This solution is equal to the part **a)** in *Fig.* 3.
The other solution is shown in *Fig.* 6.

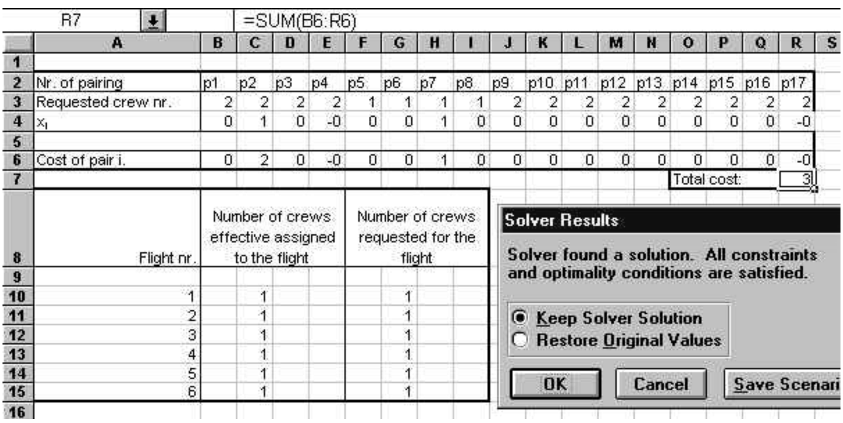

Fig. 6. Solution of the problem

According to the above:

$$x_2 = x_7 = 1, \text{ for the other } i \text{ values } x_i = 0.$$

In this case the number of crews used daily (total cost):

$$\Sigma c_p x_p = 2^*1 + 1^*1 = 3.$$

In this case one crew operates between ‘C’ and ‘A’ airports, and the other from the ‘A’.

2. If for x_i the value 0.5 is also allowed, the solution will be:

$$x_2 = x_4 = x_8 = 0.5, \text{ for the other } i \text{ values } x_i = 0.$$

This solution is the same as shown in *Fig. 3* (Gant-diagram), the optimal solution in part **b)**, so the number of crews needed for a day is as follows:

$$\Sigma c_p x_p = 2^*0.5 + 2^*0.5 + 1^*0.5 = 2.5.$$

The minimal required number of crews (2.5) can be developed many ways, if there is just one limitation, that the value of x_i shall be between 0..1. This time the period is longer than 2 days, the flights can be covered in many variations, eg. $x_2 = 0.5$, $x_4 = 0.4$, $x_8 = 0.5$, $x_{10} = 0.1$, for the other i values $x_i = 0$.
The total cost in this case is the same: $\sum c_p x_p = 2^*0.5 + 2^*0.4 + 1^*0.5 + 2^*0.1 = 2.5$.

6. Publication of the Assignment

The crew plan can be presented two ways: flight and person oriented.

- Flight oriented.
  The flights are listed first, beside them there are the crews assigned for the flights and the crews, which are not available on that day.
- Person oriented.
  Each person gets his own monthly plan. In this table the activities and the flights to be completed are listed for every day.

7. Carmen Planning System

7.1. The Possibilities Given by the System

The system (Computer Aided Resource Management) is able to build crew pairs and to optimise them. The assignment is shown graphically, so abrupt operation is possible because of the easy tracking. Interventions are easy to make on the graphical display. Data of the flights and crews are easy to load, and the problem can be solved on the display even manually, if wanted. For the automatic solving any part of the problem can be chosen, and optimisation arguments can be given.

It consists of four main parts: pairing, assignment, operation and training.

7.2. *Input and Output Data*

The relationship between the data and the system is shown in *Fig.* 7.

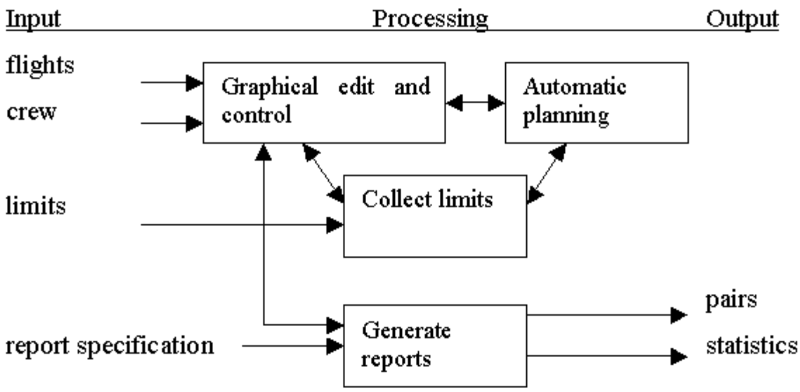

Fig. 7. The system and the input – output data

The limits are in a separated unit, so testing the feasibility of each pairing is possible. Modifying constraints and making 'what happens if. . .' simulations is also easy.

7.3. *Description and Operation of the System*

Fig. 8 shows the operation and then follows the review of each part.

7.3.1. *Generating an Initial Solution*

Due to the large number of flights the problem is handled daily, not weekly. The base is to determine the tight connections following the airplane, so delays are automatically taken over by the crew, and they are at place, too. The whole daily problem must be solved at the same time, because it is nearly impossible to find a viable solution for the given subproblems separately.

The initial solution is determined going through the flights given in the schedule starting from the left side.

7.3.2. *Choose a Subproblem*

If an initial solution is given, the daily problem can be viewed as a subproblem and in order to find a better solution it will be optimised. After several optimisations a

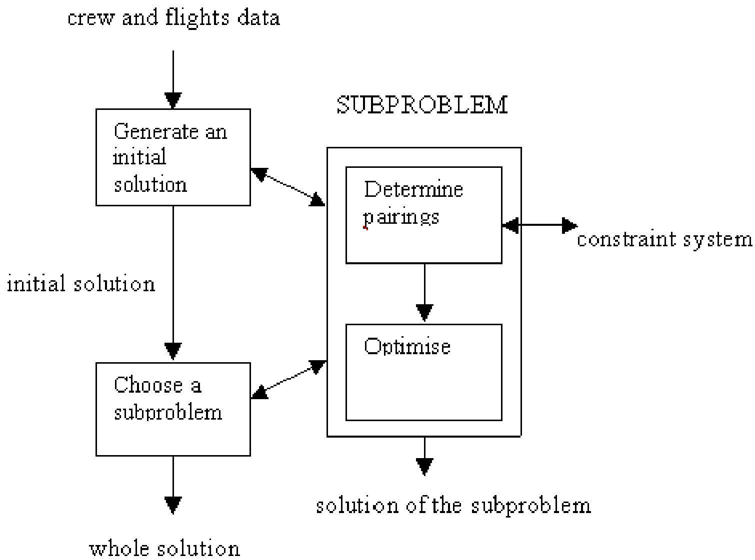

Fig. 8. Operation of Carmen system

local optimum will be found. This solution of the daily problem is not the same as the daily problem solution presented above, because I supposed daily periodicity in the schedule there.

7.3.3. Determine Pairings

This unit determines all relevant and economically feasible pairings, so not all possible pairings are processed because this would be a gigantic database (in case of 70 flights a day nearly a quarter million pairings). The bases for determination of the pairings are the connections between flights, which makes the separation of constraints from the pairing algorithm possible. The optimisation begins with such flights that start or touch a crew basis airport. For the efficient determination of pairings some limitations must be taken into consideration:

- The maximal branch is about 5–8 connections.
- Preferences can be given to the program which way to search first, this is typically to follow the airplane.
- All built pairings are matched with the constraint system. If it is not viable, this way is not analysed further.

7.3.4. *Optimise*

The difficulty of optimisation is depending on the given number of pairings. The bases are the cost factors and the static limits. The usage values of pair i. is x_i, which can be 0..1.

7.3.5. *Constraint System*

All constraints and cost data are written in a special language in order to be explicit, easy to review and not to be messed. Aim of the system is to determine the conditions, which make possible to decide if an allocation for a person is viable.

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