Criteria and methodology of determining the general flowchart for the calculation and evaluation of the aircraft balance

Jerko Rados

University of Zagreb
Faculty of Transport and Traffic Engineering

Mihaela Mise

Ericsson department of software design, Zagreb

Frane Jelusi

University of Zagreb
Faculty of Transport and Traffic Engineering

This paper deals with the criteria and requirements in developing general autonomous software related to handling the aircraft at the airport. It gives an overview of almost all the influencing factors which are relevant to "processing" an aircraft both upon arrival as well as on departure. It gives a brief description of the conventional balancing method which is being used, of the latest advancement in the field, and it offers a concrete suggestion for improving the reliability of criteria and results in aircraft handling.

The main idea of this initial work is to unify all the necessary activities and to register them by one computer, from landing until take-off, including the computer communication with other airports and companies. Currently, the programs of certain air companies are being used and they have produced individual software in co-operation with the manufacturers only for certain types of aircraft which are currently employed by them.

Since the range of aircraft types landing at airports is growing, there is the need to find a universal program which can calculate the balance chart for each aircraft, based, of course, on the manufacturer-supplied design data.

1. Introduction

1.1. In general

The development of aircraft and aircraft technology have recently been under the influence of contradictory requirements - on one hand, the aircraft should provide great efficiency and performance along with the least adverse impact on the environment (low levels of exhaust gases emission, noise and waste), and on the other hand, the reliability and safety would have to be increased. These improvements should be accompanied by low production and maintenance costs.

The parameter within this field, which can be improved by every airport is the technology of passenger handling, especially with regard to safety of the subsequent flight, which includes good balancing and technical equipping of the aircraft.

Roughly, the technology at an airport can be divided into the technical part, dealing with equipping and servicing the aircraft and the part dealing with passenger and cargo handling. These activities are in fact, at the moment, separated, and are being carried out separately by single operation services at the airport.

The recordings of these procedures are unified only in the official form used for balancing the aircraft which is filled in directly prior to the aircraft take-off, and which contains only those data that refer to changes in cargo, people and fuel, whereas the technical details regarding servicing and other operations performed on the aircraft are kept by the technical services.

This leads to the conclusion that this method of keeping the register (except in special cases) does not provide safe aircraft handling, since there are no data on the technical condition of the aircraft arriving into the airport, and therefore no guarantee for its technical condition on take off.

The performance card, in the form of a servicing card and other technical documentation is kept exclusively by the air company which owns the aircraft and provides the transportation service, in agreement with the manufacturer, according to set international regulations defined by law. In case of an accident the air company is responsible for failures.

The aim of this paper is to unify all the activities involving the aircraft during its stay at the airport and their registration by the computer network connected not only within one airport but to all other airports being in contact. The paper deals for the moment only with the new method of aircraft balancing. In this way, all the data about a certain aircraft would be available to every airport of its landing, with all the changes during its operation.

The data on the number of passengers, weight and distribution of cargo, and condition of the fuel tanks would be known before landing. Information would be available about the passengers in transit, those getting off, about baggage that has to proceed to next destination, and which baggage will reduce the load of the aircraft. Figure (1) presents the schematic function of such a system:

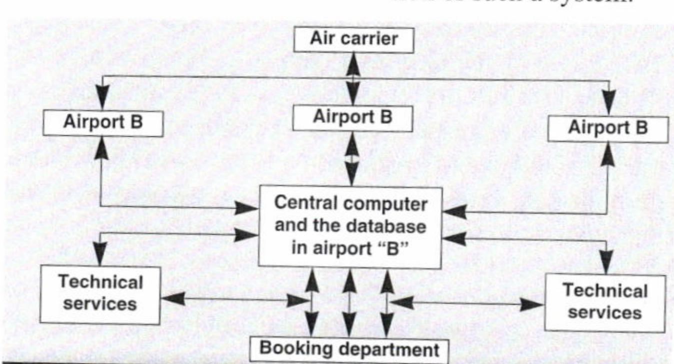

Figure 1 Schematic function "system of three airport"

First, the tendency of the paper is to find out the autonomous universal program (algorithm) for aircraft balancing, which would form a part of the comprehensive program set as the objective of this work.

2. Method of algorithm design

2.1 The proposal for the algorithm of proper aircraft balancing software

The main characteristic of the conventional programming is that the main control loop is contained in the application itself. For instance, an editor reads a character, performs the given activities, reads then the next character, etc. Upon receiving a character which represents the user's request for ending the task, the programme terminates. Figure 2 presents the flowchart of the conventional approach.

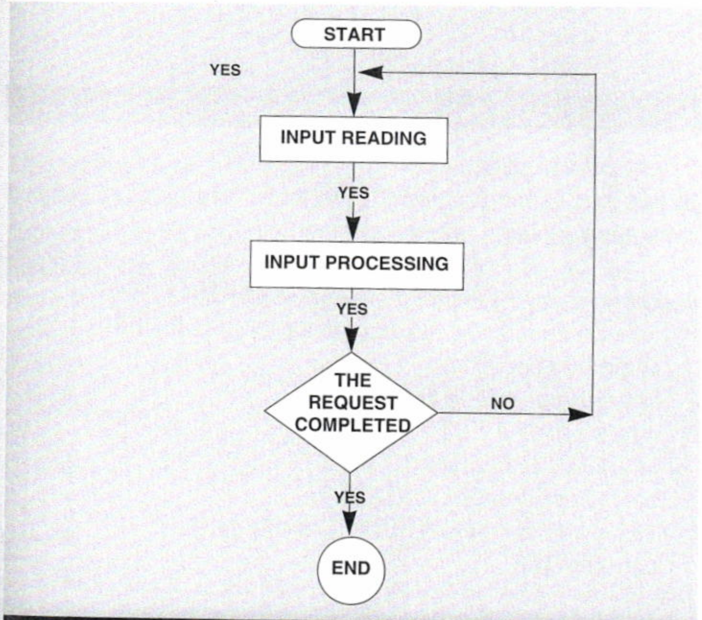

Figure 2 Flowchart of the conventional approach

Unlike the conventional approach of interactive programming, this control structure is changed in notification based systems. The main control loop is contained in the Notifier, and not in the application. Notifier reads the events and calls various procedures which the application had previously associated with them using the Notifier. This control procedure is presented in Figure 3. Notifier operates in fact as a control entity within the user process.

Program flowchart

Due to the way of using the aircraft balancing software, where constant user-computer interaction is necessary, the notification-based approach is the most appropriate solution. From the point of view of the user this means that the application (program) starts with the initial window. Upon starting the application, the control of the process is taken over by the Notifier. It registers all the events, e.g. clicking of the mouse, or moving the cursor using the keyboard. After registering the event (selection of the option) the procedure (function) is called which has been previously associated with this event by the Notifier.

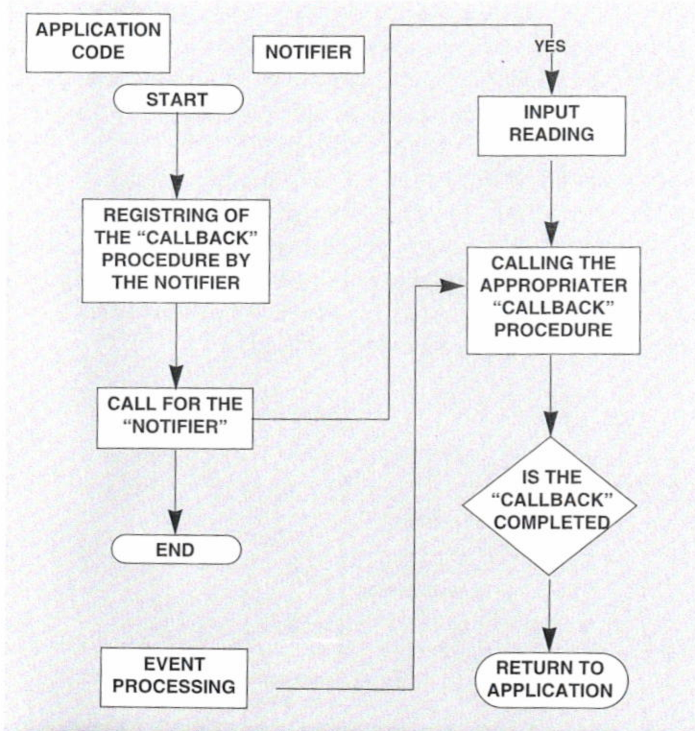

Figure 3 Notifier operates "as a control entity"

The program would consist of the main program and a range of functions. All the boxes and the objects in them would be created in the main program, and the functions would be called depending on the user. The application can be represented as a range of overlapping windows and sub-windows which appear on the screen according to the user's request. The flowchart of using the program is presented in Figure 4. Since drawing the flowchart in one piece would greatly exceed the format, it will be drawn in several phases.

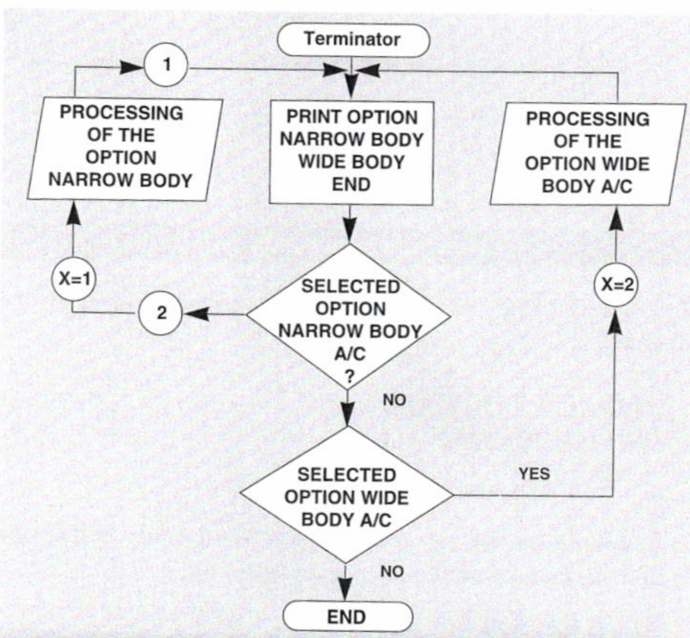

Figure 4 Range of the overplaning

After having carried out the primary selection, the selected option is processed. In order to be further able to open the appropriate windows for the given type of aircraft, the global variable (e.g. x) is introduced as an identifier. If narrow-body a/c is selected, this variable will obtain value 1 (x=1), and when wide-body a/c is selected the variable is assigned value 2. The part of the flowchart related to narrow-body aircraft will be further presented in detail (Figure 5). The procedure is somewhat different for the wide-body aircraft, but the preliminary solution suggested for the narrow-body aircraft can also be applied to the wide-body aircraft.

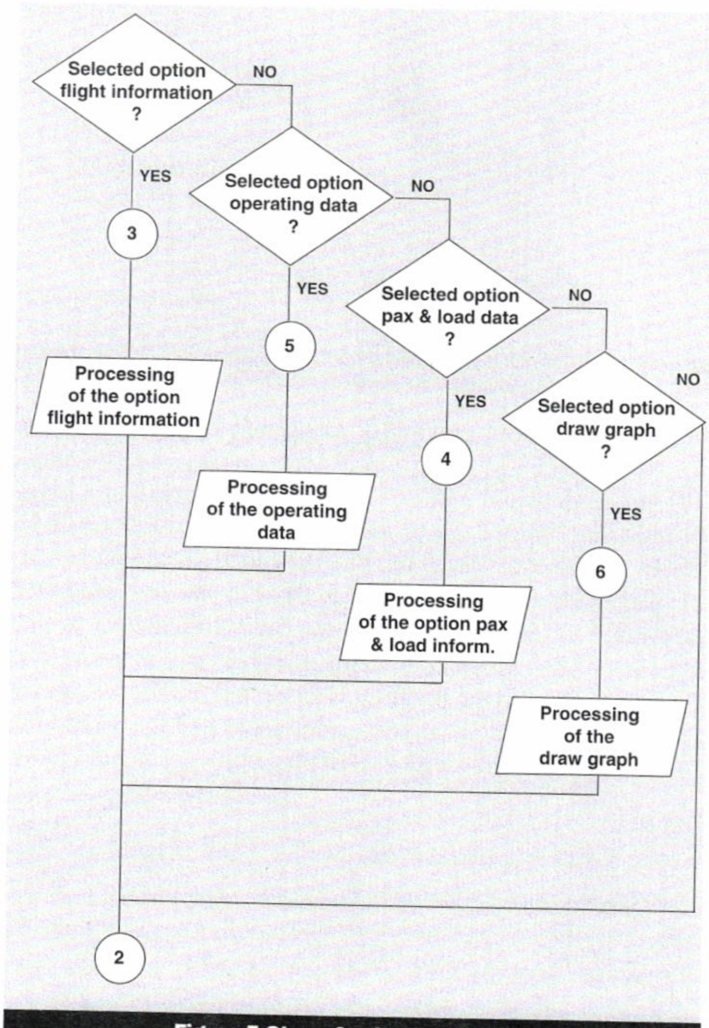

Figure 5 Step of selecting options

By starting the program the following options appear on the display:

- NARROW BODY A/C
- WIDE BODY A/C
- END.

By clicking on the e.g. menu button NARROW BODY the following menu would be opened (Figure 6)

- FLIGHT INFORMATION (the flight data can be loaded and printed)
- PAX&LOAD INFORMATION (the data on passengers, luggage, cargo and post can be entered, printed and calculated)
- OPERATING DATA (operating data can be entered, printed and calculated)
- DRAW GRAPH (graphs and lines for the actual flight can be drawn)

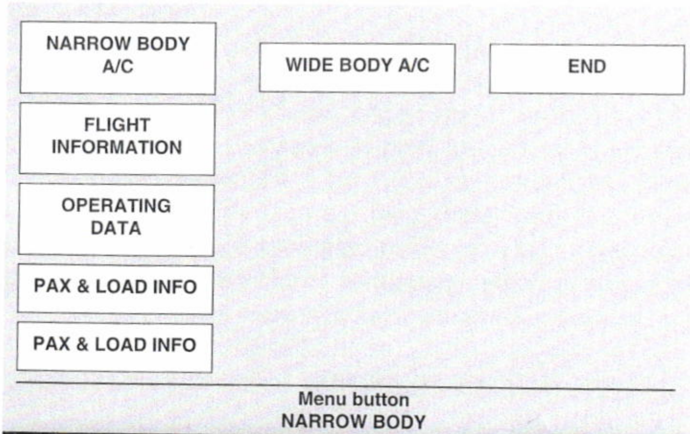

Figure 6 Aircraft balancing

Flight information

In this part of the program the flight-related data are entered using the keyboard:

- abbreviation of the take-off airport (ORIGINATOR)
- abbreviation of the destination airport (ADDRESS)
- flight number (OU)
- aircraft registration code (REG)
- aircraft type (TYPE)
- aircraft code number (CODE)
- cabin configuration (CONFIG)
- version of the crew (CREW VERSION)
- date (DATE)

Data that do not have to be entered using the keyboard but are loaded from the database are:

- Cry Operating Index
- Take-off Fuel
- Trip Fuel

The possible form of the display is given in Figure 7, and its flowchart is presented in Figure 7 and 8

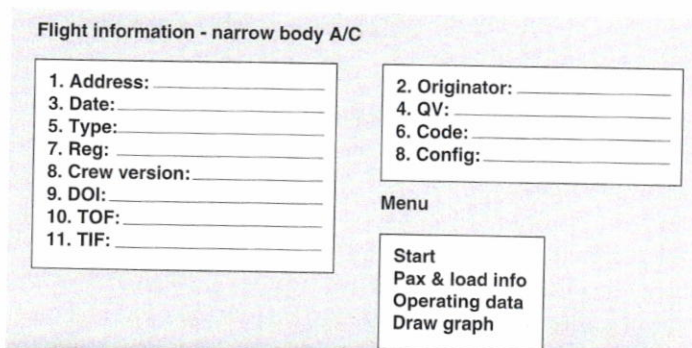

Figure 7 Flight information

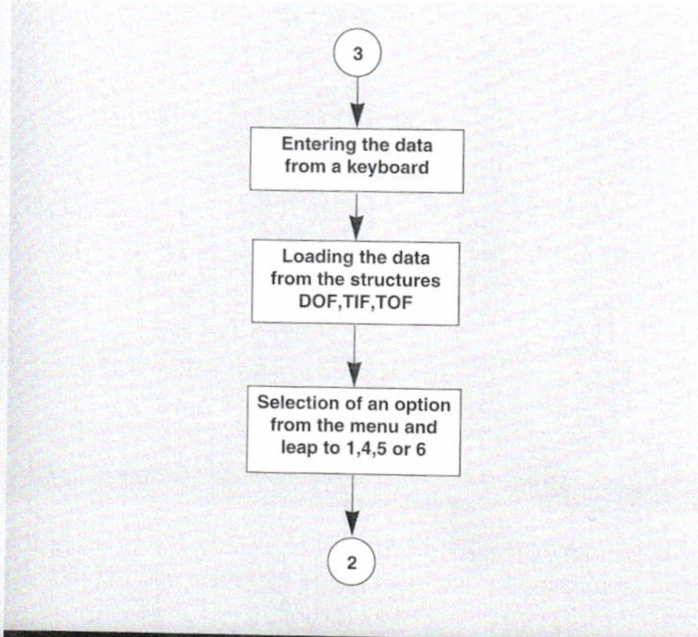

Figure 8 Selected options

Operating data

The flowchart for the OPERATING DATA window is somewhat more complex that the previous flowchart for FLIGHT INFORMATION since it contains the part for the parameters calculation. The proposal for the display is presented in Figure 9.

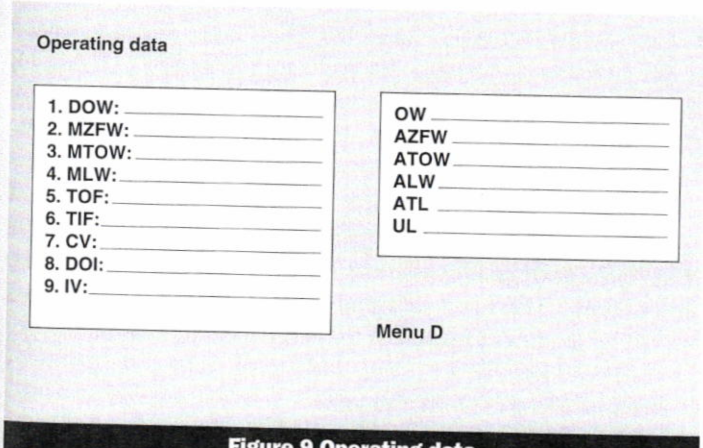

Figure 9 Operating data

This sub-window contains 9 spaces for entering the parameters including: Dry Operating Weight (DOW), Maximum Zero Fuel Weight (MZFW), Maximum Take-off Weight (MTOW), Maximum Landing Weight (MLW), Take-off Fuel (TOF), Trip Fuel (TIF), Crew Version (CV), Dry Operating Index (DOI), and change of index due to fuel (UI). These values are loaded from the database already on entering this window. If a value needs to be changed, the cursor is positioned on the value, it is deleted, the new value keyed in, and Enter pressed. The values that need to be calculated are the Actual Zero Fuel Weight (AZFW), Actual Take-off Weight (ATOW), Actual Landing Weight (ALW) and Actual Total Load (ATL). The flowchart for this option is presented in Figure 10,11 and 12

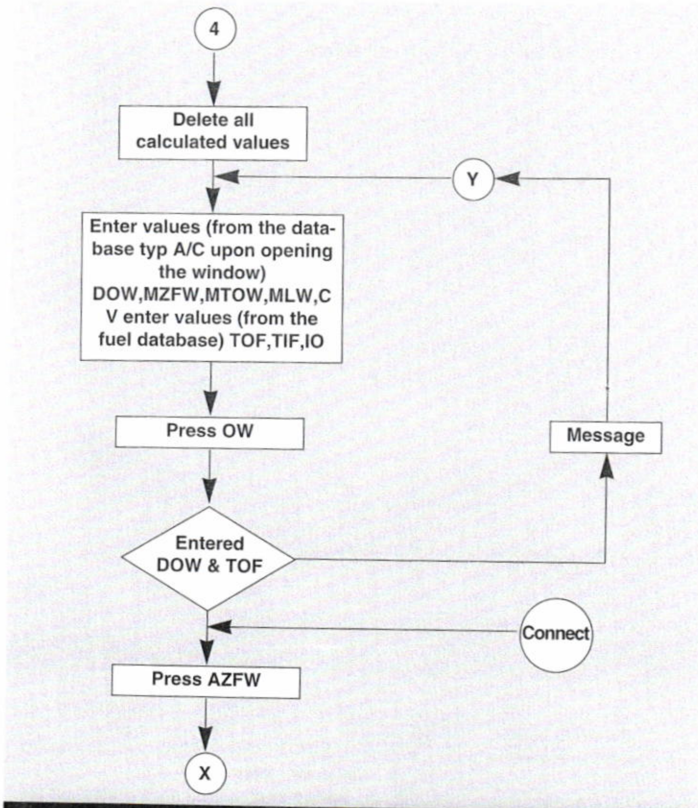

Figure 10 Iteration of "new enter"

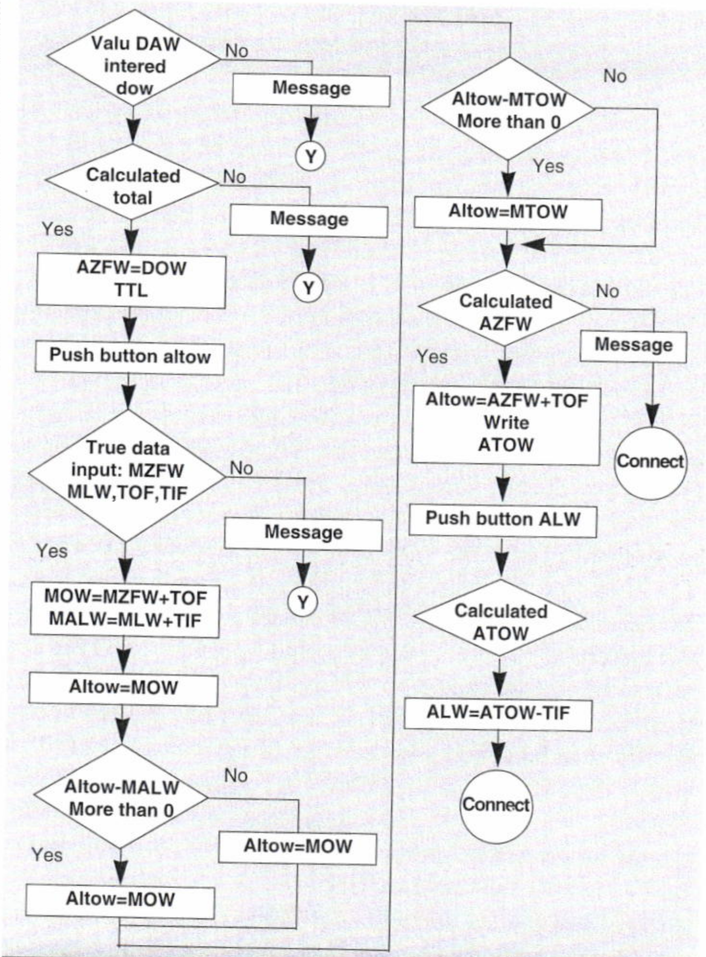

Figure 11 Calculated ALW

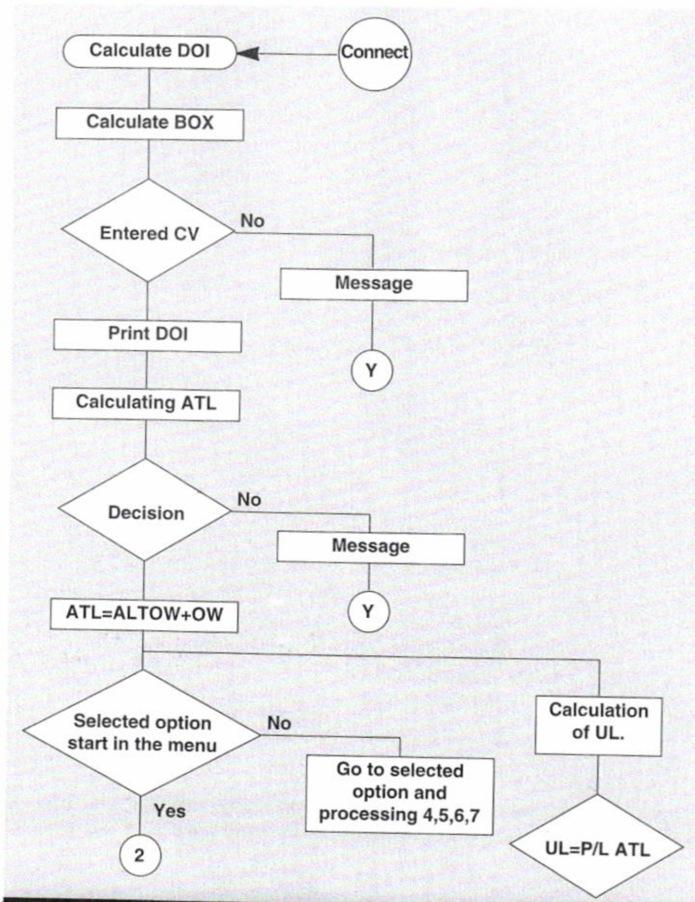

Figure 12 Calculated UL

By pressing the buttons for printing the required option, the function is performed which was assigned to this button, e.g. AZFW printing option analyses first whether the values necessary for calculating AZFW have been entered. If this is not the case, the user is notified by a message on the window that certain data are missing. If all the data have been entered, AZFW can be calculated according to the formula and printed in the appropriate space. The same procedure can also be performed for all the other values that need to be calculated. For simplification, the variables in this flowchart are designated by the standard abbreviations. The MOW variable is the weight obtained by summing up the dry operating weight and the total fuel amount. The allowed landing weight is obtained as the minimum of the values of MOW, MALW and MTOW. The minimum value is obtained by first assuming that one of the values is minimal, e.g. MOW. Then, it is checked whether the difference between the assumed ALTOW (MOW) and MALW is greater than zero. If yes, then the minimum value is MALW. Otherwise, ALTOW and continues to be MOW. Finally, it is checked whether the actual value ALTOW is greater than MTOW. If so, MTOW is considered as ALTOW. From this window it is possible to enter any of the windows offered by the MENU options.

PAX & LOAD INFORMATION

By pressing the PAX&LOAD INFORMATION button, we can open the page for entering data regarding the aircraft type selected primarily in the first window (narrow-body or wide-body aircraft). The possible display of the window for narrow-body aircraft is presented in Figure 13.

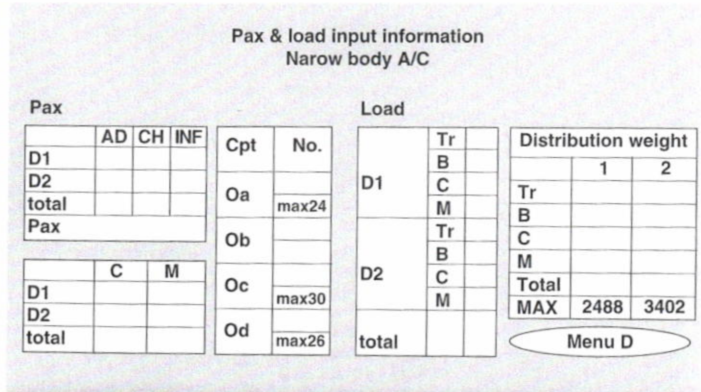

Figure 13 PAX-LOAD input information

The window consists of two parts. One is for entering the data on passengers, and the data on cargo are entered into the other part. The passenger data include:

- the number of adult passengers
- the number of children
- the number of infants
- their distribution according to classes
- their distribution according to compartments

All the values are entered into the table by first positioning the cursor in the appropriate field and by pressing Enter after the value has been keyed in. Thus the value is input and assigned to the appropriate variable. By pressing the button TOTAL, all the values on the number of passengers are calculated, and by pressing the button PAX the value of the total number of passengers is shown. In the table containing the number of passengers distributed into compartments, a warning appears if the number of entered passengers exceeds the maximum. The division into D1 and D2 denotes the number of passengers for destination 1 (D1) and destination 2 (D2). The data required for filling the tables related to the cargo distribution are:

- weight of the cargo in transit
- weight of the baggage
- weight of the cargo
- weight of the post
- distribution of cargo according to the belly compartments.

All these values are entered for the destination 1 and destination 2. The weight of the baggage shows if B key is pressed and if the number of passengers has been entered. By pressing B, the function which multiplies the number of passengers with the assumed weight of baggage per passenger (14 kg) is called. The total cargo weight appears by pressing TOTAL. This window includes also the distribution of cargo regarding belly compartments. The total weight of the cargo regarding belly compartments appears by pressing the button TOTAL in the table DISTRIBUTION WEIGHT.

Fig. 14 shows the flowchart for information on passengers and cargo.

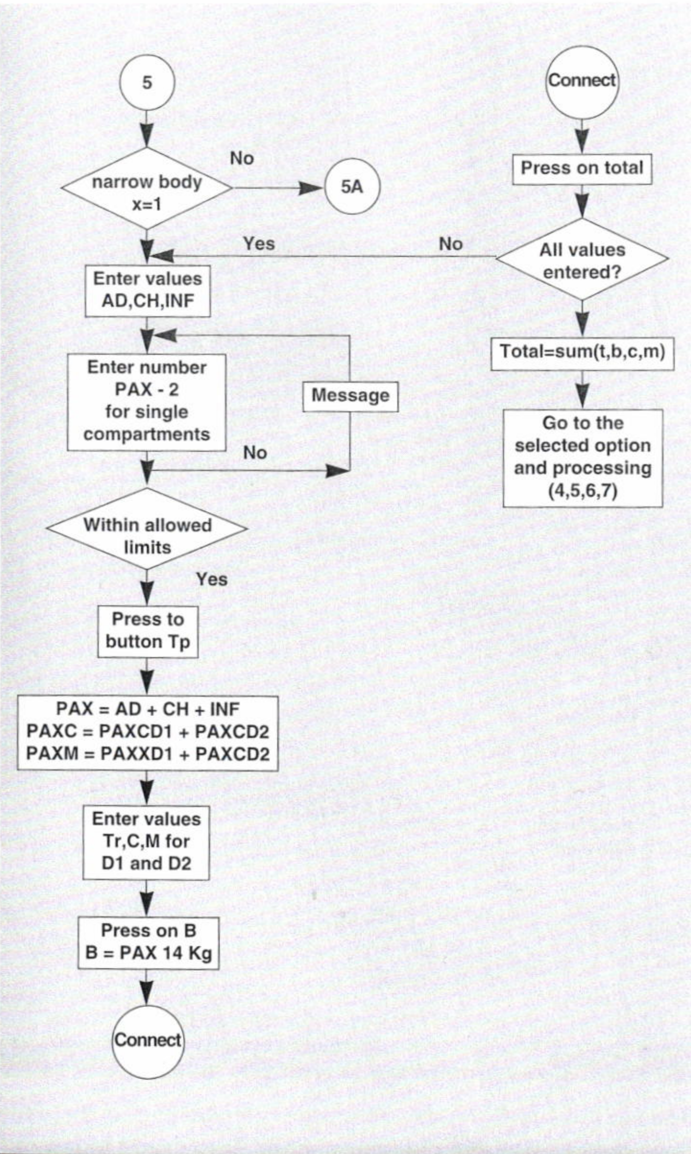

Figure 14 Information: passengers and cargo

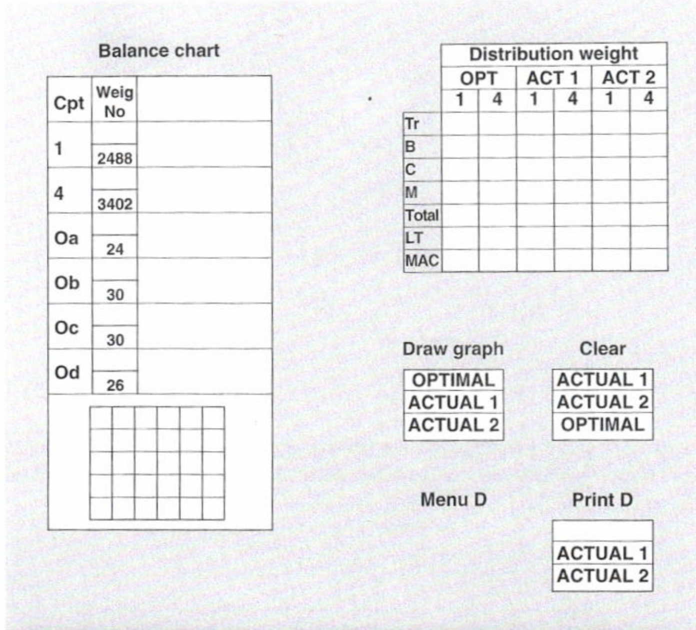

Figure 15 Balance chart

Draw graph

One of the more important parts of the flowchart is the drawing of the Balance Chart, diagram W=f(I) and the lines that refer to the actual flight. If the option DRAW GRAPH is selected, first a window opens with the drawn diagrams and updated data for the cargo distribution (ACT1) which have been entered into the PAX&LOAD INFORMATION. The possible display for this option is presented in Figure 15.

The proposed windows can be designed in the programming language C by using the X view graphical interface. This allows drawing of lines by means of ready functions included in the head of the program. Drawing of each line is defined up to the pixel level at the point exactly defined by the co-ordinates. Straight lines, as all the geometrical figures are drawn in drawing sub-windows (canvas) which are also defined by the co-ordinates. The origin co-ordinates of the sub-window are by default located in the upper right corner. Thus, the drawing of the Balance Chart and W=f(I) consists in drawing the straight lines, taking into consideration the initial and end point of the straight line. An important part in writing the programming code consists in determining the distance in pixels for e.g. 100 kg of cargo. After having determined the distance d in pixels between two distributions, every subsequent line has x co-ordinate by d greater than the previous one. For easier reading, the lines can be of various thickness and colors. Apart from the two mentioned charts, the window also contains a table of cargo distribution for the three cases. The weights entered in PAX&LOAD INFORMATION are automatically entered into the table under ACT1 upon opening the window. If we want the computer to suggest an optimal cargo distribution, in which the position of the center of gravity would be most optimal, we have to select button OPT. There is a possibility for re-distributing the cargo into belly compartments in the ACT2 part of the table. The lines (which refer to the actual flight) are drawn into the graph by pressing the key DRAW GRAPH. This enables drawing the lines for the optimal cargo distribution. By selecting the draw graph option for e.g. optimal cargo distribution, lines are drawn in both diagrams and the values of weights and numbers of passengers are entered in the table next to the graphs. The program allows lines to be of different colors for every single case (OPT, ACT1, ACT2). Button CLEAR can be used to delete the lines for the actual flight. The procedure assigned to this button opens a menu with the list of cases that need to be deleted (both lines and values entered in the table).

After having selected one of the variants which fulfils the conditions, we can print the Load Sheet. The procedure implemented in this button checks first whether all the weights are within the allowed limits and whether the loaded aircraft index is within the operational limits. Then the list is updated, and it has to be in accordance with the EDP (Electronic Data Processing) standards proposed by IATA. The flowchart of using this window is presented in Figure 16, 17a and 17 b.

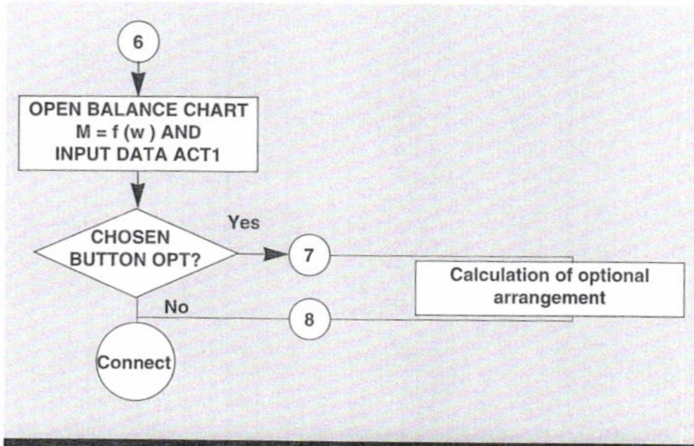

Figure 16 Accordance EDP with standard proposes by IATA

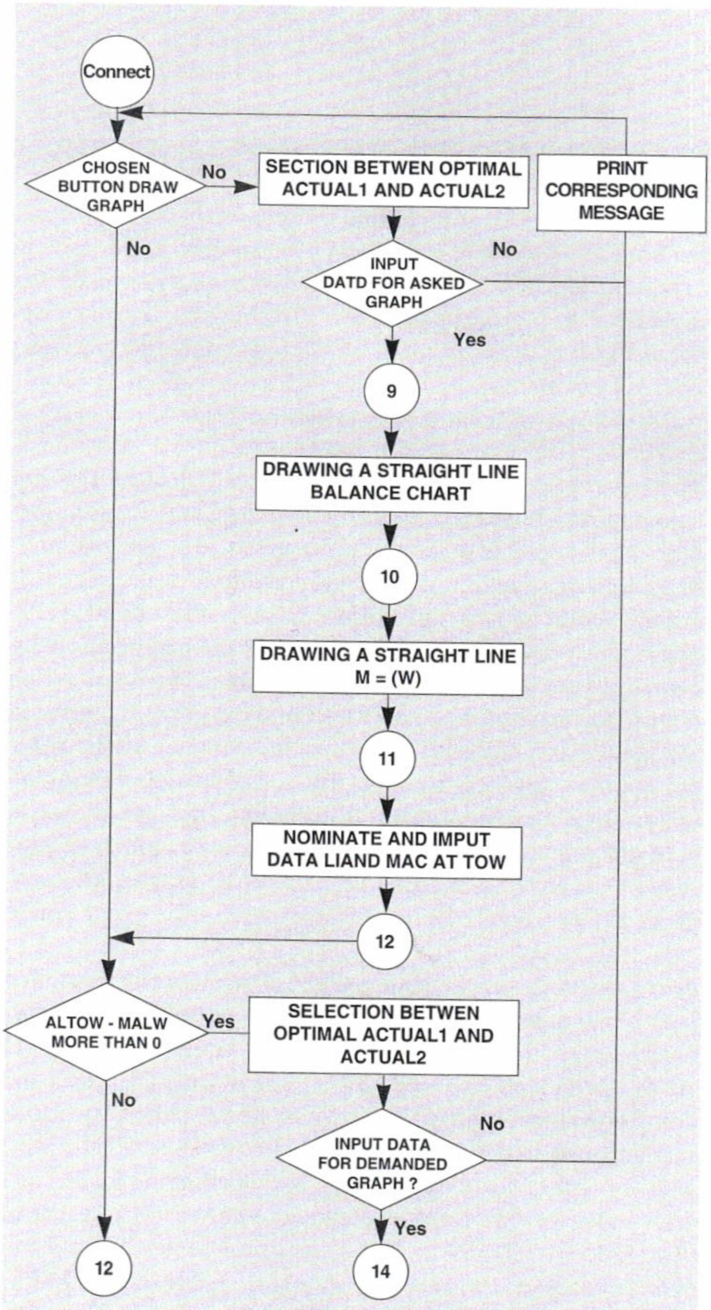

Figure 17a Block diagram Step 12-14

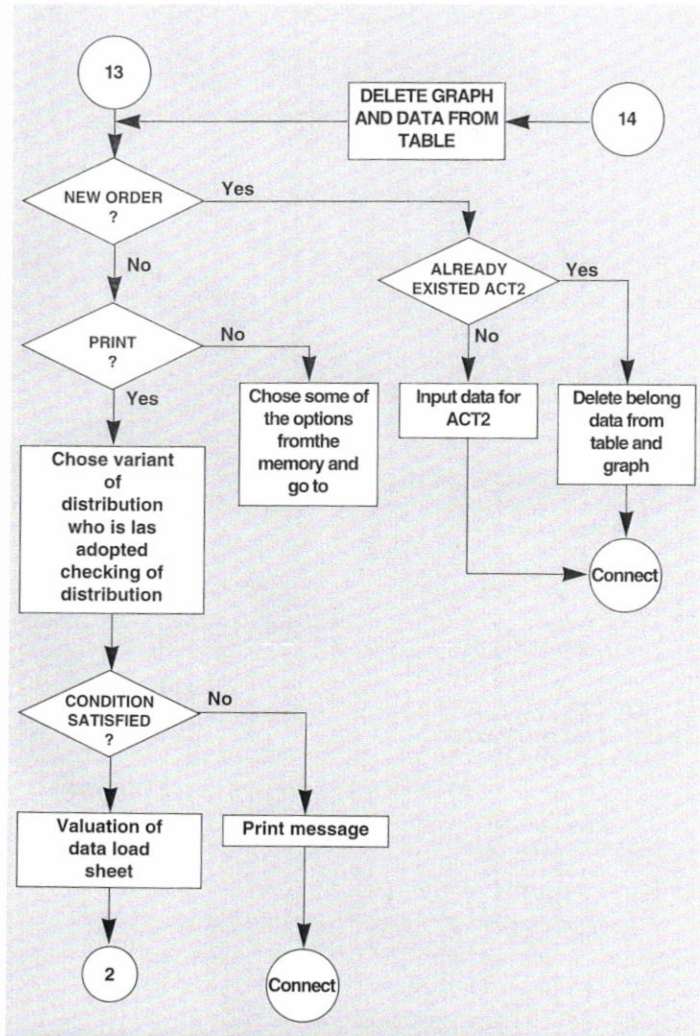

Figure 17b Block diagram step 2-13-14

The step of the flowchart describing the opening of the window and drawing the diagram may be "extended" to several phases. The sequence of phases is the following:

- drawing the straight lines representing the frames of sub-windows for drawing the Balance Chart and diagram W=f(I)
- drawing the straight lines of the co-ordinate network of diagram W=f(I) and the horizontal lines of the Balance Chart
- drawing short vertical lines of distribution in the Balance Chart
- drawing the lines of the constant amount of the Mean Aerodynamic Chord (MAC) in percentages
- drawing the lines of operational limits
- entering numerical values
- entering the textual data into the diagrams

In order to draw a line (in fact a segment of a line) with the appropriate function, it is necessary to enter the co-ordinates of the starting and end points. The precision of such a diagram depends on the accuracy of defining these co-ordinates.
The step of the diagram which describes how the optimal lugga-

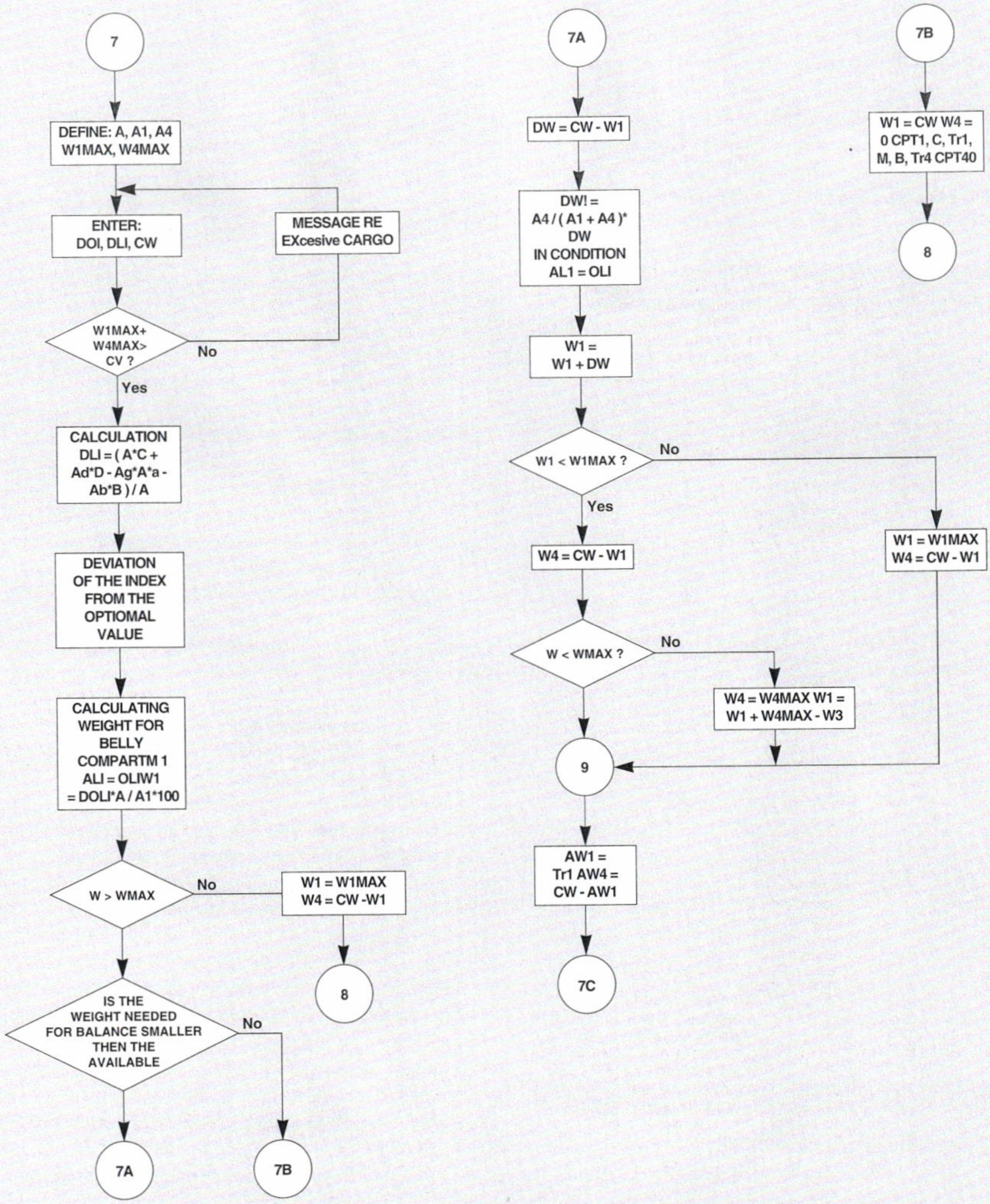

Figure 18a Optimal luggage distribution

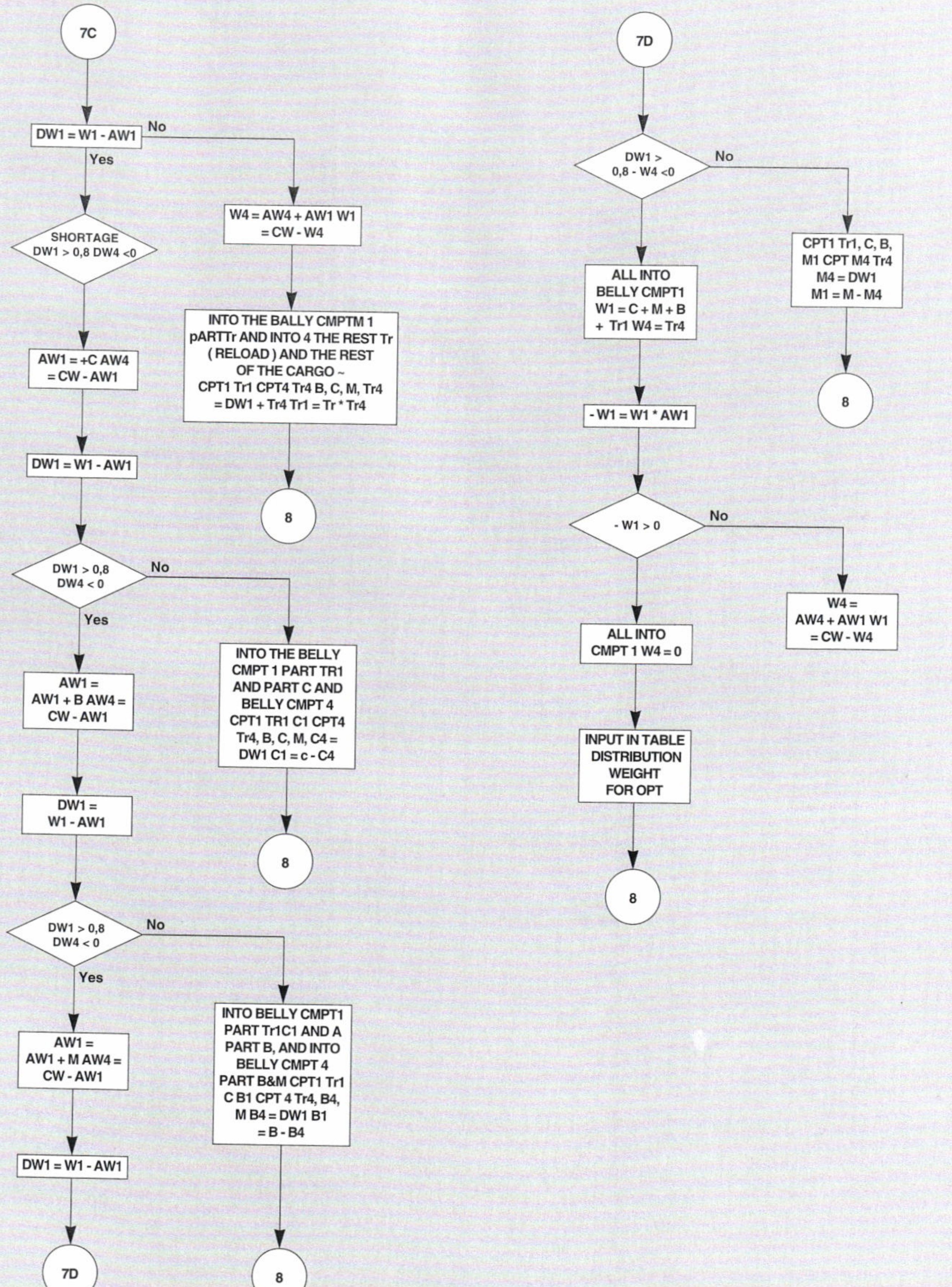

Figure 18b Optimal luggage distribution

ge distribution is calculated, is presented in Figure 18 a and b. The following is the index of variables used in the flowchart in Figure 18 a and b:

DOI - Dry Operating Index
OLI - Optimal Loaded Index
ALI - Actual Loaded Index
CW - Cargo Weight
A - the amount of unit change of index in pixels
A1 - change of index in pixels for 100 kg of cargo loaded into belly compartment 1
A4 - change of index in pixels for 100 kg of cargo loaded into belly compartment 4
Aa - change of index in pixels for one person in compartment a
Ab - change of index in pixels for one person in compartment b
Ac - change of index in pixels for one person in compartment c
Ad - change of index in pixels for one person in compartment d
AA - number of passengers in compartment a
B - number of passengers in compartment b
C - number of passengers in compartment c
D - number of passengers in compartment d
ΔLI - change of index due to the boarding of passengers
ΔOLI - deviation of the index from the optimal value
W1 - cargo weight in belly compartment 1
ΔW1 - weight of cargo which needs to be added to belly compartment 1
W4 - cargo weight in belly compartment 4
ΔI - deviation of the index from the optimal value
W1MAX - maximum weight for belly compartment 1
W4MAX - maximum weight for belly compartment 4
M1, M4 - weight of the post for belly compartment 1 and 4
C1, C4 - weight of the cargoes for belly compartments 1 and 4
B1, B4 - weight of baggage for the belly compartments 1 and 4

Tr1 and Tr4 - weight of transit cargo in belly compartments
The logic of determining the optimal distribution can be roughly divided into two phases: determining of the optimal values of weights for the belly compartments 1 and 4, and determining of the belly compartment contents. The optimal weights are determined by defining the difference between the DOI and the optimal amount of the loaded aircraft index. After that, the value of weight is determined that needs to be loaded into belly compartment 1 in order to reach the balance. If there is more cargo available, the undistributed cargo is loaded into both compartments. Of course, these values have to be checked constantly in order to remain lower than the maximum. In the second phase the belly compartment contents is selected by assuming that the weight in belly compartment 1 is cargo in transit Tr1, and the weight in belly compartment 4 is the rest of the cargo. Then the deviation from the optimal value is checked. If there is a shortage in the belly compartment 1, the whole cargo amount is added. The deviation from the optimal value is checked again. If there is still shortage in the belly compartment 1, the baggage is added, and if there is an excess then the cargo is re-distributed to belly compartments 1 and 4. The same procedure (in the case of shortage in belly compartment 1) is carried out for the post as well. A different sequence of adding weight may be selected, e.g. in case of a shortage in the belly compartment 1, the baggage or post rather than cargo may have been added to the cargo in transit. A more detailed flowchart of drawing the lines referring to the actual flight is presented in Figure 19. After having drawn all the changes of index into the diagram due to loading of cargo and passengers, the vertical lines of constant loaded aircraft indexes with and without fuel take-off weight are drawn in the diagram W=f(I).

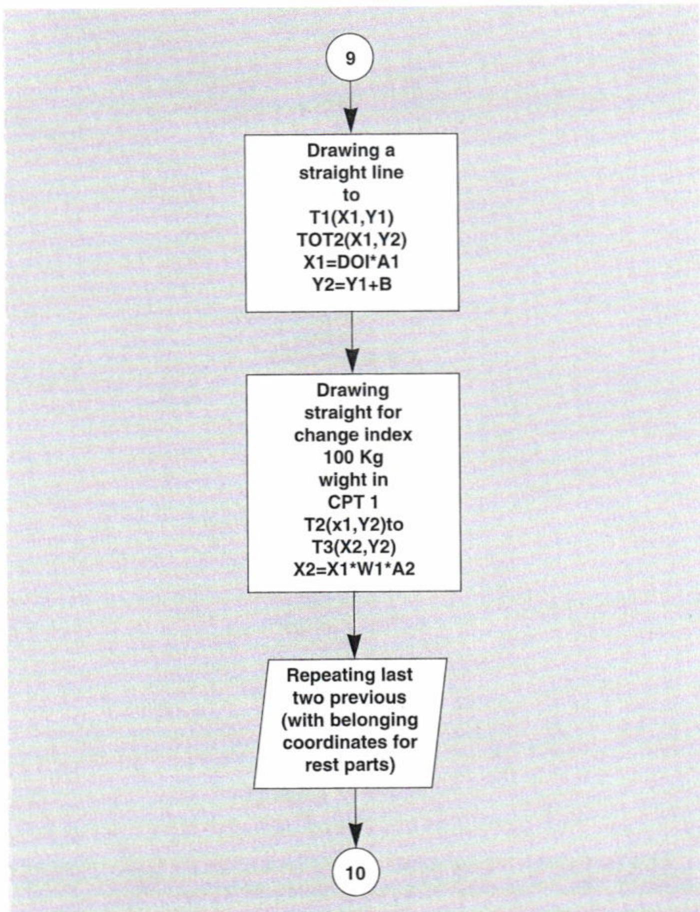

Figure 19 Diagram W=f (I)

Symbols used in the flowchart are the following:
A1 - number of pixels for the index unit value
B - number of pixels from the center to the center of the parts of the upper diagram for neighboring compartments
A2 - number of pixels for the index unit value for compartment 1
W1 - weight of cargo in compartment 1
Xn - X co-ordinate of a point
Yn - Y co-ordinate of a point